CASA

Center for Academic and Social Advancement

Building Minds: Identifying the Building Blocks of Imaginative Play

2009-2010 Pilot Study Report

The Rokenbok Fund

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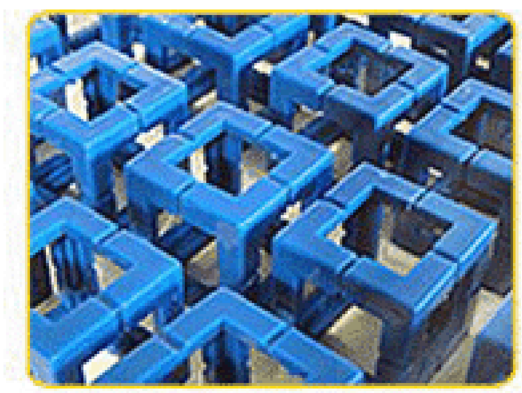

September 13, 2010

With special thanks to Maria Luiza Dantas, Research Consultant, for her assistance in the preparation of this report.

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Acknowledgements

CASA and our UCSD Research Team would like to extend our gratitude to The Rokenbok Fund and The San Diego Foundation for the opportunity to conduct this valuable research initiative. Further details about CASA and its research can be found at www.casasd.org.

Executive Summary

The Center for Academic and Social Advancement (CASA) carried out a yearlong pilot study between November, 2009 to late May, 2010 to examine the cognitive, social, and academic benefits of playtime with Rokenbok construction toys one of its La Clase Mágica after-school program located in Solana Beach, California. The goal of the study was to examine the possible educational benefits of playtime construction toys in promoting cognitive skills science-related fields such engineering and math, fields in which minority and low-income individuals are currently underrepresented. Supported by an extensive review of the literature, a theoretical perspective on development, ethnographic methodology, the study consisted of a series of on-site forty-five minute observations of two groups of children for a period of 16 weeks.

The pilot study enabled the researchers to follow the progression of 2 small groups of child participants interactions with the construction play toys. In video recording and ethnographic field notes, the team identified a series of cognitive, communication, and technical abilities garnered during play with peers and an adult mentor. The present report presents the pilot study and its findings. A study on the role of gender in construction based play presented to the Department of Communication by undergraduate Honors Student participating as part of the research team the researchers, Vásquez and Dzurova proposed to present at both the UC Links Annual Meeting and the flagship conference in education, AERA 2011 (American Education Research Association).

The pilot study lays out the framework for further study of the effects of imaginative play with construction toys on gender, age, and particular cognitive skills. Specifically, it lays the need for a scientific evaluation of the preliminary findings of the pilot study

I. Introduction

In coordination with UCSD's La Clase Mágica research team, the Center for Academic and Social Advancement (CASA, www.casasd.org) developed and implemented a pilot study to assess the impact of imaginative play on gender and learning and development of low-income, Mexican origin youth. Of interest was the acquisition of cognitive skills related to math, engineering, and communication (skills increasingly required in all scientific fields). The study focused on one after-school program serving children ages 5-13 situated at St. Leo's Mission situated in Solana Beach, California.

The study naturally falls within CASA's mission to academically and socially prepare underserved youth to succeed in school and in the new realities of the 21st century, in particular CASA's three major goals:

1. Meet the educational and epistemic needs of underserved youth and their families.
2. Strive to enhance their academic achieve in P-12 and their representation in higher education.
3. Work towards closing the existing cognitive, digital and employment gaps.

CASA grew out of the now twenty-year old UCSD research initiative called La Clase Mágica; a research-based after school laboratory that enhances the university's mission of research, teaching and service. At the same time that the research team seeks answers to one of the most challenging issues in education—the underachievement of minority youth, UCSD undergraduate students enrolled in the course, "Practicum in Child Development" are trained in the latest theories, practice and research, and 5 communities across the county receive the education resources and institutional support to meet the educational needs of local youth. La Clase Mágica's theory of change is founded on creating the best learning conditions in which learners can excel to their optimal potential within a context that mixes play and education, encourages dialogic collaboration, and uses technology-assisted pedagogy to bridge the cognitive and digital gaps between mainstream and underrepresented populations.

In conducting the present study, CASA and La Clase Mágica added the "employment gap" of minorities and women in the fields of science, engineering, architecture and mathematics to their current areas of concern. The study tested not only the viability of the Rokenbok toy to enhance children's cognitive, social, and academic performance, it also tested La Clase Mágica's theory of change in creating optimal learning conditions based on the cognitive ecology provided by the Rokenbok Toys (http://www.rokenbok.com), an innovative construction based manipulative that combines construction elements with radio-control systems. The pilot study focused primarily on identifying the kinds of cognitive skills related to math, science, and communication that the Rokenbok toy made available.

II. Research Question

The pilot study was guided by the following overarching question and subsequent questions.
How do playtime construction-based manipulatives affect learning and development of participants in an after-school educational activity, specifically, the acquisition of cognitive skills related to math, science, and communication?

Specifically:

- How does play-interaction with manipulatives impact participants' abilities to use these devices as intellectual tools in the problem-solving process?
- What scientific concepts and cognitive skills related to the fields of engineering, science, and math do these devices and play materials promote?

• Does engagement in construction activities promote dialogic collaboration and cross-cultural collabo ration and what does this look like?
• What role does gender and age play in the engagement and successful construction of the toys?

III. Orienting Theories on Cognitive Activity

The pilot study draws on the conceptualization of the individual's cognitive activity as socially and historically situated (Vygotsky, 1978), and distributed throughout an interconnected "sociocultural system" (Hutchins, 1995). Cognitive abilities, rather than isolated and enclosed within the mind of an individual, develop through interaction with others as well as the environment, which is transformed in culture-specific ways over time and across generations. Cognition is thus: situated and distributed in a complex socio-cultural world, specific and dependent on the context and the goals and tasks that are organized for participants to achieve. Thus, the child's mind develops as it internalizes culturally constituted forms of thought, action and ways of speaking. The infusion of cultural artifacts into the life fabric of social life and interpersonal communication, and their internalization in the individual mind constitute the process of culturally mediated development of human thinking. In this context, imagination is viewed as a multimodal interaction of the individual with its social and the material world. Such a perspective moves the thinking and imagining mind outside of the skull into the external socio-cultural space in which the cognitive activities take place. Thus, within this cognitive ecology, a way of seeing becomes a valuable tool that is provided to the participants. As such, this study proposes that the Rokenbok toy creates a cognitive ecology in which a way of seeing related to scientific fields and mainstream education is made available.

The study investigates the complex processes and set of practices that characterize the cognitive ecology of children playing with the Rokenbok toy. In line with Hutchins (1995), the distributed cognitive system that is created in by playing with the toy brings to the fore a variety of socio-culturally embedded cognitive tools: the Rokenbok pieces, building plans/instructions, pictures on the boxes, and "environmentally coupled gestures" (Goodwin, 2007) that are an essential part of the participants' interactional framework and engagement with the toy. Play with the Rokenbok interweaves participants' practical skills, the meditational value of the toy, the social context in which the play is embedded, and external media and abstract representations for effective use of the toy. This means that the more familiar a participant is with this cognitive ecology, the more successful he or she is in moving through the required steps in the construction of the projects. In other words, the investigation of culturally informed practical skills are an integral part of the study of cognitive skills (Goodwin, 2007; Malafouris, 2004; Sutton, 2008). With its specific affordances, the Rokenbok toy both informs and constrains the cognitive and practical skills that are used to perform the particular way of seeing necessary to complete the tasks that are part of its construction and operation.

The present study investigates these complex processes and set of practices that characterize the cognitive ecology in which children play with the Rokenbok toy. This ecology can only be understood through close observation of the actual activities and interactions of participants—i.e., communication during play, the interaction of multiple systems involved, the material world around them, the tools that are used, and the skills and knowledge employed. This study explores the practices of mediation supplied by the Rokenbok toy and the ways it helps to promote the conceptual relationships negotiated and internalized by children. Furthermore, it investigates the cognitive benefits that the Rokenbok toy affords Spanish-English bilingual children attending an after-school educational program characterized by the culture of collaborative learning and participatory pedagogy (Moll et al., 1992; Vásquez, 2003).

IV. Description of the Study

The pilot study was carried out at one of the five CASA's programming sites that is situated at St. Leo's Mission in the community of Eden Gardens, a sector of the city of Solana Beach located in north San Diego County. This particular location serves a population of predominately Spanish-English bilingual children from low-income families of Mexican origin background.

The pilot study centered on children's exploration of the Rokenbok Toy. In particular, it examined the possibility that Rokenbok toy, a multifaceted manipulative, enables children's understanding of the complex mechanisms and principles behind the functional operation of elementary devices and whether this understanding facilitated the acquisition of technical, social, and cognitive skills related to fields such as science, engineering, architecture and mathematics, and, equally importantly, whether it boosted children's curiosity and interest in pursuing participation in related fields. The children were exposed to the Rokenbok toy once a week for two, 45 minute sessions, over the course of 16 weeks. This time period was broken into a phase in which children were allowed to play with the toys with minimal adult intervention and a phase in which the adult directed the children's attention to the graphic instructions and the long term goals of building a construction project.

Data Collection Process

The study was implemented by a core UCSD Research Team under the supervision of Principal Investigator and Assistant Professor of Communication, Dr. Olga Vásquez. The research team consisted of the principle investigator and Communication doctoral student, Ivana Dzurova, and two undergraduate students, Robert Carr and Sensi Graves. Robert was a long-term member of the research team having received his initial training on the theory, pedagogy, and research of La Clase Mágica during his enrollment in the practicum course that served the 5 after sites and then joining the research team as a member of the staff. Sensi had also been a former student of Vásquez and her participation in the study served as the basis of her Honors thesis.

Data was collected over the course of three academic quarters, and it incorporated local children who participated in La Clase Mágica, Solana Beach. The study was conducted in a Head Start classroom on the other side of the courtyard from La Clase Mágica. Many of the children attended the same elementary school and therefore had a high level of association with each other before the beginning of the pilot study. The child participants formed two groups: a younger group of 3 boys and 3 girls ranging from 6 to 8 years old, and an older group of 3 boys and 3 girls ranging in ages 8 to 10 years old. The children were observed in these small groups with their peers of the approximate age and/or grade level. Each group had approximately six children and, in general, included equal numbers of boys and girls.

Before each observation session, the research team convened to identify the point of progress that the children had achieved up to the previous session in using the toy to its maximum effectiveness and to discuss where modifications may be needed to encourage optimal use of the toy. After each session, the team convened again to discuss the progress throughout the session, the quality of children's engagement, and the influences of gender, language, and age. Afterwards, field notes were written by each member of the research team to provide a more focused observation of the social context and to provide incidents in of theoretical constructs were played out. Such debriefings provided a more detailed perspective on the children's behavior before and during play.

Video recordings were also made of the children during each session in order to further expand the opportunities for observation. Two video cameras were placed on opposite sides of an square-like enclosure created for reading time for the children who attended Head Start, with a third camera entering into the play area with the children. Two walls made up half of the square while two low standing bookshelves provided the other half of the area. The video cameras were placed on the bookshelves, aiming down at the children. The audio-recorder was placed amongst the children on the rug in the play area, however it was only utilized for the first two sessions because it did not provide additional information. The children were aware of the presence of these recording devices, however they typically ignored them, choosing instead to concentrate on the toys before them.

Initially, the research team was careful not to impose its expectations on what the children "should do" or what "they wanted" to see the children do. The initial goal was to simply observe them "playing to learn", in self-directed play, without coming across as directive or authoritative. To do this, the children were offered as little guidance as possible, with the exception of some indirect intervention—i.e., placing box covers of the toys and the instruction guides in front of them. Although the play environment that the children enter into could be seen as disorganized and unfocused to the untrained eye, it enabled the researchers to assess their play without direction and to answer such questions as— How much familiarity did the children have with such toys? What would they do differently with the toys if they did have familiarity and what would they do if they did not? What resources would they draw into their game play? What role gender would play in such a situation? Halfway through the study, however, it became clear that the children required a greater level of intervention to help them achieve the completion of the projects as they are pictured on the box covers.

This intervention involved the inclusion of an adult mentor in the Rokenbok play area. As stated above, Robert Carr had formerly enrolled in the Practicum in Child Development course that provided the expertise to "scaffold children's progress through their zone of proximal development" (Vygotsky, 1978) and was well equipped to provide the children with just the right kind and amount of intellectual resources—i.e., mnemonic devices, vocabulary, visual direction—to facilitate their progress. Without explicitly dictating the specific set of rules that children had to follow, he guided the children in the use of external models—i.e., the pictures and graphic instructions—to help their construction of the toys. As such, he provided the mechanism for children to understand that there is a particular order in the steps that must to be pursued to construct a sturdy structure that does not collapse. Based on their personal preference and inclination, children were not expected to follow the adult direction if they did not feel like doing so, but they were given enough room to respond to the adult's prompts— e.g., "let's build," "use the instructions," "what piece is missing?," "what's next?" etc. This intervention marked the turning point of game-play. Although some children initially objected to using the instructions—"that's cheating!"—others incorporated the theoretically informed guidance into their building activities.

The children demonstrated clear signs of becoming more engaged, showed greater perseverance, and increased collaboration was readily visible. For the first time they completed projects with relative ease and success. Whereas the first stage of the children's game-play was random and their projects, objects of their imagination— i.e., the blocks made a fenced enclosure, a tower, a gun —, in this second stage, their game-play became systematic and directed towards the construction of the specific models being presented to them.

The Pilot Study's Timeline

The pilot study involved three phases (see Table 1). The First Phase took place during the UCSD Fall 2009 academic quarter. This phase involved an extensive review of the literature that formed the theoretical and empirical foundation of the pilot study's emphasis on the acquisition of skill sets related to the fields of engineering, science and math. This initial phase also included the development of a mix-method methodology— i.e., ethnographic and survey methodology— to be carried throughout the study, and the selection and training of two undergraduate students who interacted with the children in the second phase.

Table 1. Pilot Study's Timeline

Timeline	Fall 2009	Winter 2010	Spring 2010	Summer 2010	Fall 2010
Phase	First Phase	Second Phase	Third Phase		
Focus	-Bibliographic review. -Review and finalize research methodology. -Selection and training of two undergraduate students.	-Data collection: weekly observations, video recordings and interviews. -Regular meetings by CASA's core research team. -Preliminary data analysis.	-Data Analysis. -Final Report.		

The Second Phase, during the middle part of the Fall 2009 quarter and Winter and Spring 2010 quarters, involved the implementation of scheduled and monitored play at La Clase Mágica located in Solana Beach. The research team observed Spanish-English bilingual children attending after-school educational program once a week for 1 and ½ hours over the course of 7 months. The researchers collaborated with the child participants during scheduled playtimes with the construction-based manipulatives, and then documented their interactions through written ethnographic field notes, as well as audio and visual recordings. The data include approximately 50-70 hours of video recordings, 40-45 ethnographic field observations, and individual interviews with participants. The data collection process was organized in two stages. During the first stage of data collection the children engaged in the construction-based, Rokenbok manipulatives on their own without any guidance. The second stage involved adult-guided playtime sessions.

The Final Phase of the pilot study took place during the UCSD Summer and beginning of Fall 2010 quarters and involved the analysis of the field notes and media recordings by UCSD's La Clase Mágica research team. This report focuses on the detailed analysis of the videos and the field notes.

Data Analysis

The data analysis centered on close reading of the data corpus and identification of patterns across the entire collection. As analytical framework, cognition was situated at the center of the ongoing organization of human action and the systematic transformation of the local spatial-material environment (Goodwin, 2010; Hutchins & Palen, 1997). Of interest were the ways in which the child participants, as 'novices' to the Rokenbok toy, developed a 'common vocabulary' and interacted in the practice of producing material representation. Informed by Goodwin's (1994) framework for the examination of the ways novices are socialized into a 'common vocabulary' of particular professions, we examined how the two groups of children transformed the environment into categories of signification, relevant to the ways of seeing and common understanding necessary for the manipulation and building of functional structures within the Rokenbok cognitive ecology. Through this analysis, we categorized significant cognitive skills and scientific concepts that were present in the children's practices of producing material representations.

V. Findings

The pilot study examined the impact of the playtime manipulatives, called Rokenbok, on learning and development—i.e., the acquisition of cognitive skills related to math, science, and communication of the child participants in an after-school educational activity. In this section, we organize the findings in line with our guiding questions, which informed the data collection and analysis processes:

1. How does play-interaction with construction-based manipulatives impact participants' abilities to use these devices as intellectual tools for the problem-solving process?
2. What scientific concepts and specific skills necessary for the fields of engineering, science, and math do these devices and play materials promote?
3. Does engagement in construction activities promote dialogic collaboration and cross-cultural collaboration and what does this look like?

Since the cognitive skills and scientific concepts are intricately inter-related, the distinct research questions cannot be answered separately. These skills and concepts are interwoven to form the Rokenbok's cognitive ecology. Therefore, even though a portion of the findings is discussed separately for cognitive and scientific competencies, they should not be understood as disconnected units.

Children's problem-solving abilities from playtime with Rokenbok manipulatives

The child participants were exposed to the Rokenbok manipulatives in two stages: initially as part of free unstructured play with access to pictorial instructions, and, later, in adult-guided playtime sessions. During free unstructured play, the children's visual and manual examination and exploration of the toys preceded the actual play. This exploratory stage did not generate operable constructions. Many of the children were not able to associate the pieces as being part of a larger system with some organized logic, which they had to follow in order to create. They showed resistance when prompted to utilize pictorial instructions. Instead, they explored the toy randomly, trying to figure out how to connect the pieces together through rudimentary manipulation.

This difference was especially visible in the group of younger children and the girls. Many younger children (age 6-7 years old) seemed to struggle to progress beyond the "exploration" phase on their own. They spent the whole session exploring the Rokenbok pieces, trying to figure out how to connect them together, and less often they would look at the pictures on the boxes as well as the visual instructions. Both groups displayed a greater enthusiasm as a result of the adult mentors' intervention and guidance. The younger childen were very cooperative and eager to "help", waiting for the adult mentor to assign small tasks to them— e.g., finding the individual pieces based on the picture shown to them, attaching that piece to the bigger construction project that the group was working on. More often, the younger children began to participate in the activity as a group and only rarely would they play with the toy on an individual basis. We did not observe a significant gender difference in terms of younger children's technical or cognitive skills, or motivation to play with the Rokenbok toy. The younger children wanted and needed time to familiarize themselves with the toy on their own, and they sought help from the adult mentor. They struggled to construct things on their own but were extremely eager to participate in the common group project under the adult guidance.

Many of the younger children explored the pieces and made repeated attempts to figure out how to put the individual pieces together. Physically, connecting the pieces together presented a challenge for most of the younger children, which probably hindered their building capabilities. The introduction of the vehicles into the session also prompted children to refocus their attention from the construction projects to the vehicles and approximately half of the children in each of the observed groups spent a considerable amount of time playing with the trucks. As it were, their preoccupation with vehicle manipulation kept them from the construction task.

Similarly to these observations of the younger groups, the older children tended to use the Rokenbok manipulatives in the first phase in ways that did not generate operable constructions. Many of these children were not able to perceive the pieces as smaller components of a larger system with an organized step-by-step progression. Girls especially were more likely to use Rokenbok pieces to build designs that were abstract formations conceived by their imaginations, such as aesthetically arranged patterns of circular forms or simple geometric designs. The internal logic of such projects was grounded more in the appearance of the individual pieces, their size, shape and color, and not their function within the construction system. The dominant pattern can be described as an enclosure that appeared as fenced areas of simple structures representing houses. As a result of not being able to figure out the 'correct' function of the pieces, the girls used their imagination to play with them in novel ways. On a couple of occasions, two older girls, moved outside of this scheme by using the manipulative pieces in accordance with their intended function to create a tower or an odd shaped structure.

The older boys, on the other hand, without any direction, interacted immediately with one another, punctuating their exploration with questions— e.g., "What is this?" "What can this be?" and "Does the train have the tracks?" Boys were also more likely to cooperate together, talk to each other, ask questions, use gestures, and for the most part, work on one project together. Boys were continually engaged in the process of investigating the particular pieces. They wanted to know what they were and how they could be used (what was their function). Once they figured out the purpose of one piece, they tried to find out how that piece related to other pieces and how could they be put together to form a larger structure. They seemed to work towards some goal in mind and at times created something that had a vague resemblance to the picture on the boxes but nothing that was sturdy or operable. At times boys worked separately on their mini projects, but they frequently combined their individual products towards the common goal of constructing something bigger together.

In the beginning, the children struggled to construct the full-fledged projects that were outlined by Rokenbok materials as the target products of play. Only occasionally and over time some of the children were able to build simple constructions which were, however, mechanically inoperable. The children seemed to follow their own pace when playing with Rokenbok. Almost all of them seemed to be enjoying playing with it to some degree. Additionally, once the adult was introduced in the play area, all of them progressed in terms of their ability to "read" and use the instructions and technical skills to build bigger and operable constructions.

In the second stage of the observation, the adult-guided playtime sessions (or adult-guided intervention) made a dramatic difference in children's engagement, interaction and progress on the project at hand. Most of the children seemed to be more eager to participate in the construction of a common group project within the activity that was structured by the adult.

The adult-guided intervention also changed the communication dynamics of the group. The adult mentor provided an ongoing dialogue with the children in every aspect of the building process—i.e., construction planning and the division of tasks and thus, socializing them into "seeing" the Rokenbok manipulatives in a way that provided them with perceptual categories for classifying the Rokenbok pieces, the set of instructions, and the pictures on the boxes in a scientifically informed way. They learned to engage in problem-solving discussions over a shared set of instructions when they worked on the same project. This orientation towards a common goal coordinated a process of imagining through a shared perceptual field. That is, their imagination was informed by a guided perception.

The children progressively engaged in collaboration with one another and the adult mentor. The Rokenbok toy facilitated such collaboration by presenting the objective of the task at hand as one big project in which each piece in the box had a specific function in the larger project. Several children, shortly after the introduction of adult guidance, showed some resistance towards adult "management" of their activities. But, over time the collaborative dynamics between the adult mentor and the children become more balanced. The children showed an awareness of what it meant to build with Rokenbok and a realization of their own limitations when playing at random in comparison to when they followed the adult mentor's instructions. During the last sessions, children appeared to have developed a vision of the common project that they were building together, something that did on appear in the earlier stages of the study. In other words, the children's constructions indicated their understanding of "the bigger picture".

Gender Dynamics

Gender clearly mediated the interactions and communication between boys and girls; they explored the pieces and carried out tasks differently; b) their interactions tended to be gender specific-- their teamwork was guided by gender roles; c) both interacted with the adult mentor –i.e., the boys interacted more easily and, d) both groups held different impressions of the toys that influenced their gender-stereotypical play.
Cross-gender play was limited. Only some of the girls were able to enter the boys' playing space, either by surpassing boys' building abilities or because of to familial relations— e.g., one of the girls was a younger sister.

The boys' interaction with more competent girls was limited to working on the same construction with little cross-gender communication. The moment the construction crashed or seized to exist, the boys turned away from the girls to play together with their trucks. With no common construction, the relationship between the boys and girls seized to exist as well. By rebuilding the same construction over and over again, two girls were able to re-introduce themselves into the boys' world. More research is needed to explore the interaction between girls and boys including the role of the adult mentor as a facilitator of cross-gender play interactions.

The contrast between high and low levels of peer interaction based on gender indicates differences in the ways boys and girls play and their socialization to gender-specific roles. The girls, as a whole, interacted less with the Rokenbok toy than the boys—they didn't seem to think that the toy was for girls as well. Their interactions involved small movements, limited conversations and promoted more individual work. In contrast, the boys showed excitement and enthusiasm for the toys by constantly interacting with one another through hurried motions, expressive terms and constant body movements. These interactional patterns were also consistant same among children of the younger group. However, the older boys actions suggested a definite awareness of gendered roles within society and inside the learning context.

The exploration of patterns formation with Rokenbok pieces was also mediated by gender. Girls were more likely to use Rokenbok pieces to build actual constructions that related to the home and aesthetics such as arranging patterns in a coherent manner. The internal logic of such projects appeared to be more grounded in the appearance of the individual pieces, their size, shape and color, and not their function within the construction system.

Girls and younger children (boys and girls) exhibited periods of inactivity—i.e., just sitting and looking around without manipulating the toys. These two groups were more likely to work individually, one-on-one with the adult mentor or in silence. Lara is a prime example. She was the most active of the girls in the beginning and utilized the most resources. However once the group setting was introduced, she preferred not to participate in the collective construction of structure. She followed her own agenda although she was intrigued by the boys' level of play and often went over to their side to pick up pieces. Jade, as well, played alone and used her constructions in individual ways to serve her own purposes.

The boys (especially older boys), on the other hand, interacted with one another without any direction, exchanging questions such as; "What is this?" "What can this be?" "Does the train have the tracks?" Boys were also more likely to collaborate with each other, talk with one another, ask questions, use gestures, and for the most part, worked on one shared project together. They also demonstrated a lot of curiosity about the function of the particular pieces. They wanted to know what they were and how they could be used. Once they figured out the purpose of one piece, they tried to find out how it related to other pieces and how they could be put together to form a larger structure. They seemed to work towards some goal in mind more easily than the girls. They searched the piles of toys for the pieces they could use in their project. At times, they worked separately on their own individual projects, but they frequently used their individual products to contribute towards the common goal of constructing something bigger together with the group.

Boys did not seem to be very enthusiastic about the idea of playing with girls. Most of the time they ignored the girls and their interactions with them were limited to matters surrounding the process of building. Most of the playful interaction between the girls and boys sprang from the girls' patient and continuous attempts to play with the boys. However, the boys repeatedly came over to the "girls side" and took pieces for their projects.

However, there were occasions of interactions between the two groups. During one session, the level of peer interaction shifted so that Lara became involved with the boys. By demonstrating her knowledge and capacity to build the crane, Lara was granted access to the group. However, at that point, John asserted his authority and directed the group to integrate the crane that Lara had built into the project the boys were working on. The collaborative cross gender lasted only a short time before the boys smashed the project.
When the adult mentor was introduced into the game area, the setting became more focused on group work without regard to gender. The result was a shift in peer interactions from gender specific interactions to cross-gender collaboration towards a common goal. The children appeared less aware of their individual tasks and gender differences. Instead they concentrated on the guidance of the adult, the new concepts he was presenting them and the development of new ideas.

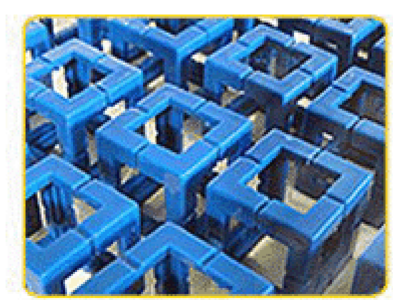
Age also generated some affect as the older groups were relatively more independent and took on distinct roles during play than the younger group that was more apt to disregard gender and collaborated easily across groups and gender. The older boys were also more likely to contribute new ideas or components during their group play. They tended to work as a team like the younger group but were more vocal and directive. Among the girls, the younger ones tended to look to the older girls for guidance and direction.

Scientific concepts and cognitive skills promoted by Rokenbok toys and play materials

The variety of shapes and functions of the Rokenbok Toy's building pieces initially puzzled the children. This feature invited problem solving at the very basic level of physically putting the pieces together, as well as facing the problem of how they all came together to construct the pictured structure. The task presented by the toy required more advanced cognitive skills to develop a mental representation of the construction project which could only be achieved through a combination of familiarity with the actual manipulation of all of its parts, and understanding of the logic of the instructions and pictures on the box covers. It is through play and adult intervention that children's cognitive strategies were visibly transformed.

The developmental trajectory of children's cognitive abilities using the Rokenbok toys began with a marked absence of knowledge of the construction process in general and the role that external models played in the construction process, in particular. The children entered into a rather unfamiliar activity that required a new kind of literacy — symbol-object recognition of the construction as a whole—that is, how the pieces came together to form a structure. While they could easily construct imaginative objects by connecting different constructions pieces together, they had a difficult time relying on the graphic representations to construct the pictured objects on the box covers. It was not until the introduction of the adult, that the children's metacognitive skills—i.e., their knowledge and what they knew—began to flourish. The theoretically informed scaffolding provided by the adult prompted the children to see the logic of the step-by-step progression and enabled them to achieve the building of a structure that was pictured on the Rokenbok box. Although this guided structure may have hindered the children's unstructured exploration and creativity, it did socialize them to a variety of cognitive and scientific competencies that once acquired could be utilized for novel and imaginative projects. As their competence developed, they easily diverted away from the original instructions towards new and creative possibilities for utilizing the Rokenbok pieces.

Playing with the Rokenbok toy encouraged the formation of complex inter-relationships of systems and patterns in a multi-modal cognitive ecology. The Rokenbok toy was utilized to stimulate different types of information processing styles— it operated at the level of concreteness and non-verbal cognition, but also promoted sequential and linear thinking typical of school instruction by utilizing model-based instructions that require a step-by-step temporal ordering of construction. Later on, as children familiarized themselves with the Rokenbok toy they were able to construct operable projects without closely following the instructions and in a more conceptually oriented, intuitive and holistic way.



Importantly, the Rokenbok Toy combined the cognitive processing endorsed in school environment such as sequential and linear type of learning that is enhanced with non-verbal forms of thinking such as visual reasoning and physical manipulation. In other words, the Rokenbok toys and play materials employed two styles of learning: auditory-sequential and visual-spatial learning (Silverman, 2002) (see table 2 below). Rokenbok play stimulated thinking through images and objects in spatial relations, as well as require learners to follow linear and sequentially ordered building instructions with one right answer at each step. According to Silverman (2002), "visual-spatial learners" who think primarily in pictures, respond well to demonstrated instruction, and prefer drawing and manipulation of the objects (p. 306). They are "right-brained" learners, as opposed to left-brained who think in words. Silverman claims that only 25% of people think exclusively in words. Right-hemisphere cognitive processing is characterized as non-verbal, holistic, concrete, intuitive, fantasy-oriented, while left-hemisphere cognitive processing is more linear, sequential, symbolic, logical, and verbal. Below is the difference between these two learning modalities.

Table 2. Learners' characteristics comparison	
The Auditory-Sequential Learner	**The Visual-Spatial Learner**
Thinks primary in words	Thinks primary in images
Has auditory strengths	Has visual strengths
Relates well to time	Relates well to space
Is a step-by-step learner	Is a whole-part learner
Learns by trial and error	Learns concepts at once
Is an analytical thinker	Is a good synthesizer
Attends well to details	Sees the big picture and might miss details
Follows oral directions well	Reads maps well
Does well at arithmetic	Is better at math reasoning than computation
Learns phonics easily	Learns whole words easily
Can show steps at work easily	Arrives at correct solutions intuitively
Excels at rote memorization	Learns best by seeing relationships
Has good auditory short-term memory	Has good long term visual memory
Learns well from instructions	Develops own method of problem solving
Is comfortable with one right answer	Generates unusual solutions to problems
Usually maintains high grades	May have very uneven grades
Enjoys algebra and chemistry	Enjoys geometry and physics
Is well organized	Creates unique ways of organization

Note: The table was adapted from Silverman's (1999) Upside-Down Brilliance: The Visual-Spatial Learner. Denver: DeLeon Publishing.

Silverman further argues that thinking in images is a preferred learning style of the novices who find the auditory and sequential manner of instruction, such as lectures, difficult to follow. Many of Silverman's (2002) instructional recommendations to stimulate the learners' right hemisphere are in line with the affordances provided by the Rokenbok toy: (1) present the materials visually/ show rather than tell; (2) provide ample opportunity for use of imagination; (3) offer hands-on experience such as manipulatives, construction, movement, and action; (4) make available discovery techniques: finding patterns, inductive learning, and inquiry learning; and (5) connect to the children's interests. Learning and thinking processes are enhanced when both sides of the brain participate in a balanced manner.

Visualization and visual reasoning abilities, as Silverman (2002) contends, have become an essential part of scientific fields and their development is a necessary critical skill in "an image-oriented technological era" (p. ii): Success in our technological era depends upon different skills than are currently emphasized in schools: visualization, grasping the big picture, multi-dimensional perception, pattern-finding, thinking graphically, and creativity. Scientific progress relies heavily on the brilliance of people who think in images (p. 307).

Attention and Visual Thinking

The development of children's perceptual field was an important component of their understanding of the Rokenbok toy. The children's perceptual field relied heavily on the conceptual relationships required to carry out the tasks and the mediation provided by accouterment of Rokenbok artifacts. According to Ware (2008), attention is at the heart of visual thinking, "seeing is all about attention" (p. 3). The Rokenbok activity is driven by the need to look for a piece of visual information, that holds one's attention in order to make connections across symbols and objects. The cognitive processes emobodied in Rokenbok construction requires a patterned perception necessary for the building know-how. For example, perceiving, in Ware's model of visual thinking, is not only a passive intake of images projected on people's eye retina, but is also consciously structured and directed by attention that is bound to "pattern-finding circuits" (p. 3) lodged in cognitive processes and memory. Such "visual queries" are driven by the need to look for a piece of visual information in order to perform a cognitive task at hand. The properties of the local environment thus become an intrinsic part of cognitive processes that require a pattern perception necessary for certain scientific know-how.

Visual representations are distinctively involved in the scientific practice and in the very construction of scientific facts (Lynch, 1990; Ware, 2008). This study reveals that "reading" and using multimodal visual displays is an integral part of the Rokenbok activity. Only after the adult mentor guided children's process of building, did the perceptual world and the attention to the relevant visual foci to accomplish the task at hand, became evident as a semiotically rich environment in which children could construct according to the represented models.

The Rokenbok visual representations adds visual information, which clarifies, completes, extends, and identifies theoretical relations and must be understood in order to build operable and sturdy construction. It uses various representational conventions to produce images that are theoretically informed. Models in the visual instructions are positioned to reveal multiple sides and features that are critical for formulating the explanation provided by the adult mentor. The instructions do not necessarily simplify the Rokenbok pieces but add theoretical information so it assumes a generalized, didactically useful, and mathematically analyzable form. The children in the study were resistant to using the instructions and they struggled to "read" them correctly because it was an unfamiliar literacy event that when mediated by adult intervention became notable and practiced. The children naturally did not want to do what they did not understand. The adult mentor provided children with conceptual tools and scientific competencies to employ the instructions and guided them throughout the building process. It also became evident that the children in the sample needed opportunities to develop this type of literacy competency—that is opportunities to practice using visual displays to form physical objects.

Scientific Imagination

Scientifically informed physical manipulation of objects helped children to develop abstract thinking and the ability to make rational judgments about the concrete observable phenomena. According to our findings, the Rokenbok toy facilitated creative problem solving and imaginative play only after children familiarized themselves with the toy in terms of the technical and cognitive skills required for the construction. After they were able to put the individual pieces together, they started to build constructions, which were difficult to operate and repeatedly collapsed. The failure to build durable construction caused significant frustration and caused the children to change their focus toward the vehicles or random talk and play.

The adult mentor guided children the through step-by-step process of the construction in a systematic manner using the visual and oral instructions. Although this guided structure may have hindered the children's unstructured exploration and creativity, it did socialize them to a variety of cognitive and scientific competencies that once acquired could be utilized for novel and imaginative projects. The time limitation of the present study did not leave enough room to explore this phase of children's construction development but our data from the last sessions of our observation show that this could very well be the future direction of the participants' development. More research, however, is needed to prove this hypothesis.

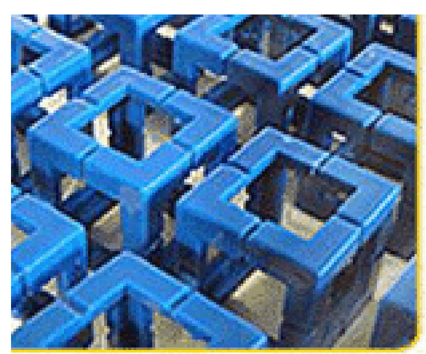
The analysis of the videotapes and field notes revealed ample opportunities for children to develop a set of valuable cognitive skills and scientific concepts such as the ability to:

1. Identify real objects (pieces, and small constructions) based on their pictorial representations;
2. Recognize and comprehend geometric relationships in the pictures (such as lines, sides, planes, angles, and topological properties), which determine a child's ability to make sense of this visual information and replicate it by correctly connecting the pieces to build such shapes;
3. Replicate the construction based on the already built three-dimensional model;
4. Form general abstractions through the process of mapping and establishing correspondences between the material pieces (3-dimensional external objects) with their mental images (internal representations) with the help of the pictorial building plan (2-dimensional external representations). The ability to manipulate/rotate this abstract images "in the head" and align the angle of the real objects in the space with the point-of-view of their corresponding representations in the instructions;
5. Monitor the statics of the construction (where to strengthen the construction so it does not collapse, either on its own or after operating the vehicle from the top of it);
6. Figure out the mechanics of operation; that is, how the individual parts of the larger construction model work together in order for the construction to function appropriately;
7. Problem solve– e.g., learn to identify and frame the problem space for the particular task, then searching for possible solutions within this problem space (i.e., method of trial-and-error); and,
8. Think logically by determining why a set of rules has to be followed and to predict how the changes to these rules affect the construction (what variations would they bring), where is a given building plan going to lead the builder in terms of having a vision and "seeing" a desired end product of the building process.

Cognitive skills emerged through adult-guided children's interaction with the Rokenbok toy. The observation over time illustrated the detailed process of learning. However, it was difficult to pinpoint the "Aha! moments" in which children's "improved" cognitive skills were clearly demonstrated. The process of learning how to construct using the Rokenbok Toy, including following the instructions, was a complex activity that requires a number of cognitive skills as well as practical competencies. Children learned in small increments (there can be only small "aha moments"), such as children automatically reaching for the instructions before starting building, being able to identify the individual pieces based on the pictures.

In the last few sessions several children pointed out that they would not know how to build without the instructions. Such statements demonstrate their increased familiarity with the tools and goals of the Rokenbok toy, a noticeable difference from the early phase of free unstructured play. At the same time, these assertions also suggest the possibility of an overemphasis by the researchers on using instructions during the course of the research. Or, put in another way, it is a possibility that the team did not communicate clearly that children could create operable projects without following the instructions. Thus, one of the possible avenues for future research is to encourage children who demonstrate advanced cognitive and technical skills, to build in non-prescribed ways.

Scientific Literacy Skills



The children in the study, who had no prior experience with using the instructions, were at first very hesitant, even resistant, to using the pictorial instructions. After the intervention was introduced the children became absorbed in learning how to use the instructions. One older boy, for example, showed a particularly strong resistance when prompted to use the instructions. He tempered down his resistance to the instructions after he saw other children working collaboratively with the adult mentor. This episode illustrates that the socialization of children into literacy skills that are unfamiliar to them is a multifaceted process which can easily fail if children cannot see the purpose of what it is being suggested to them. This example also suggests that in the process of child socialization into the desired educational activities grouping a motivated and/or unmotivated child together can help incite natural inquisitiveness by children who would be otherwise resistant to participate in such activities and thus be deprived of its future benefits.

The adult mentor worked towards socializing children into a set of practices that would help them build the perceptual world and attend to the visual foci significant for the process of building according to the represented constructions in the pictures. The strategies the children were encouraged to use as scientific literacy competencies for problem solving tasks were as follows:

1. Children were prompted to examine the link between the actual pieces and their depicted equivalents in the pictorial representations. The adult mentor constantly pointed to the different versions of the same part/shape in the pictorial instructions. He aimed at finding the most illustrative picture to support the children's understanding of the link between the actual pieces and their depicted equivalents in the pictures. The pictorial building plan had multiple steps showing how and where to attach the new pieces to the already built construction.
2. Children were prompted to identify the parts in the picture even if they were shown at a different angle. This strategy was supposed to help children understand that the looks of the depicted pieces could vary in different steps based on the angle at which they are shown being attached to other pieces. Children had generally hard times identifying the particular piece by looking at the picture if it was depicted at an angle different from the previously portrayed one.
3. Children were socialized into understanding that the same object can be represented in different semiotic modalities such as language (i.e., the word "square"), gestures (i.e., using the index fingers and thumbs of two hands to form a shape of the square), pictorial representations (i.e., the picture of the square made of the Rokenbok pieces), material objects (i.e., the actual Rokenbok construction pieces).
4. Children were encouraged to use various semiotic representations of the shapes that needed to be constructed to help them "deconstruct" the shapes into elements that could be identified in the process of building and helped them attach the individual pieces together to build the larger constructions.
5. Children were encouraged to communicate verbally and non-verbally about scientific concepts. The adult mentor simultaneously used verbal and non-verbal requests when communicating with the children about scientific concepts. Modeling proved to be a successful strategy for the children who might be less verbal in their learning and prefer a haptic experience to comprehend the task and solve the problem successfully. The adult mentor used his index finger to point to the picture the children were to construct. The visual aid in the form of picture instructions accompanied with the verbal clarification seemed to work well with the children.

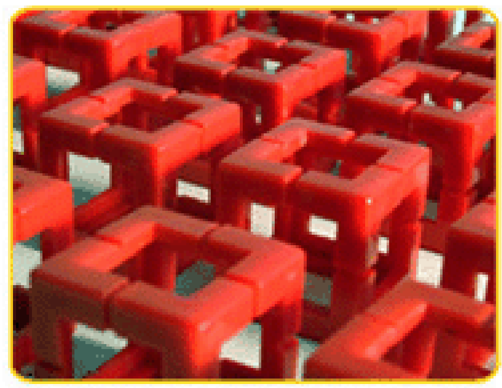
Dialogic collaboration in children's engagement in construction activities

The social aspects of the Rokenbok toy exploration seemed to have a crucial role in children's development. The children showed progress in the development of competencies after adult-guided playtime interactions. It appears that that during the free unstructured phase of the study, the children lacked the vocabulary to express themselves in a "scientific way". In communication with each other and the research team, they often used gestures, pointing, and manipulation of the pieces to express their intentions and ideas. They tended to form a circle around one of the start-up sets of toys, while disregarding the other piles. They also tended to manipulate the toys quietly and by themselves. Mostly they asked questions of the adult member of the research team. After the intervention, they directed their attention to the adult mentor and only occasionally communicated with one another.

There were children who preferred to play on their own even after the intervention. These children showed preference for individual unstructured play, and would not follow the instructions even after the importance was repeatedly pointed out to them. There were two types of children in this group of "solitary players"; those who had a clear idea as to what they wanted to do with the Rokenbok toy and those who resisted cooperative group play throughout the Rokenbok study. These children tended to roam around the area while trying out different available options without investing their attention on one chosen project. Such behavior may point to a lower interest in the actual play with the construction toy itself or simply a personal characteristic.

During the sessions, children code switched effortlessly between English and Spanish when speaking to adults, depending on which language the adult used with them. It was, however, difficult to determine English proficiency of the younger group because they did not communicate enough among themselves in either language. The Rokenbok activity presented an unfamiliar social context that took the children some time to figure out what to do with the toys, how to engage in the activity, and how to become more verbal in their communication.

The adult mentor's verbal and non-verbal modes of expression also scaffold children's competencies and understanding of concepts that improved their ability to talk about their actions, plans, and strategies for constructing the structures. Several children resisted the "management" of their activities by the adult, but over time the cooperative dynamics between adult mentor and children became more balanced.



VI. Final Thoughts and Future Research

According to Vygotsky (1978), "Internal and external action is inseparable: imagination, interpretation, and will are the internal processes carried by external action" (Vygotsky, 1978, p. 100). For Vygotsky (1978), there is a difference between action based on the externally visible stimuli and action steeped in relying on cognitive and internal motivation. Playing with the Rokenbok toys provided the children with the ability to seamlessly merge these skills in the context of play. Furthermore, it inspired children to construct an identity of "scientist." While it is too early to know for certain, it is likely, that play with the Rokenbok toys, introduced an option in children's vision of their future as architects, engineers, and scientists. However, it is clear that the playful environment encouraged the practice of an identity of someone who thinks and creates. In is also likely, although further research is required, the Rokenbok manipulatives also seemed to engender non-prescriptive creative and holistic solutions by the more advanced builders who mastered the technical skills necessary to build mechanically and architectonically solid Rokenbok constructions without utilizing model-based instructions. In constructing these structures, it was clear that the children had acquired an understanding of basic architectural properties and mechanics of the construction process. For example, although some children were able to build structures, their creative constructions were weak and tended to collapse. Additionally, there was evidence that children were able to uncouple meaning from the physical object— e.g., a stick is seen as a horse they can ride on— and thus emancipate themselves from situational constraints. This transition marked their ability to operate within the field of meanings, and not only within the constraints of the visual tactile field.

The pilot study looked at the creative endeavors of children playing with the Rokenbok toy and the specific ways in which the toy informed the imaginative play and the effects it had on learning and development. The study conceived imagination as the mental construction of images in the individual mind, and investigated its emergence through perception and involvement with the external social and material world. "The act of imagining" is a "joint social activity" (Murphy, 2004). Through interpersonal communication and play, the children's scientific imagination emerged as a function of their guided perception and involvement with the external social and material world. The engagement with the Rokenbok toys and playtime activities not only mediated and supported the construction of children's mental images, it also created opportunities for active enactments of visualization through talk, gestures, embodiment, and the manipulation of the material objects.

Overall the Rokenbok Toy represents an innovative learning tool with the potential to promote children's acquisition of cognitive and scientific competencies. Playing with the Rokenbok toy entails a complex configuration of internal as well as external tools that have to be mastered in order to build advanced projects. Playing with the Rokenbok Toy is a cognitively challenging activity that can promote the development of cognitive and technical skills heavily drawn upon in the scientific practice. The Rokenbok toy's pictorial step-by-step instructions can be utilized to stimulate different information processing styles. It operates at the level of visual concreteness and non-verbal visual-spatial cognition beneficial for the instruction of English language learners, but at the same time, promotes sequential and linear thinking and literacy skills heavily utilized in the mainstream education.

There are many aspects of these findings that require further research—e.g., a more focused approach at encouraging girls to develop the type of skills embodied in construction play and the creative and imaginative play of advanced children in Rokenbok play. In particular, more research is needed to assess the influence the acquired skills have on under-performing children's school performance or their motivation to pursue science related fields. This pilot study foregrounds the framework for a more extensive, longitudinal study that examines the long-range effects of construction-based toys on child participants' levels of meaningful participation in construction-based play. Moreover, current underrepresentation of minorities and women in science-related fields warrants the need to investigate the long-term impact of imaginative activities on the academic profiles of minority and low-income boys and girls, in the short term the impact on achievement in K-12 as well as their selection of a field of study in higher education.

This research confirms the team's intuition that the "employment gaps" that CASA strives to bridge is based on the lack of access to opportunities for low income minority youth and girls to acquire the competencies so critical in science, engineering and mathematics. It also confirms Vygotsky's theoretical proposition that given the right learning conditions, the tasks and the tools to achieve them, that learners will perform at their optimal potential

As stated above, science related fields require specific technical and cognitive skills and this pilot study provides some evidence children both practice and acquire such skills in their play with the Rokenbok toy. This is not a conclusive statement but a preliminary conclusion that requires further scientific exploration—i.e., an experimental design study. However, the close observations and scrutiny of the data reveal very promising benefits for building minds through Rokenbok imaginative play. Below, are some possibilities for future research as stated in an earlier communication:

- The pilot study lays out the possibilities for further research in particular, a longitudinal study that examines the long-range effects of construction-based toys on the pursuit of science related areas of study of low-income minority learners. The aim of the longitudinal study would be to identify specific learning tools and strategies that better facilitate the advancement of under-served minority learners into the higher education science related fields. The subsequent findings would contribute to development of education programs aimed at the integration of minority individuals in the mainstream workforce, and in specific in the fields of engineering, math and science. Such a study could include other research teams across a consortium of similar university-community projects located in California (UC Links, www.uclinks.org).

- A study that develops, implements, and assesses a new school curriculum using Rokenbok toys to promote the development of cognitive skills and scientific concepts among under-represented minority learners.

- A comparative study on the cognitive, social, and academic benefits of construction toys such as LEGO, K'nex, and Tinkertoys. Such a study could also conceivably include La Clase Mágica's colleagues in the UC Links consortium and/or its national or international partners in the University of Texas campuses at Austin and San Antonio and at the Universidad National Abierta y Distancia (UNAD) in Bogota Colombia.

- A continuation of the present study with the same children as competent players exploring the creative affordances of Rokenbok and digital media to represent both their involvement and their representation of the world they have constructed and in the process test the viability of Rokenbok Toys to enhance learning the competencies connected to digital media, such as pictures, working with the computer software, and learning to exchange their experiences on Rokenbok website, sharing the pictures, making short movies, and creating their own blogs

- A 3-way comparison study on the affordances of the younger version of the Rokenbok toy to enhance the social, cognitive and academic readiness of for pre-schoolers attending the Head Start Program and two control sites.

- A follow up study on the development of scientific skills among girls using Rokenbok toys.

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