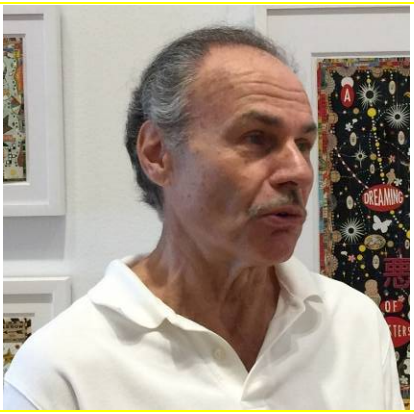

Generative semiotic mechanism links representational drawings of young children with early literacy *(paper)*

Topic: Visual arts and cognitive development

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Abstract

"Drawing is writing . . .", Sulzby, 1992

The visual arts have a unique status in the evolution of humanity and civilization. "The capacity to use symbols, to appreciate the beauty of objects, and to create them, marked a significant turning point in the evolution of Homo sapiens". A milestone in understanding this phylogentic progression is the discovery of stochastic generative mechanisms, which are fundamental to the creative arts, and in this research, they were linked to early literacy development of young children.

Central premise here is children use a recursive cognitive mechanism to link representational drawings to abstract conceptual systems, which generates new knowledge. How do children leap from drawings to new concepts? This research looked at young children's drawings to infer cognitive changes as they invented literacy concepts. Semiotic theory is proposed to describe the generative mechanism that transforms spoken language through drawings into early literacy.

Empirical strategy implemented here emphasized collecting children's drawings before and after a preschool intervention, which was designed to stimulate children to think and talk about family-centered themes. Then drawings were examined for qualitative cognitive changes as children advanced toward early literacy. A central hypothesis was authentic child drawings and narratives would transform along a three tier hierarchy of sensorimotor, iconic, and abstract cognitive components predicted by Peirce's theory of categories.

Quinian bootstrapping was implemented in a quasi-experimental, within group design (pre and post) for several months to stimulate thematic oral narratives among three and four year old preschool children (n = 120), then trained observers rated semiotic signs (n = 14) in drawings and narratives, which were parameterized with a Rasch model to document cognitive change.

Empirical results showed reliabile rankings (alpha = .86), as well as significant group differences between pre and post drawings. Signs accounted for 79% of rater variance, while semiotic components accounted for 70% of variability among drawings. An implementation of dual coding theory to classify verbal versus nonverbal preschool environments revealed significant positive correlations between semiotic child measures and preschool outcomes. In conclusion, the semiotic construct developed in this research established a useful objective framework for examining cognitive changes during a transition from early childhood to emergent literacy.

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Generative Semiotic Mechanism Links Representational Drawings of Young Children with Early Literacy

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1. Introduction

"Drawing is writing . . .", [1]

Visual art making has a remarkably prominent place in the advance of humanity and civilization from its Pleistocene legacy, as the "capacity to use symbols, appreciate the beauty of objects, and to create them mark a significant turning point in the evolution of Homo sapiens" [2]. The instrumental function of visual art making, in fact, continues to command attention in contemporary developmental research. Researchers have found learning the symbol system of representational drawing preceeds learning to write [3, 4]. Yamagata, in particular, described a progression from drawing to conventional writing [5]. Other research has found a stochastic generative mechanism (SGM) underlying creative arts expression [6] that may explain the contribution of visual arts to written human expression.

The present research extends the above line of inquiry by investigating a SGM link between representational drawing and early literacy during story dictation (SD). SD is a loosely defined preschool activity common in American schools, which is frequently conflated with journaling, storytelling, shared book reading, and storybook reading. SD typically involves a storybook reading followed by thematic whole group discussion. Then in some versions, young children draw about the central theme and dictate a personal account to an adult who transcribes it on paper. The particular SD model examined here implemented representational drawings to promote early literacy.

SD through the medium of representational drawing presents an unusual opportunity to observe children's acquisition of new concepts in context of their autobiographical experiences. Empirical studies support broad claims of SD effectiveness emphasizing practical skills such as phonology, letter writing, and comprehension [7], which establish explicit links to writing literacy. However, virtually nothing is known about the underlying generative mechanisms that purportedly link children's spoken language with conventional writing literacy. A central question in this research is the contribution of a SGM during representational drawings to the narrative and thematic foundations of early literacy.

Writing literacy is an artificial, invented system of logically interrelated concepts that imposes structure on human expression. A basic idea presented here is young children acquire this system by implementing a dynamic, recursive process that executes a generative mechanism to create fundamentally new concepts from their spoken language. A triadic recursive mechanism with generative properties is proposed to establish the conceptual linkages necessary for young children to advance from only spoken language to writing literacy.

Representational drawings are central to this research because they provide a convenient bridge between spoken language and writing literacy for young children. While representational drawing presents children with difficult challenges such as implicit rule structures and cultural expectations that are fundamental to symbolic communication, children are irresistibly attracted to drawing and find enormous satisfaction in solving the problems presented by them.

1.1 Purpose

The general development of narrative organization and thematic cohesion are important to preschool children, yet a rationale, evidence-based foundation for their implementation in preschools is generally weak. Instructional strategy and implementation are largely guided by personal insight and experience, and preschool variability is broad. Therefore, a purpose of present research was, first, to expand the theoretical foundations of early literacy research by empirically testing a SGM model that is believed to function during children's SD transition from pre-literacy to early literacy. Specific goals follow below:

- Describe semiotic foundations of a SGM during SD.
- Statistically construct a psychometric dimension for measuring semiotic ability of young children.
- Identify SD statistical effect on early literacy outcomes.
- Examine SGM effects in preschools that differ in predominant language mediation -- visual versus verbal media.

A related goal was to implement a Quinian bootstrapping (QB) procedure and collect representational drawings during SD. Carey presented QB as a learning process that explains how children dramatically expand innate cognitive structures called primitives by bootstrapping new conceptual systems from spoken language [8]. QB is actively debated in the literature [9], and some commentators have criticized Carey's formulation of QB as being vague and ambiguous [10], yet its contribution to understanding conceptual development is widely awknowledged. SD was conducted in present research during a QB procedure with an imagery component (visual imagery) and adult modeling of a placeholder concept that was implemented across participating preschools.

1.2 Significance

This research investigated the semiotic dynamics of thematic narration during representational drawing, which increases an understanding of children's construction of complex conceptual systems from their spoken language. In particular, SGM investigation during representational drawing should increase understanding of children's formulation of narrative organization and thematic coherence, which facilitates their mastery of conventional writing literacy.

2. Background

Historically, child development studies of visual art making in the late 19th century led to speculation about mental structures and human development. Studies by Luquet [11, 12] and Piaget [13], for example, described systematic, age-related changes in child drawings related to spatial abilities, memory, and ideation, which suggested maturational stages. Goodenough then found predictive relations between human figure drawings and intellectual development [14], which reinforced a maturational perspective on developmental change. Piaget countered maturational interpretations by proposing stage changes that are mediated by children's cognitive operations -- assimilation and accommodation during equilibration. Piaget's emphasis on children operating on experience was fundamental to the rise of constructivism, a philosophy and theory about human development. However, a generative mechanism was not identified. In addition, a maturational commitment to predictable, unfolding innate abilities remains prominent in contemporary developmental theory.

During the past 30 years or so, interest in children's drawings has drifted from maturational progressions and mental stages to instrumental contribution of the creative arts to cognitive development and school learning. Researchers, for example, have found musical training to have significant effects on visuospatial and language abilities, and possibly IQ [15]. Other studies have found cognitive effects of visual art making that are promising but less definitive [15]. Neuroscience studies have contributed to this inquiry by identifying common brain processing sites for drawing and writing [16], and relations between the arts

and human development continue to draw interest as more is learned about their fundamental relations. An alternative maturational perspective, however, is generally dismissive about art making approaches to reading and writing literacy and emphasizes instead more conventional approaches such as basic skills.

2.1 Emergent writing and literacy

In addition to developmental progressions, early literacy research has discovered the central importance of playing and talking to cognitive development and specifically, drawing and writing. A differentiation between them occurs during early childhood [3, 4, 5]. These studies have found young children developing symbolic repertoires when they talk and draw about story themes that support multiple modes of expression [17]. Through an idiosyncratic and spontaneous process still not well understood, children develop competencies to address specific communication needs [18]. According to this perspective, children shift unpredictably between sophisticated and naïve competency levels depending on difficulty of tasks presented hence children do not follow strictly ordered skill progressions. Writing development follows more generally the lines of creative generative art products than traditional areas of school-related cognitive development. This emphasis on play and talking contrasts with traditional writing instruction and an incremental progression through fixed skill sets.

Discovery that writing literacy depends on idiosyncratic child-mediated competencies has led to a loosely defined perspective called emergent literacy [19], which has demonstrated significant empirical links among representational drawing, emergent writing, and preschool outcomes [20]. An assumption of this perspective is early language, play, and graphic representation dynamically interact to facilitate children's grasp of formal symbol systems such as writing literacy. Not surprisingly, this perspective on the generative function of children's early learning has rejected traditional writing stages in conventional literacy theories that emphasize decontextualized writing instruction of rigid, incremental skill progressions [21].

2.2 Story dictation

Emergent writing has led to intense interest in the role of cultural context during growth and learning and recognition of the instrumental role of talking and drawing has evolved into many SD-type activities. Several investigations implementing rigorous inferential methods have established SD outcome benefits [22, 23, 24, 25, 26, 27]. Other research has described specific SD effects on narrative writing [28], and positive correlations with cognitive abilities [29]. Hall presents a review [30].

Several issues limit generalization of SD studies. Typical emergent literacy studies are observational and examine single cases or small samples, and typically without comparison groups. In addition, multiple SD definitions and inconsistent implementation create ambiguity about general effectiveness. For example, SD studies have been conducted within a play context that emphasized spontaneous child drawings [31], while other research concentrated on application of new vocabulary in child drawings. Other SD studies did not implement representational drawings [32, 33]. Moreover, surprisingly little research has investigated drawing as a coherent, explicit symbol system that prepares children for early literacy or recognized the common generative aspects of drawing expression and spontaneous emergence of literacy.

Studies have investigated scribble progressions and emergent writing [3, 4, 5, 20]. Likewise, Dyson [34] emphasized "learning to write is a process of gradually differentiating and consolidating the separate meanings of these two forms of graphic symbolism, drawing and writing" [34]. The social cultural context has also been emphasized for its function. "Writing developed as it became embedded in the children's lives and as it became a way of understanding their own experiences and of interacting with others" [35].

Emergent literacy research, however, has not addressed the question how children advance from talking and drawing to early writing or their reformulation of spoken language and drawing into an entirely new symbol system of conventional writing. Virtually none of the research has established a convincing framework for describing how children acquire the conceptual foundations of writing literacy.

Complicating a deeper understanding of the generative foundations of emergent literacy are contemporary efforts to absorb emergent literacy discoveries into traditional theoretical models of writing development. Emergent literacy is now presented simply as an intervening stage linked by learning task and skill sequences [36], which tends to diminish the generative aspects of spontaneously emerging literacy knowledge.

2.3 Semiotics and concept learning

A priority in present research was to address the weak philosophical foundations of the early literacy and developmental literature, first, by asserting that Peirce's theory of semiotics offers a generative mechanism for describing children's transformation of spoken language during early literacy [37]. While Peirce is recognized for his philosophical architectonic, other aspects such as levels of consciousness and his triadic semiotic mechanism are directly relevant to literacy development. Figure 1 presents Peirce's triadic model, which describes dynamic recursive relations among signs, symbols, and meaning, which represent important insights into the conceptual foundations for "meaning making" during emergent literacy.

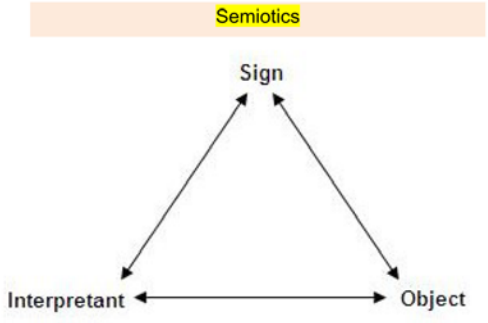
Peirce's philosophy also shares ideas with a developmental theory of symbol and concept formation by Werner and Kaplan [38]. A distinctive feature of that theory is "spirality", which emphasizes "differentiation, articulation, and hierarchical integration [of psychological processes]". This integration is also referred to as an 'orthogenetic principle of development'' [39]. Of particular importance is Werner and Kaplan's emphasis on developmental movement in a spiral not in a linear manner from stage to stage. Moreover, spirality asserts that developmental functions may be simultaneous and parallel hence co-exist and reoccur, which addresses long standing controversies in developmental research about non-uniform mental growth. The generality and coherence of an orthogenetic principle and the flexibility of growth patterns provide a coherent alternative to fragmentation in contemporary developmental theories.

Following outcomes are expected when a SGM modeled with Peirce's triad is implemented during SD with young children:

- Contextual meaningfulness is expanded for spoken language vocabulary.
- Spoken language reformulated into hierarchical knowledge structures.
- Recursive triadic mechanism leads to perceptual externalization, foundations of objective reality, and a theory of mind.
-

Peirce's semiotic triad

Dynamic conceptual mechanism for "meaning making"



Peirce's semiotic triad

Figure 1. Semiotic theory [37]. Triadic epistemology underlies semiotic growth. All objects by necessity are mediated by signs, which embody meaning that ultimately must be interpreted. Personal knowledge generated by this recursive mechanism is embedded within a social-cultural context as mental schema.

2.4 Dual coding theory

DCT, a theory of cognition, describes visual and verbal mediation during cognition that is relevant to school learning and literacy in particular. According to DCT, nonverbal mediation implements visual neuro-processing with analogue code, which preserves physical characteristics and properties of an image. Moreover, retrieval of this information is holistic and simultaneous. In contrast, verbal information implements symbolic code to form mental representations of words, which are processed unit by unit in sequential order. These differences then have implications for memory storage and information retrieval. Figure 2 presents DCT processing applied to the concept of “royal wedding” represented both visually and verbally. DCT neuro-processing implications of SGM during SD were examined in the present research.

The semiotic-developmental ideas presented above makes assumptions about visual and verbal learning during emergent literacy, and DCT provides an opportunity to test them. First, the most efficient generative function for young children was expected to be predominantly visual, hence instructional approaches that rely on visual media were expected to be more effective. Moreover, verbal mediation is not expected to access the same generative mechanisms as visual media. Therefore, independent visual and verbal pathways were expected to produce fundamentally different conceptual structures, which should have implications for early literacy. Validity of these assumptions was tested by examining predictions of dual coding theory (DCT) [40, 41, 42].

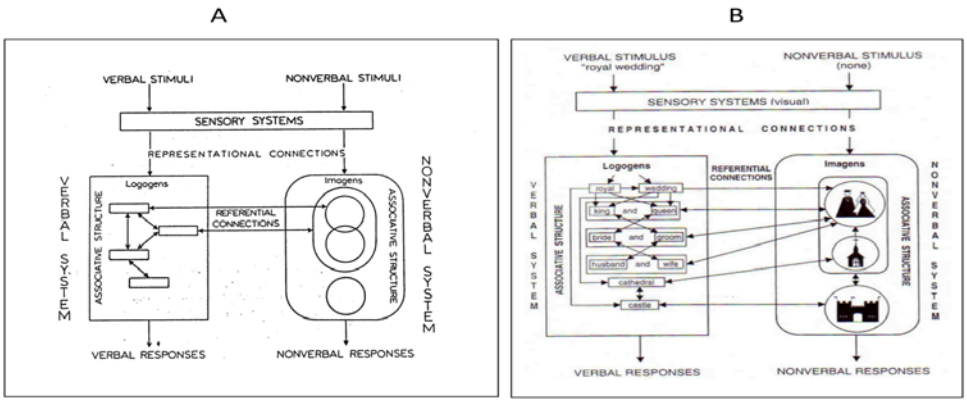


Figure 1. Dual Coding Theory for verbal and nonverbal symbol systems. This schematic depiction shows the association of interconnections within verbal and nonverbal symbolic systems, as well as referential links between them (Reprinted from Sadoski and Paivio, 2001, p. 78; See also Paivio, 1986). Panel A presents an overall schematic of verbal and nonverbal symbol systems. Panel B presents simultaneous activation of both systems with the concept "royal wedding". In the verbal system Royal Wedding corresponds to a hierarchical association of language terms, which have direct referential links with nonverbal symbolization.

Figure 2. Dual coding theory. In dual coding theory verbal and nonverbal symbol systems are referentially linked during cognition. Panel A presents general structure of overall schematic representation, while Panel B demonstrates simultaneous, instantaneous activation of both systems for the concept "royal wedding”, p.78" [42].

2.5 Quinian bootstrapping

A central goal of this research was to increase understanding of the generative mechanism that links spoken language and representational drawing with emergent literacy, and a challenge was to develop an operational model of Peirce’s triad. Quinian bootstrapping (QB) was selected for this purpose.

In general, QB describes how humans learn concepts by starting with a placeholder for the unknown, new concept. In other words, a symbolic placeholder substitutes for the unknown concept, then details about the new concept are added to the placeholder as more experience is gained with it. Principally through analogies and metaphors, new information is related to that already known about the new concept. As the capacity to predict logical relations with other concepts increases, "meaning" of the placeholder concept expands. Consistency and replication of predictions across varied experiences leads to confidence about the new concept.

A QB procedure involves an initial conceptual status, C_1, and a new, reformulated conceptual status, C_2, which represents a qualitative cognitive transformation of C_1. Carey applied this procedure to learning number systems [8]..

QB was adapted for this research by representing children's spoken language at C_1 and new, conceptual foundations for thematic narration at C_2. A SGM modeling Peirce's triad was implemented between C_1 and C_2, which was expected to execute several cognitive functions such as analogical reasoning and inductive reasoning. During QB, a qualitative cognitive reformulation occurs between C_1 and C_2, which establishes new knowledge for children.

A concrete example of the process when initial concepts confront new or unexpected concepts, which are then evaluated for consistency with initial knowledge is presented below in a quote from Eco appearing in Scolari [43].

> At the lower threshold we can identify semiotic micro-processes, like the first inference a driver makes when he sees something in the middle of a country road on a foggy morning. The driver thinks. . . What's that? A car? A cow? These hypotheses demonstrate that perceptual activities may be of semiotic interest, even if interpretative processes are not working to their full extent, p.131, [43].

Directly related to the question of how children generate new knowledge from only existing language is substantial research that shows children to implement probabilistic hypothesis testing during periods of cognitive uncertainty [44, 45]. In general, hypothesis testing during dynamic recursion occurs when children compare new or unexpected experiences with their personal histories. They test logical hypotheses based on perceived patterns of regularity. Children form judgments about similarities and differences from prior perceptual patterns and will act on postulation. Visual arts researchers have also commented on the dynamics of generating images during representational drawing, and they have referred to a process of establishing "graphic equivalents" between perceived reality and children's representation in a drawing [46].

3. Research questions, goals, and hypotheses

3.1 Research questions

Several questions motivating this research are presented below.

1. Can an empirically-defined semiotic hierarchy inferred from children's representational drawings describe advancement from pre-literacy to emergent or early literacy?

2. Does conceptual mediation by visual media versus only verbal presentation affect advancement to emergent literacy? Does media presentation affect preschool outcomes?

3.2 Goals

To answer above questions, this research pursued several goals that establish, first, objective reality of a qualitative semiotic construct inferred from representational drawings. This construct was intended to provide an objective framework for locating children before and after implementing a QB procedure. A central goal was to demonstrate that as children moved across the parameterized construct, they acquired narrative and thematic

conceptual foundations of early literacy. Another goal was to demonstrate the function of a recursive mechanism during children's cognitive movement on the parameterized semiotic construct.

Finally, a goal was to examine the validity of the parameterized semiotic construct by demonstrating the influence of preschool classroom language on children's semiotic ability. Consequently, preschools were systematically observed and classified into verbal and visual environments based on DCT criteria, and those preschools with highest semiotic levels were expected to achieve the highest literacy-related preschool outcomes.

3.3 Hypotheses

3.3.1 Semiotic construct

An initial hypothesis was a construct of sensorimotor, iconic, and abstract relations inferred from children's representational drawings would conform to the structure of Peirce's triad. Moreover, cognitive change represented in their drawings would follow this hierarchy. Then a prediction was child location on the semiotic construct would correlate positively with literacy-related preschool outcomes. In other words, children with the higher semiotic values would show stronger correlations with readiness for kindergarten and literacy-related outcomes.

3.3.2 Reformulation of mental schemas

Peirce originally presented a functional, recursive triad as a central generative mechanism for establishing symbolic meaning, which was adapted in this research to describe children's formulation of personal ideas in drawings. Children were expected to activate existing mental schemas during a QB procedure, and then formulate new schemas as they discovered their original conceptions were inadequate for representing their interpretations of SD themes in representational drawings. This reformulation of initial status was expected to demonstrate qualitative cognitive transformations as indicated by the change in narrative organization and thematic cohesion. Their representation of physical objects, concepts, and meanings in drawings is the product of this mechanism.

3.3.3 DCT hypothesis

Semiotic-related cognitive structures inferred from representational drawings were hypothesized to be sensitive to contextual preschool learning conditions described by DCT criteria of verbal versus nonverbal processing. Therefore, child locations on a semiotic construct were expected to be significantly higher for preschools that embraced visual rather than predominantly verbal instructional environments. In other words, preschool environments with higher visual emphasis were expected to show higher semiotic function, that is, greater generation of symbols and richer meaning and stronger relations with early literacy than preschools that emphasized predominantly verbal instructional methods.

4. Method

4.1 Sample

Thirty elementary schools from Chicago Public Schools (CPS) participated in this research from a citywide population of several hundred thousand, which would be generally representative of large, urban American cities. These particular preschools, however, were exceptional because they were receiving special "coaching" to improve their "effectiveness". Through an independent, objective evaluation, these schools had been identified as very low performing. In contrast, all other CPS elementary schools were classified as "more effective" or "highly effective". In other words, these particular preschools represented the lower tail of the CPS performance distribution, hence they presented special challenges related to educational effectiveness.

Demographically, these schools were comparable to typical CPS schools, that is, predominantly multi-ethnic with roughly equal proportions of white, African American, Asian, and Hispanic children. Socio-economically, many children were English language learners, and the majority was eligible for federally subsidized school lunches, which

requires income verification below an explicit federal poverty threshold. Another relevant characteristic of the overall CPS population is transiency rate, which is annually around 30 percent. Of those that remain in schools, about 20 percent do not maintain steady preschool attendance. Therefore, only children participating in both initial and final assessments were included in this research.

Given the circumscribed sample of 30 schools described above, four children, three and four years of age, were randomly selected from each preschool, *(n* = 120). Approximately equal boys and girls participated in the study.

4.2. Data

Drawings, child narratives, and standardized preschool outcome observations were collected of the study sample. In addition, preschool instructional environments and teacher-child language interactions were observed with standardized rating scales and recorded with appropriate interview protocols.

4.2.1 Child samples

Teacher coaches collected child drawings and narratives during the first and last QB session some six months later. An explicit procedure for collecting samples is presented below.

4.2.2 DCT classroom observations

Teacher-coaches rated preschool classroom language interactions with an observation form derived from DCT principles. These items were intended to distinguish between visual and verbal preschool environments.

4.2.3 Scoring rubric for drawings and narratives

Several aspects of Peirce's triadic model were examined in child drawings and narratives and together with theory of mind criteria; they were formulated into 14 discrete rating scale items. These items represented the following triadic components:

- Objects: Children frequently represented objects in their drawings.
- Signs: Children recognized differences between iconic representation of objects and arbitrary "signs" intended to substitute for objects.
- Interpretants: Child interpreted signs and their meaning in both drawings and narratives

In general, each drawing evaluation addressed the following questions:

- Does child present an identifiable object or icon?
- Does iconic representation change between fall and spring?
- Does object representation, as well as relations among objects change during QB?
- Does attribution of affective states appear in drawings?
- Does child show evidence of theory of mind?
- Are drawing and narrative coherently integrated?

Conducting SD during QB established a uniform process for presenting children with novel concepts, then providing them with cognitive modeling to address the predominant challenge -- interpret the story theme in their own terms. The entire QB procedure was intended to introduce children to a recursive method of thinking about a new or unfamiliar concept. Therefore, the scoring rubric was intended to address whether children changed their graphic representations in conformity with the cycles of a recursive triad.

4.2.4 Preschool outcomes

Standardized preschool outcome assessments were based on child interviews that surveyed preschool performance across specific early literacy-related outcomes.

4.3 Procedure

4.3.1 QB in preschool classrooms

Thirty teacher-coaches were assigned to preschools, one per preschool. Teacher-coaches met individually with preschool teachers weekly for six months, first to model QB, then to address questions and issues that might arise during QB implementation. Several SD themes were presented to children during QB such as sharing, family, and friends, which were supplemented by teachers throughout the experimental period. Figure 3 presents a schematic of a QB procedure implemented in this research.

During teacher-coach modeling, a placeholder concept such as “sharing” was presented orally and pictorially to children, which was reinforced by teacher led storybook readings. Auditory and visual presentation of the placeholder concept was followed by a small group discussion. Concepts then were explicitly reinforced with a visual imagery exercise described below.

> During whole group discussion, children were encouraged to talk about personal sharing experiences with friends and family. Spontaneous expression was encouraged and ample time was provided for all children to participate. Children were then given instructions for an ”imagery" exercise, which requested children to: a) close their eyes, b) imagine how they might “see” sharing at home, in their neighborhoods, or at school, and c) think about how they would like to make a drawing about sharing. Children concentrated intensely for about three minutes, prompts were provided to maintain concentration on sharing before children opened their eyes. All children successfully completed both discussion and imagery portions of QB. Finally, children formed small groups to talk about sharing and were given materials to draw it. After completing an untimed drawing, each child narrated a story about their drawing to an adult who transcribed it on a space next to drawing.

Teacher coaches collected initial drawings and narrations in preschools in the fall and final child samples in spring. Drawings were organized in a binder, both schools and child identify were masked. Then each drawings was randomly assigned and rated by three teacher-coaches.

4.4 Empirical analysis

4.4.1 Semiotic construct parameterization

Three trained evaluators rated each child drawing with 14 rating scale items (ordered categories = 0, 1, 2, 3, 4, & 5). Ratings, both drawings and transcribed narratives, were summed for each child then transformed to linear scale values with a Rasch partial credit model for rating scales. Rasch models implement a mathematical procedure (one parameter logistic) that transforms ordinal scores and ratings to linear (equal intervals) values [47].

Rasch models are probabilistic representations of traditional Guttman scales, which have been applied in emergent writing research [20]. The cumulative, hierarchical structure of Guttman scales are attractive to developmental researchers, yet two issues, ordinal structure and impractical deterministic expectations limit their usefulness [48, 49]. Rasch models address both limitations with an additive transformation function that is summarized below. Winsteps software [50] provided Rasch model parameter estimates for this research.

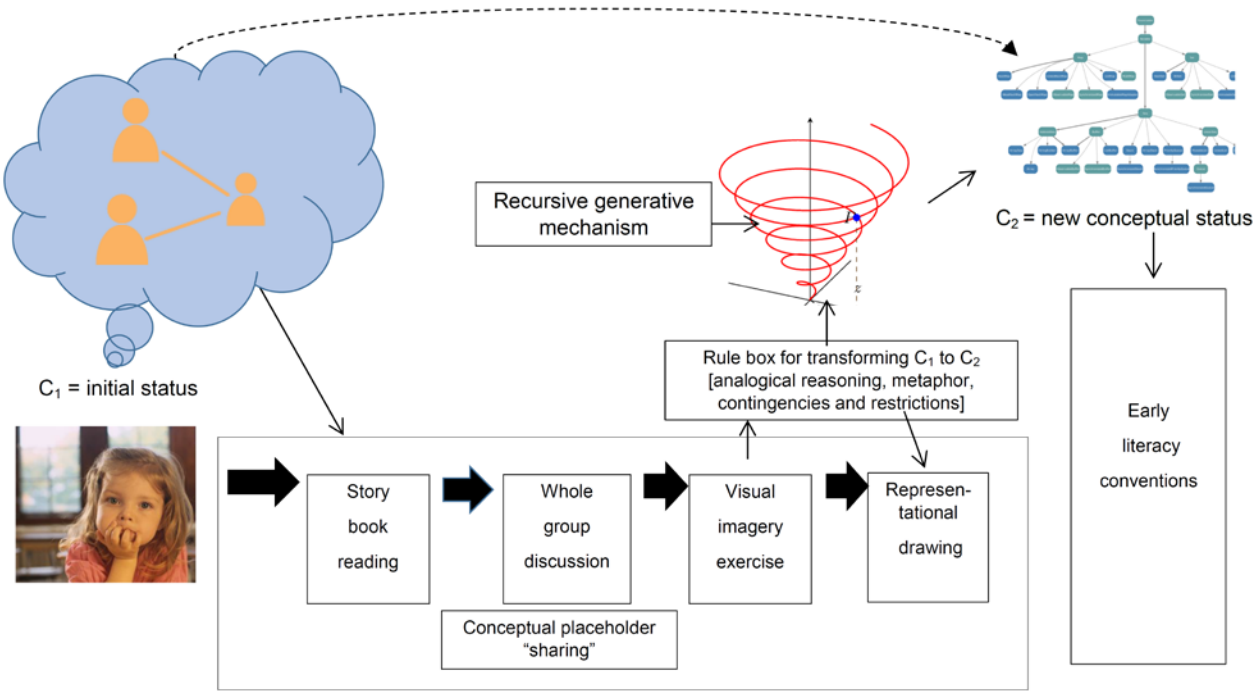


Figure _. Quinian bootstrapping model for early literacy. Child's spoken language represents a cconceptual schema.

Figure 3. A Quinian bootstrapping model for early literacy. Child's spoken language represents a conceptual schema.

x

$$\exp \Sigma [\beta_n - (\delta_i + \tau_j)]$$
$$j = 0$$
$$\Pi_{nix} =$$
$$m \quad k$$
$$\Sigma \exp \Sigma [\beta_n - (\delta_i + \tau_j)]$$
$$k = 0 \; j = 0$$

where β = observations, δ = item difficulties, and τ = rating scale thresholds. Π_{nix} is probability any item δ, will be rated X by participant β_n where X takes a value from a fixed range (j = 1, 2, 3, 4, & 5), m = number of steps for an item, and k = ith step. Following properties of Rasch models make them useful for this research.

- Parameter separation
- Specific objectivity
- Linear units
- Probabilistic ordering
- Sufficient parameter estimation

4.4.2 Statistical analyses

Psychometric reliability of the semiotic construct was investigated, as well as validity from several perspectives. First, internal construct validity was examined by regressing theoretical components (sensorimotor, iconic, and abstract) on item calibrations. This procedure identified proportion of item parameter variance associated with cognitive semiotic theory, which was estimated with the following hierarchical model.

$Y_1 = Component_A + Component_B + Component_C$

Where:

Y_1 = item difficulties (logits)

Drawing properties and characteristics were coded into following components:

A = Sensorimotor
B = Iconic
C = Abstract.

4.4.3 Evaluation of triadic function

Theoretical validity of a semiotic perspective was also examined by evaluating Rasch person fit statistics. Observed ordering of changes in child drawings was expected to conform to the semiotic construct, that is, least mature performance would be located lower in an area with sensorimotor characteristics. Those children presenting abstract ideas in their drawings and narratives defined the highest level of symbolic expression. Iconic representation was expected to define a middle group. Mean square and standardized fit statistics were evaluated for this purpose. Specifically, fit statistics involved comparing model expectations, E with observed child actions, O, then a residual (E-O), was aggregated across items and a Chi-square goodness of fit test conducted. Children and items with large residuals were further evaluated with a mean square statistic.

5. Results

5.1 Child performance samples

5.1.1 Drawings and narratives

Thirty evaluators rated drawings and narratives and their inter-rater agreement was high (r>.90). Therefore, results were averaged across raters. Figure 4 presents examples of initial and final drawings and their narratives collected six months later.

In general, initial drawings collected during a QB session presented idiosyncratic images, and children emphasized mainly sensorimotor exploration. Many children produced large, undefined color masses, frequently embellished with scribbling and stray marks. Those marks are interesting as they appear explicitly organized into primitive object configurations though not formed well enough yet to be interpretable to observers. In general, initial drawings rarely presented identifiable objects, and narratives were typically only isolated words or occasionally a phrase. Narratives were unrelated to drawings. In general, observers were unable to interpret drawing content after the initial assessment without explicit child narration.

In the final drawing collected approximately six months later, children generally shifted to higher semiotic function, and these differences were frequently dramatic. Many children “leaped” from large, undefined color masses (sensorimotor exploration) and idiosyncratic narratives in their initial drawings to explicit object-sign productions, and many drawings were full of iconic indexing – boxes for houses, circles for apples, and so on. Not surprisingly, those children initially highest on the parameterized semiotic construct advanced higher at spring assessment and presented even more complex imagery with denser meaning. Some children also drew alphabet letters on their drawings and expressed abstract ideas about feelings and attitudes. These drawings populated with abstract symbols and personal introspections represent precursors to conventional literacy.

After several months of SD, children not only talked about objects and figures, but included them in drawings and formed conceptual inter-relations among them. Some children demonstrated a theory of mind that attributed beliefs and values to human figures. In addition, some children included arbitrary symbols, and introduced abstract concepts to represent projected beliefs and opinions about hypothetical events. Demonstration of theory of mind by young children in particular is a cognitive milestone and promising advance toward narrative competency necessary for writing literacy.

Fall Spring

Figure 4. Child drawings in fall and spring. Initial drawings tended to be less organized than those in the spring. Narratives in the spring were more closely related to drawings than those produced in the fall.

5.1.2 Principle components analysis

Prior to parameterization, principal components analysis (PCA) identified a single prominent factor (Eigen value = 7.0), which accounted for 47 percent of raw ratings. Aggregation of three largest remaining factors accounted for ~20 percent of variance.

5.1.3 Measurement properties of ordinal transformation to linear scale

Rating scale items were ordered on the dimension from less coherent and less organized to highly organized drawings with explicit expression. With exception of two items, standardized Chi-square item fit values confirmed model fit, which supports dimensionality of these items as measuring units, as well as consistency of child response patterns with the theoretical construct. Likewise, all rating scale threshold parameters were ordered across categories (0, 1, 2, 3, 4, & 5), and conventional psychometric reliability was acceptable (alpha = 0.84). Targeting, however, was problematic. Initial sample performance was very low, well over an entire logit separated the sample from the item mean on the construct. Many children from this population will not have had much prior drawing experience hence their weak initial performance is not surprising. A qualitative description of this ordering is discussed below.

5.2 Semiotic construct analyses

5.2.1 Parameterized semiotic hierarchy

Figure 5 presents 14 rating scale items in a hierarchy after parameterization with a Rasch model. The items define an order from low to high, and the central vertical line represents the equal interval measurement dimension. Children ordered by ability measures appear on left and drawing criteria on right side, while units (logits) are common between them. Performance on the construct is cumulative; therefore, children higher on the construct presented drawing criteria appearing below them.

Results show narration items generally easier than drawing attributes, while spatial relations, human figure details, and identifiable graphic expression were observed less frequently hence were more difficult. Semiotic criteria near bottom were more frequently observed in drawings compared to criteria near top. For example, drawings with stick figures, tadpoles, primitives, and scribbling were observed more frequently hence they appear lower on this hierarchy, and, in general, those drawings were more difficult to interpret. Slightly higher were drawings with human figures and details, as well as those with narratives that were clearly consistent with drawings.

Drawings at highest level were rare, and they tended to emphasize spatial organization of several objects and figures. In those drawings, objects were spread around the drawing consistent with narration, which contrasts with disorganized spatial arrangements of lower drawings. A group of drawings higher on the construct is interesting because they tended to include randomly placed letters and names.

Validity of the qualitative hierarchy was investigated by examining the component structure of parameterized items. Sensorimotor, iconic, and abstract symbolic processing components, which represent levels of consciousness in Peirce’s

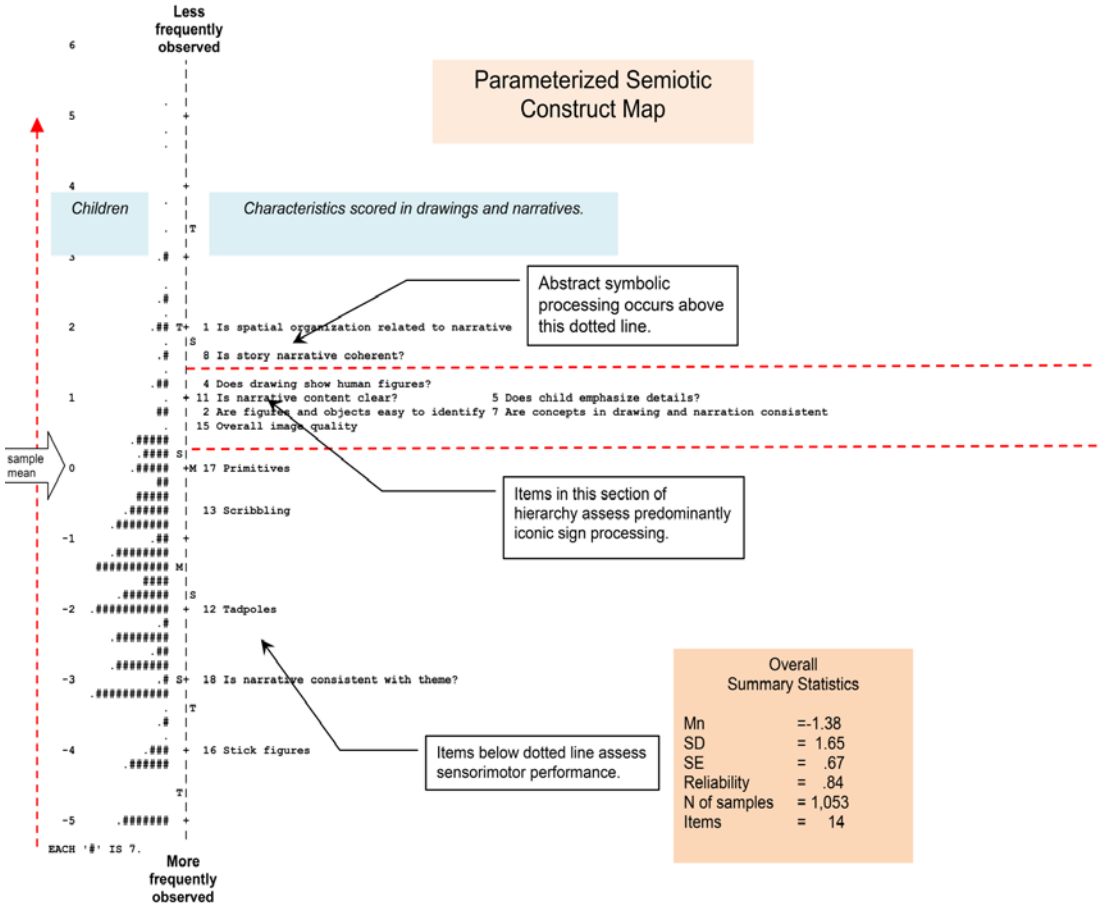


Figure 5. Ratings transformed to linear units. Transformed ratings present children and items in common units (logits).

semiotics were statistically regressed on item parameters. Hierarchical regression indicated semiotic components were associated with 70 percent of item difficulty variance (R^2 = 0.71, F = 13.32, p < .001). With few exceptions, fit statistics confirmed that child progressions across the semiotic construct conformed to theoretical expectations.

5.2.2 Item parameter invariance

An important issue from a validity perspective was confirmation of statistically stable item parameters between initial and final samples, as well as stability in several comparisons such as gender, economic status, and home language background. Figure 6 presents those results and with only a few exceptions, an invariant construct was confirmed.

Another question concerned the movement of children between fall and spring. Results show children tended to advance through the criteria consistent with Peirce's hierarchy of categories. An unexpected result was the conformity of items to Peirce's levels of consciousness, and many children shifted to Peirce's level of Secondness.

Of particular interest are those children near threshold or category boundaries in the hierarchy because they unexpectedly presented both sophisticated and primitive characteristics in their drawings. These children shifted back and forth between assessments, which suggest very loose constraints separating qualitative performance. These results provide less support for rigid mental categories than simultaneous performance layers and overlapping stages, and they suggest "slippage" between them, possibly related to the difficulty of specific story themes.

Figure 6. Item parameter invariance. Two SE control lines show fall and spring item calibrations are statistically comparable.

5.2.3 Residual analysis

Despite results suggesting systematic order on the hypothesized semiotic dimension described above, some drawings were unusual because children occasionally included both complex abstract ideas and less sophisticated primitive characteristics such as scribbling, stick figures, and tadpoles, which led to ambiguity about their semiotic cognitive status. In order to clarify the contribution of multidimensional item properties interacting with the overall construct, PCA was conducted of Rasch item residuals. An examination of residuals should identify non-random patterns such as residual clusters consistent with the overarching dimension. Substantial disruption of random residuals would threaten intended dimensionality of the cognitive semiotic construct and indicate confounding of child cognitive status and item variability.

PCA results indicated the calibrated semiotic dimension defined by 14 criteria accounted for 79 percent of overall ratings, while systematic residual variation accounted for only 3.2 percent of residual variation. Consequently, these results generally eliminated concerns about dimensionality threats from unexpected residual factors.

Figure 7 presents the parameterized semiotic dimension horizontally in uniform logits and item residuals scattered in Eigen value units. The dotted lines provide 95 percent control bands for evaluating residual variability. Most item estimates followed the expected vector trajectory and their residuals present a random error distribution. However, three item residuals formed a cluster. While their disturbance is minor, the following items should be monitored in future research.

- Item 2. Are figures and objects easy to identify?
- Item 4. Does drawing show human figures?
- Item 5. Does child emphasize details?

Another concern is the “clumping” of items in a concentration at the higher end of the construct, which raises a question about the continuity of semiotic function as a quantitative variable.

5.2.4 Differences between initial and final samples (fall and spring)

Although initial semiotic functioning was generally defined by sensorimotor exploration. After an extended QB procedure most children advanced to iconic processing at spring assessment. Although children replaced undefined, ambiguous sensorimotor masses in their drawings with simple objects, very few children actually reached abstract symbolic functioning though fall and spring differences were statistically significant. Overall fall mean was -1.04 logits (*SD* = 2.21, *SE* = 0.79), while spring mean was -.93 logits (*SD* = 1.42, *SE* = 0.60).

5.2.5 Classrooms

Preschool observations conducted with Paivio’s DCT criteria to identify predominantly verbal versus nonverbal preschool environments showed substantial variability. Surprisingly, these differences did not show significant correlations with measures of child semiotic function but were significantly related to preschool outcomes.

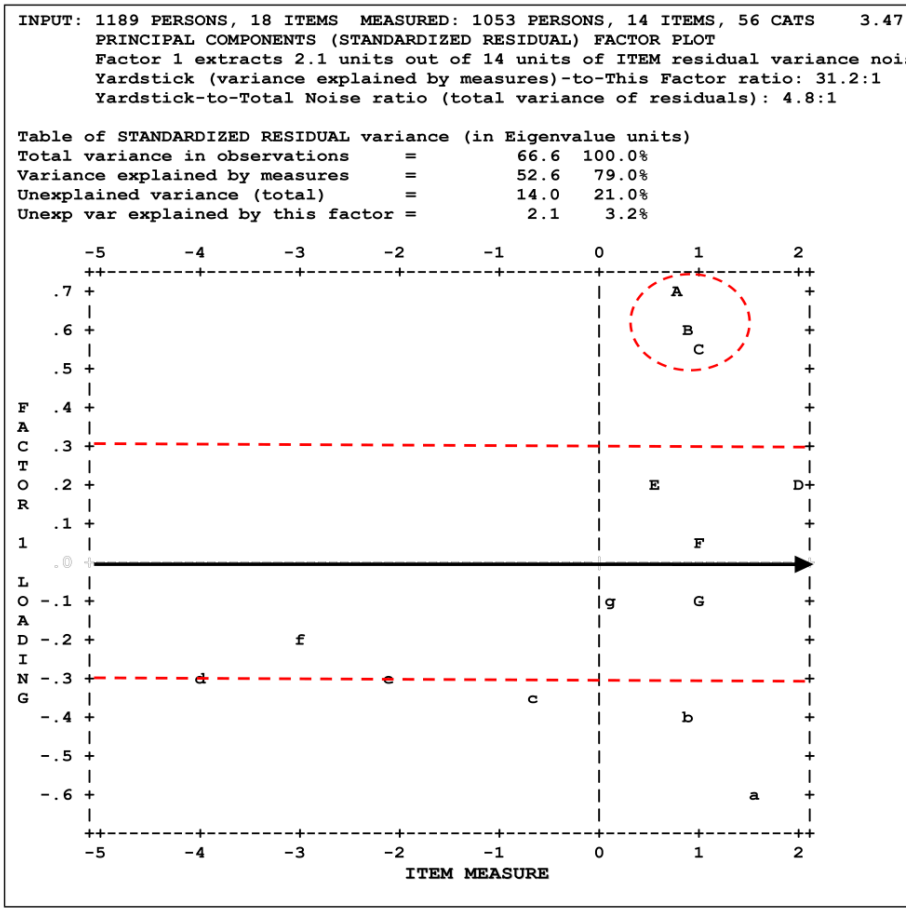


Figure 7. Item residual plot. Item residuals falling outside the measurement zone (factor loadings > +/- 0.3) indicate violation of local independence, which may threaten unidimensionality. PCA, however, indicated only 3.2 percent of residual variance was associated with nonrandom residual structures. Calibrated measurement dimension is represented by horizontal line bisecting the factor plot.

6. Discussion

6.1 Empirical results

6.1.1 Differences between fall and spring assessments

Although statistical power was relatively weak, and the sample presented severely restricted range, results obtained here generally supported the validity of a semiotic-cognitive construct in preschool. In particular, the obtained item hierarchy was theoretically plausible, and construct validation was consistent with expectations from several perspectives. Moreover, parameter invariance and objective dimensionality were adequate for measuring semiotic function.

Children measured on a cognitive semiotic construct based on Peirce's semiotic philosophy demonstrated significant advances between fall and spring. In general, children showed greater narrative organization and thematic coherence, which was an explicit goal of the construct. In addition, children's semiotic measures were positively correlated with preschool outcomes such as Beginning Sounds and Prints Letters, which presents literacy-related validity for this construct.

Not surprisingly, results show that standardized semiotic effect sizes were largest for younger children in more disadvantaged neighborhoods, mainly because they displayed lower performance at fall enrollment. Many five year olds had already passed from lower to higher semiotic performance before QB implementation. An unexpected result was preschool outcomes did not significantly differ between older and younger children, which suggests targeting of preschool programs on younger, less able children.

6.1.2 Comparison of DCT criteria

Results comparing language media in preschools were surprising because semiotic differences were not significant. These results suggest a generative mechanism underlying early literacy is functionally independent of representational drawing. Despite an instrumental contribution to literacy learning, drawing is not required to generate foundational literacy concepts. These results raise the question whether a generative mechanism underlying early literacy is functionally an innate structure generalized across language behavior.

6.2 Significance and implications

6.2.1 Schooling implications

Results here suggest semiotic sophistication among young children varies along a continuum of symbol making competency, and its identification should be useful to preschools. Semiotic function at a sensorimotor level requires much different preschool attention than children functioning at an abstract level. Semiotic performance levels, however, are highly personalized, and diverse subgroups may require special efforts to detect them precisely.

A key step in utilizing a generative mechanism during learning is to lead the child into self-reflection, and ultimately to express an interpretation of the new concept. First the child has to identify spoken language that corresponds to the new concept, then consider plausible alternative relations for that concept. In other words, the child has to “step outside” his or her immediate experience with the concept. Fundamentally, the child has to identify differences of the new concept compared to the familiar representation in spoken language.

In a general sense, drawing during SD is a stochastic generation. As the child executes recursions, order is imposed on the concepts represented in the drawing. Each level of the process involves stochastic generation of alternatives that are tested for validity in the drawing.

Semiotic differences among children can be accommodated in preschools not only by presenting activities that encourage individual language expression, a practice already common practice in preschools, but by introducing conceptual systems that actively challenge the recursive mechanism already under children’s control. SD success in this research was promoted by relatively sophisticated story themes that presented reasonable goals for children. Moreover, support from cognitive training and adult modeling facilitated their progress at narrative organization and thematic cohesion. Likewise, exposing children to multiple sign systems should help establish confidence with a range of symbolic experiences.

6.3 Limitations

Several limitations limit the generality of the results presented here. First, the sample represents a restricted population and differences found between initial and final assessments will probably differ for samples representing a broader socio-economic background. Another limitation is the semiotic construct in this research represents a narrow perspective on the underlying abilities hypothesized to contribute to emergent literacy and conventional writing literacy. While generative mechanisms linking visual art and emergent writing contribute to an understanding of early literacy, the overall process is undoubtedly much more complex.

Also, the semiotic construct presented here was limited by a relatively low ceiling, as well as lack of a control group. Consequently, these results are limited predominantly to three and four year olds.

6.4 Future research

Future research should be conducted with a longitudinal perspective to evaluate the long term effects of semiotic function in preschools related to a range of elementary school

outcomes. Likewise, preschool environment differences defined by DCT criteria should affect student performance in elementary school. Principle areas would be school attitude, learning efficiency, attendance, and special education referral.

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