A developmental psychology perspective on preschool science learning: Children's exploratory play, naïve theories, and causal learning

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CHAPTER 2

A sciencing program and young children's exploratory play in the sandpit

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ABSTRACT

A six week sciencing program, directed at stimulating exploratory play, was implemented with 2- and 3-year-olds in a daycare center. The core of the program consisted of guided play with children in the center's sandpit. The effectiveness of the program was determined with ecologically valid methods consisting of pre- and post-observations of children's exploratory behavior during free sandpit play in the experimental group as well as in a control group. A systematic observation scheme for exploratory play, the Exploratory Play Scale, was used for this purpose. The experimental group showed an increase in level of exploratory play from pre- to post-observations, while the control group did not. This study shows that a small-scale sciencing program can have an effect on children's level of free exploratory play.

INTRODUCTION

Science is part of everyday life of young children. When they explore their environment, they manipulate, sort and make connections between their actions and the effects. Babies put play objects in their mouth and observe the taste and texture; toddlers look intensively how water disappears in the sand. The present view is that young children have strong cognitive competencies and can, to a certain extent, reason scientifically (Eshach & Fried, 2005; Gelman & Brenneman, 2004). Eshach and Fried (2005) state: *'Whether we introduce children to science or whether we do not, children are doing science. We are born with an intrinsic motivation to explore the world.' (p. 332)*

However, enormous differences exist in children's attitudes, skills and knowledge in the field of science (Aubrey, Bottle & Godfrey, 2003; Klibanoff, Levine, Hedges & Vasilyeva, 2006), that may have long-lasting implications for later school achievement (Denton & West, 2002; Klibanoff et al., 2006). This insight has led to an increased interest in preschool science education. Studies done in several Western countries, however, have shown that little science learning has been going on in daycare centers and nurseries (Gifford, 2004). Teachers missed most opportunities for play-based exploratory activities and reasoning in the outdoor environment; only 8.8% of their activities were related to informal sciencing (Maynard & Waters, 2007). There also was a lack of emphasis on providing wide experiences with patterns, measurement or shapes (Aubrey et al., 2003). To train and motivate teachers, special preschool science programs have been developed (e.g. French, 2004; Gelman & Brennenman, 2004).

Sciencing programs for young children

The term 'sciencing' is often used to describe science-related activities for young children (Neuman, 1972). This term accentuates the importance of process skills and attitudes in contrast to formal knowledge (Tu, 2006; Wasserman, 1988). In sciencing programs teachers design environments rich with science activities and support children's exploratory play and learning by expanding their spontaneous play and by initiating playful activities. Teachers are engaged in so-called ‘guided-play interventions’ (Wasserman, 1988).

Guided-play interventions are in line with constructivist views of young children’s development (Göncü, 1993; Vygotsky, 1978). Children are seen as active learners who construct their own learning experience (French, 2004; Gelman & Brenneman, 2004). Teachers help children make connections, they challenge their misconceptions, ask open-ended questions and focus their attention on the outcomes of their actions. In this way, they scaffold children’s exploration to the next level and stimulate them to reflect on their explorations (Gifford, 2004; Vygotsky, 1978).

Preschool science programs have been found to improve science skills (Van Egeren, Watson and Morris, 2007), math skills (Arnold, Fisher, Doctoroff & Dobbs, 2002) and general learning related skills such as self-regulation skills (Van Egeren et al., 2007) and functional behavior (French, 2004).

Our study

With regard to very young children, the 2- and 3-year-olds, effect studies on sciencing programs are rare. There have been qualitative studies of sciencing programs that give rich descriptions and theoretical insights into very young children’s learning processes during playful interactions with adults (Aubrey et al., 2003; Pramling Samuelsson & Pramling, 2009; Ruby, Kenner, Jessel, Gregory & Arju, 2007). These studies have focused on scaffolding processes and mechanisms by which adult-child interactions can support young children’s development of science skills, and on differences in adults’ teaching styles and children’s learning styles. These qualitative studies suggest that scaffolding affects children’s performances with respect to science; first in the cooperative interaction or conversation with the adult and, eventually, in the child’s own self-regulated science activities (Aubrey et al., 2003; Peterson & French, 2008).

The innovative value of our study is that we have developed an ecological valid method to quantify the effects of a sciencing program for 2- en 3-year-olds. We found ways to integrate the classic design of pre- and post-observations and comparison of experimental and control group with the realities of daily life of young children in a daycare center. The core of the sciencing program that we implemented consisted of a guided-play intervention in the sandpit in line with the pedagogical ideas that have been discussed before. The program focused on two related science subjects: sorting & sets and slope & speed. The program was performed by extra science teachers. The observations were performed when the children were playing on their own without the science teachers or regular teachers. We focused on observing children’s process skills, in particular their exploratory behavior.

Our focus on exploratory behavior had several reasons. First, exploration is the behavioral manifestation of curiosity and motivation for science (Chak, 2002). Exploratory behavior consists of skills that are central in science: observing with different senses, manipulating and looking for effects and investigating relationships. Second, young children's knowledge levels are very hard to access using a measure that relies on children's language skills. Third, based on earlier studies we were able to construct a systematic observation scheme to distinguish simple from more complex levels of exploratory behavior (Dunn, Kontos & Potter, 1996; Rubenstein & Howes, 1979; Smilansky, 1968). The so called Exploratory Play Scale (EPS) enabled us to measure differences in level of exploratory behavior between the experimental and control group. At the lowest levels of exploration children only make passive contact with their environment (EPS level 1, passive contact) or attentively manipulate an object (EPS level 2, active manipulation). At the higher levels of exploration children are involved in applying repetition and variation to their manipulations (EPS level 3, exploratory play), making constructions (EPS level 3, construction) and using objects to represent other objects that are necessary for symbolic play (EPS level 4, object replacement).[1]

METHOD

Participants

Two licensed daycare centers in Amsterdam that belonged to the same organization and had the same pedagogical policy participated in the study. Center A provided the experimental group, center B the control group. The centers were associated with the University of Amsterdam until recently and the mean educational level of parents was high. In line with the Dutch regulations, the teacher-child ratio was 2 teachers and 12 children in the mixed age groups (0- to 4-year-olds); and 2 teachers and 14 children in the toddler groups (2- and 3-year-olds). All teachers were qualified and their education varied from junior to higher vocational training. For the sciencing program specially trained extra teachers were recruited and trained.

The experimental group consisted of 35 children (14 girls, 21 boys) averaging 35.51 months of age at the first observation day in center A (range=25 to 44, *SD*=6.10). The control group consisted of 12 children (5 girls, 7 boys) averaging 34.50 months of age at the first observation day in center B (range=26 to 45, *SD*=6.91). The selection of the children was based on age (2- and 3-year-olds), parental permission, presence on observation days and willingness to play in the sandpit.

A first line of analyses included all 47 preschoolers. Not all of these children happened to be videotaped during pre- and during post observations (see Procedure). Therefore, considering all participants did not allow us to perform a repeated measurement analysis. For the second line of analysis, we included the 28 children that had been videotaped during both observational periods in the so-called Repeated Measurements (RM) groups. The 19 children in the experimental-RM group (7 girls, 12 boys) averaged 36.56 months of age at the first observation day in center A (range=27 to 44, *SD*=6.47). The 9 children in the control-RM group (3 girls, 6 boys) averaged 33.69 months of age at the first observation day in center B (range=26 to 42, *SD*=6.47).

Procedure

Before the beginning of the study, toys from both daycare centers' sandpits were replaced with new play objects matching subjects of the upcoming sciencing program in center A. For sorting & sets, different types of natural and non-natural materials of different colors and sizes were provided, together with buckets and sieves in which the objects could be collected. For slope & speed, PVC tubes with different diameters were provided, together with balls and other small objects that could be thrown through the tubes.[2] The new play objects stayed in the sandpits of both daycare centers until the end of the study.

Sciencing program

The sciencing program in center A was performed in six successive weeks in 2006. The guided play took place in small groups (1 to 5 children) during regular morning outdoor playtime. The children were encouraged to participate at least once a week in the games, but they were free to join the science teacher and their peers in the sandpit as often as they wanted. Two science subjects were alternated week by week: sorting & sets and slope & speed. In order to connect the sciencing program to other parts of the preschool curriculum, the science subjects were matched with themes that were elaborated on in the classrooms. The regular teachers read theme related books to the children and the classrooms were provided with posters and dressing clothes aimed at encouraging conversation about the science subjects and themes.

Sorting & sets was matched with the theme "Baking cakes". During sandpit play objects were sorted according to color, size or function and attention was given to the distinction between natural and non-natural materials. For example, cakes could be made with red or blue objects or with natural or non-natural items. The next passage gives an impression of the sorting & sets games:

Jody has her bucket full of sand and repeatedly pats with a plastic spoon on top of it. Simon is watching her. Both have a low level of exploratory behavior (EPS level 2 and 1). Then the science teacher points at a bucket filled with sand with yellow, blue and green play materials on top and asks: "Shall we make a cake?" Jody and Simon look at the bucket and take some of the objects. The teacher continues: "If we want to make this one into a green cake, which ones do we have to take away?" She clarifies her question by asking the children to name the colors of the objects and then repeats her initial question. Simon responds by removing the yellow and blue materials. Next, she asks the children to look for other green materials to put on the cake. Jody and Simon start to search the sandpit for green objects and place them on the cake (EPS level 3).

During the guided play, the children actively *manipulated* the objects, *repeatedly* sorted the objects, they *varied* the sets, and they *observed the effect of their manipulations*, which are the four criteria that we use for classifying the behavior as exploratory play (EPS level 3).

Slope & speed was matched with the theme "On the top of the mountain". In the sandpit, balls were rolled of piles of sand and through PVC tubes. The slope of the piles and the position of the tubes was varied, while the speed of the balls was monitored. The next passage gives an impression of the sloop & speed games:

Rose, Michel and Jan are exploring PVC tubes. They hold them and watch attentively (EPS level 2).The science teacher is sitting at the lower end of one of the tubes. She places a ball in this end of the tube and says to Jan who is standing at the higher end of the tube: "I'll give this one to you" She gently pushes the ball into the PVC tube. The ball comes out of the tube on her side. She keeps placing the ball in the tube and it keeps coming out on her side. She then asks Jan: "Why don't you have it yet? Isn't it coming out?" Jan then responds by lifting the teacher's side of the tube to make it the higher end (EPS level 3). The ball rolls out and the teacher responds enthusiastically.

During this interaction the teacher and children explored the effect of the slope of the tube on the side where the ball exited the tube. They actively manipulated the tube and the balls, they repeatedly threw the balls through the tube, they varied the slope of the tube, and they observed the effect of their manipulations, which are the four criteria that we use for classifying the behavior as exploratory play (EPS level 3).

Observations

In both centers, pre-observations were performed during the five weeks before the start of the sciencing program in center A and post-observations were performed in the five weeks after the program had terminated. On four different days during regular outdoor playtime, one hour video recordings were made of children's free sandpit play, i.e. without science teacher.

To keep the play situation ecologically valid, the regular outdoor play routines were followed as closely as possible. The children were encouraged to play in the sandpits, but they were not obliged to do so and could leave the sandpit whenever they wanted. This procedure resulted in a different number of video recordings of different lengths for each child. In order to be able to study the effects of the sciencing program on children's free exploratory behavior without scaffolding teachers, we asked the teachers to interfere as little as possible with children's play during observation hours. As Dutch daycare teachers have relatively low frequency of interactive play with children (De Kruif et al., 2009), this request was easily met.

Measure - Exploratory Play Scale (EPS)

We developed the Exploratory Play Scale (EPS) based on existing play scales (Dunn et al., 1996; Rubenstein & Howes, 1979; Smilansky, 1968) and literature on exploration (Lindahl & Pramling Samuelsson, 2002; Weisler & Mc Call, 1976). The EPS consists of four levels of increasingly difficult exploratory interaction with the physical environment. The levels of the EPS and the accompanying coding procedures are described in a technical report (Van Schijndel, Singer & Raijmakers, 2007).[1]

Exploratory play was coded from videotape over successive one minute intervals by means of the program "Filmpjes scoren op de UvA" (Grasman, 2005). Using the EPS, each child present on tape was assigned the highest level of exploratory play he or she demonstrated within a time interval. Besides children's nonverbal behaviors, children's verbal behavior was also taken along in determining the appropriate exploratory play level.

Four trained psychology students who were blind to the precise goals of the study coded the videotapes. 20% of the tapes were double coded to assess inter-observer-reliability between all four coders. This yielded an average percentage agreement of 78 % (range 73 – 83%) and an average kappa of .56 (range .47 - .60). This kappa is considered sufficient (Sattler, 2002). Regarding the validity of the EPS, a correlation of r=.43, p=.02 was found between mean level of exploratory play and age.

RESULTS

Analyses on all participants

A first set of analyses was performed that included scores of all participants. By means of a loglinear analysis, the relationship between group (experimental and control group), time (pre- and post-observations) and exploratory play (four levels of the EPS) was investigated. The three-way loglinear analysis produced a final model that retained all effects. This result indicated that the highest order interaction (group x time x exploratory play) was significant, $\chi^2(3)$=35.10, p=.00.[3] To break down this effect, chi-square tests on the time and exploratory play variables were performed separately for the experimental and control groups.

In the experimental group, a significant association between exploratory play and time was found, $\chi^2(3)$=24.36, p=.00. Based on the odds ratio, children in the experimental group were 2.33 times more likely to demonstrate a high level of exploratory play (EPS level 3 or 4) during post-observations than during pre-observations (see Figure 1A). The chi-square test for the experimental group was based on twice as much post-observations (569) as pre-observations (252). In the control group, a significant association between exploratory play and time was also found, $\chi^2(3)$=15.40, p=.00. However, the effect was in the opposite direction. Based on the odds ratio, children in the control group were 2.12 times more likely to demonstrate a high level of exploratory play (EPS level 3 or 4) during pre-observations than during post-observations (see Figure 1B).[4] In the control group, the chi-square test was based on roughly the same amount of pre-observations (182) as post-observations (211).

On the basis of the analyses on all participants, the conclusion can be drawn that the sciencing program made the experimental group demonstrate a higher proportion of high-level exploratory play. In Table 1 we included several examples of high-level exploratory play that were observed throughout the study.

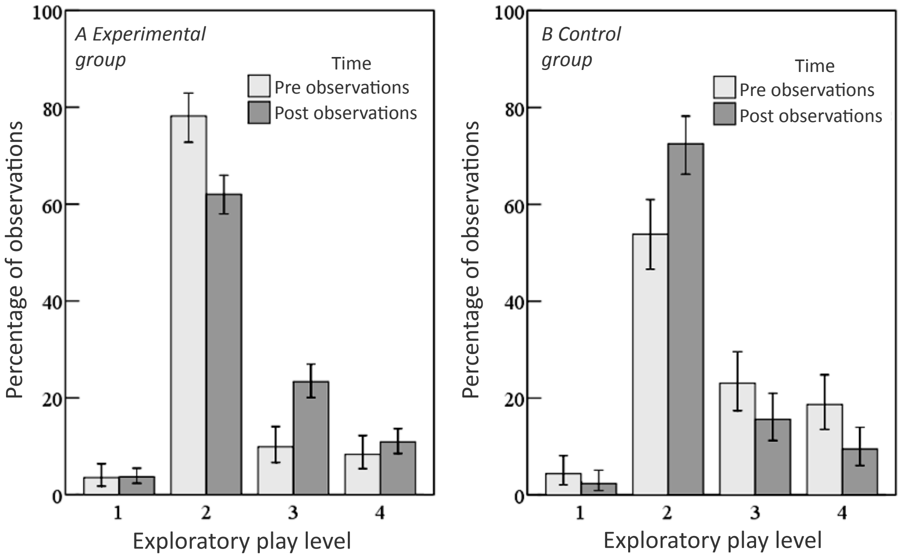

FIGURE 1. Distributions of levels of exploratory play during pre- and post-observations for the experimental (A) and control group (B). Error bars indicate 95% confidence intervals.

Analyses on the Repeated Measurements (RM) groups

Only a subgroup of participants was observed during both pre- and post-observations: the Repeated Measurements (RM) group. The following analyses are based on the scores of this group that can be subdivided in the RM experimental and RM control group.

A factorial repeated measures analysis was conducted with time (pre- and post-observations) as within-subjects factor and group (experimental and control group) as between-subjects factor on mean exploratory play level.[5] No main effects were found. There was a significant interaction between time and group, $F(1, 26)=6.53$, $p=.02$. The experimental group showed an improvement in mean exploratory play level from pre-observations ($M=2.15$, $SD=.26$) to post-observations ($M=2.52$, $SD=.42$). The control group on the other hand, did not show a significant change in mean exploratory play level from pre-observations

TABLE 1. Examples of observed high-level exploratory play: EPS levels 3 and 4.

Level 3 Exploratory play: child actively and attentively manipulates an object. In addition, child repeats and applies variation to his or her actions.

- *A boy (2 years, 4 months) builds a track of wooden planks on the edge of the sandpit. He repeatedly rolls a ball over the track. He varies the length of the track and the speed of the ball. Time after time he pays attention to the effect of his actions on the way the ball rolls.*
- *A girl (3 years, 1 month) plays with a set of buckets. First, she collects balls in a bucket. Next, she places three buckets upside down on top of the bucket filled with balls. She tries to sit on her construction, but the buckets fall over. She then starts moving the balls from one bucket to the other. Finally, she places the buckets on her head.*

Level 3 Construction: child actively and attentively manipulates an object. In addition, child constructs something in a way that suggests that he or she works according to a plan, the resulting construction consists of several parts.

- *A boy (3 years, 10 months) works together with his friends in making a construction. The construction consists of a large pile of sand with a flattened surface. Objects are hidden under the sand and placed on the surface of the pile. He clearly states a plan: "We are building a castle!"*

Level 4 Object replacement: child uses an object to represent another object that is necessary for symbolic play.

- *A boy (3 years, 5 months) uses a wooden plank to smooth the sand in the sandpit. He then repeats this action using two planks at the same time. Finally, he puts one of the planks in a vertical manner in a small hole, moves the top of the plank around and makes a "drilling noise".*

Note. In the descriptions of all levels an object is defined as any part of a child's physical environment.

(*M*=2.48, *SD*=.50) to post-observations (*M*=2.37, *SD*=.30) (see Figure 2). Two effect sizes were computed. First, the mean post exploratory play scores of the experimental and control groups were compared using pooled standard deviations, resulting in an effect size of .41. Next, an effect size was calculated over the difference scores (post exploratory play scores – pre exploratory play scores) of the experimental group; resulting in an effect size of .76. These effect sizes indicate an average and a large effect (Cohen, 1988).

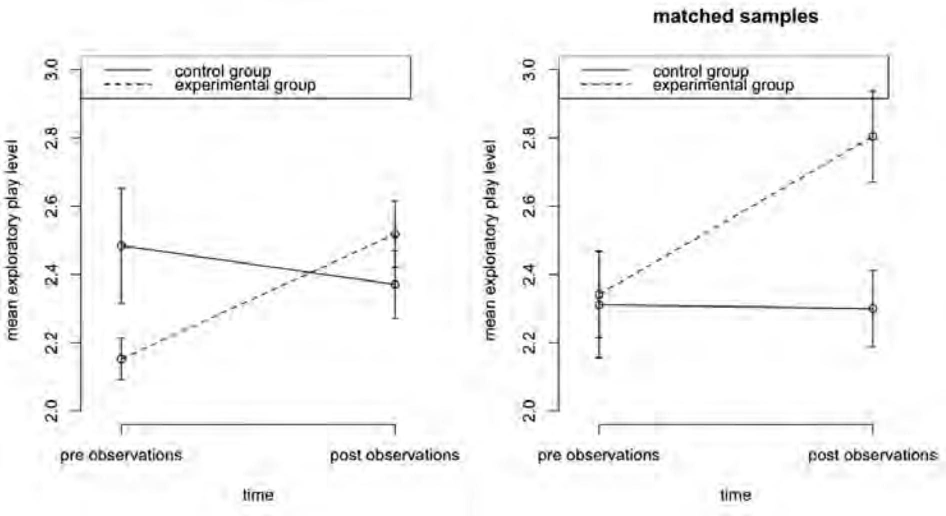

FIGURE 2. Mean exploratory play levels during pre- and post-observations for the experimental and control groups for non-matched and matched samples. Error bars indicate standard errors.

As shown in Figure 2, mean exploratory play levels during pre-observations were higher for the control group than for the experimental group, $t(26)=-2.31$, $p=.03$. One could argue that the difference in mean initial exploratory play level between the experimental and control groups caused the difference in improvement in exploratory play level from pre- to post-observations between both groups (regression to the mean). To address this issue we matched the experimental group with the control group on initial exploratory play level and number of subjects (experimental group: $M=2.34$, $SD=.33$, n=7; control group: $M=2.31$, $SD=.41$, n=7). A two-sided t-test showed that the mean exploratory play level differed between the two matched groups on the post-observations, $t(12)=2.9$, $p=.013$ (see Figure 2).[6] These results suggest that regression to the mean cannot explain the difference in improvement between the experimental and control group completely.

Next, we investigated the effect of initial exploratory play level on the increase in exploratory play level as a result of the sciencing program in the matched samples. We performed an ANOVA with initial exploratory play level and group (control group, experimental group) as between-subjects factors on the difference scores (post exploratory play scores – pre exploratory play scores). As expected, main effects of group ($F(1, 10)=7.24$, $p=0.02$) and initial exploratory play level ($F(1, 10)=26.55$, $p=0.00$) were found.[7] The interaction effect, group x initial exploratory play level, indicates that the participants with the lowest initial exploratory play level profited most from the program ($F(1, 10)=5.02$, $p < 0.05$) (see Figure 3).

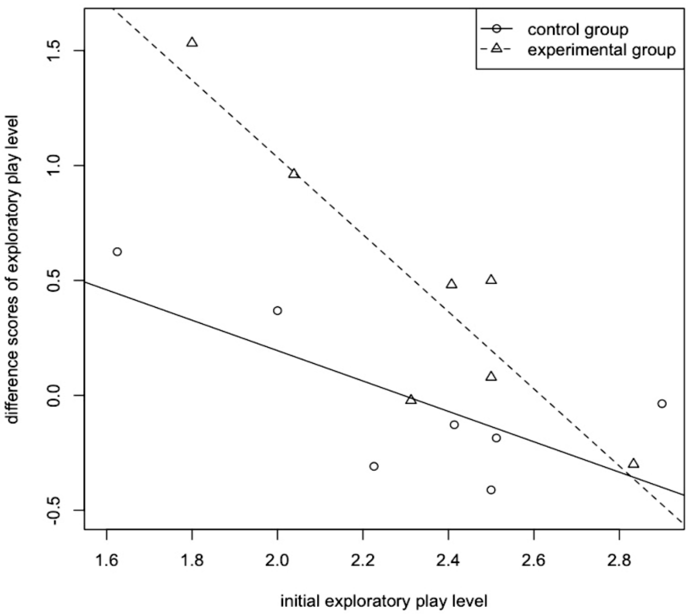

FIGURE 3. Matched samples: Difference scores (post exploratory play scores – pre exploratory play scores) as a function of initial exploratory play level. The regression lines are calculated per group: control group (plain line) and experimental group (dashed line).

The analyses on the RM groups support the finding that the sciencing program led to an improvement in children's exploratory play. In addition, it was found that participants with the lowest initial exploratory play level profited most from the sciencing program.

DISCUSSION

This study demonstrates that a sciencing program consisting of guided play can improve young children's spontaneous exploratory behavior. The analyses on all participants showed that in contrast to the control group the experimental group demonstrated a higher proportion of high-level exploratory play during post-observations than during pre-observations. Analyses on the Repeated Measurements groups confirmed these conclusions. The analyses on the matched RM groups made clear that the results could not be explained by regression to the mean.

These quantitative findings are in line with constructivist theories and earlier qualitative studies that showed that guided play leads to exploratory behavior at a higher level. (Aubrey et al., 2003; Peterson & French, 2008). This is especially the case for children with low initial exploratory play levels, because it was found that they profited most from the sciencing program. This finding is consistent with work concerning social influences on young children's exploratory behavior (Henderson, 1984).

An unexpected finding in the analyses on all participants was the decline in exploratory behavior in the control group. This finding may be due to the fact that the sandpit toys were relatively novel to the children at pre-observations compared to at post-observations. This explanation is in line with observations in qualitative studies that young children easily loose interest in play objects when they don't get attention from an adult (Peterson & French, 2008; Pramling Samuelsson & Pramling, 2009).

In this study we did not focus on the effectiveness of specific characteristics of the program, such as the specific science subjects or the specific aspects of the scaffolding behavior of the teacher (Kontos, 1999; Sylva et al., 2007). To say something about the relative effectiveness of these factors, new studies are needed. In line with that choice, we did not measure children's behavior related to the specific science subjects, but focused on behavior at a more general level: children's exploratory behavior, including non-anticipated behavior. A related point is that this study does not answer the question whether the effects of the sciencing program were directly caused by the guided-play, or indirectly by the effects of the program on the regular teachers. The regular teachers of the experimental group saw the science teachers at work and were encouraged to incorporate the science themes in their daily routines while the regular teachers of the control group were not stimulated in these ways. However, if this alternative explanation is correct, this can be considered a success of the program: influencing the behavior of adult teachers might be at least as difficult as influencing the behavior of young children. Note that the pre- and post-observations have been performed without any scaffolding teacher being present; the effects of the program and possibly of the altered behavior of the regular teachers, were visible in children's spontaneous exploratory play.

Finally we would like to point at the relevance of this study for practitioners. As we showed that at a sciencing program can be a valuable addition to young children's curriculum, we plea for more attention in the initial and in-service training of teachers for science related subjects. Our study shows that the curiosity of young children in natural phenomena and in how things work, needs to be supported by playful and scaffolding teachers. Probably, this is especially true for children with a low level of exploratory behavior.

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APPENDIX A: THE EXPLORATORY PLAY SCALE (EPS)

Level 1 Passive contact: child walks, stands, leans on something or sits and may hold or transport an object.

- *A child sits on the edge of the sandpit and watches other children play.*

Level 2 Active manipulation: child actively and attentively manipulates an object

- *A child attentively scoops sand into a bucket.*

Level 3 Exploratory play: child actively and attentively manipulates an object. In addition, child repeats and applies variation to his or her actions.

- *A child makes prints in the sand with a bucket after which he repeats this action with a sieve. The child closely watches the result of his actions.*

Level 3 Construction: child actively and attentively manipulates an object. In addition, child constructs something in a way that suggests that he or she works according to a plan, the resulting construction consists of several parts.

- *A child makes a pile of sand and places several pineapples on top of the pile.*

Level 4 Object replacement: child uses an object to represent another object that is necessary for symbolic play.

- *A child pretends drinking out of a strainer as if it is a cup.*

APPENDIX B: PLAY OBJECTS PROVIDED TO THE PARTICIPATING DAYCARE CENTERS

Plastic materials in primary colors

- Buckets
- Scoops
- Sieves in different sizes
- Stack and nest cups in different sizes
- Letter-like building elements that can be attached to each other, in different sizes
- Balls in different sizes
- Balls with holes

Natural materials

- Pineapples in different sizes
- Seashells in different sizes
- Twigs in different sizes
- Feathers

Other materials

- PVC tubes in different sizes (different diameters, same length)
- Wooden planks that could serve as holders to place PVC tubes in (semi-) horizontal positions in the sand
- Wooden rings that could serve as bucket lids through which objects could be thrown

NOTES

1. Appendix A gives short descriptions and examples of all EPS levels. Table 1 in the results section gives short descriptions and examples of observed high-level exploratory play (EPS level 3 and 4).
2. Appendix B gives a complete list of the provided play objects.
3. An alpha level of .05 was used for all statistical tests.
4. One could argue that in an exploratory play scale, level 4 (object replacement) is not per se higher than level 3 (exploratory play/construction). Therefore we repeated the analysis of the data with recoding level 4 to level 3. The results are comparable with the original scoring: In the experimental and control groups, significant associations between exploratory play and time were found, $\chi^2(2)=22.06$, $p=.00$ (experimental group), $\chi^2(2)=14.79$, $p=.00$ (control group) and these associations were in opposite directions.
5. In the analyses in this study we did not model dependencies between participants. This type of modeling would only have been possible with a bigger sample of daycare centers.
6. These analyses were also repeated with recoded data (See footnote 4). The results for the same matched sample remain equal: experimental and control group are equal on pre-observations (experimental group: $M=2.20$, $SD=.08$, $n=7$; control group: $M=2.21$, $SD=.11$, $n=7$). Scores for the post-observations differ between experimental and control group, $t(12)=2.9$, $p=.01$ (two-sided).
7. The main effect of initial exploratory play level is expected on the basis of regression to the mean.