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

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CHAPTER 8

Summary and general discussion

This thesis contains six empirical studies concerning preschoolers' science learning. The studies focus on preschoolers' exploratory play, naïve theories, and causal learning in both natural and controlled settings. In the following paragraphs, we will discuss the findings concerning each of these topics and indicate directions for future research. Finally, we will come back to the collaboration between the UvA research group and science center NEMO. We will briefly summarize the activities that were undertaken to bridge the gap between research and practice, and discuss the added value of the collaboration for both parties.

PRESCHOOLERS' EXPLORATORY PLAY IN NATURAL SETTINGS

The studies in Chapters 2, 3, and 7 concerned effects of adult guidance on preschoolers' exploratory play. We started by investigating effects of a wide range of adult behaviors in Chapter 2, but focused increasingly on investigating effects of specific aspects of adult behavior in the subsequent chapters. In a daycare setting, we found that a sciencing program affected the quality of young preschoolers' exploratory play (Chapter 2). In a museum setting, we compared the effects of different adult coaching styles on preschoolers' exploration at exhibits (Chapter 3). We found that, dependent on the exhibit, a different coaching style resulted in the highest quality of exploratory play. In a second experiment we found that informing parents about an effective way of coaching influenced their children's exploratory play at exhibits. In Chapter 7 we investigated relations between different types of parent explanation and preschoolers' exploration in a museum setting. It was found that children whose parents gave more evidence descriptions demonstrated a higher quality of exploratory play. However, the design of the study does not allow us to draw causal conclusions about this relation. Future research might therefore be aimed at replicating this finding with an experimental paradigm.

To quantify preschoolers' exploration in natural settings we developed the Exploratory Behavior Scale (EBS). This scale has the advantage of being domain-general and applicable in different settings, while at the same time being a relatively detailed measure that can be used to assess the quality of preschoolers' exploration. We have shown that the EBS is a suitable measure for investigating effects of parent guidance on preschoolers' behavior (Chapters 2, 3 and 7). However, the EBS's domain-general nature might make the scale less suitable for investigating relations between exploration and domain-specific learning (Chapter 7).

PRESCHOOLERS' EXPLORATORY PLAY IN CONTROLLED SETTINGS

The study in Chapter 6 concerned the effect of conflicting evidence on preschoolers' exploratory play. Previous studies demonstrated effects of uncertainty caused by the ambiguity of evidence on preschoolers' exploration (Cook, Goodman & Schulz, 2011; Gweon & Schulz, 2008; Schulz & Bonawitz, 2007). Bonawitz, Van Schijndel, Friel, and Schulz (2012)

demonstrated the effect of uncertainty generated by conflicting evidence on the duration of young children's play. We extended those results by showing that this type of uncertainty also affects the quality of play: children who were shown evidence conflicting with their naïve theory conducted a higher number of unconfounded, informative experiments during free play than children who were confronted with consistent evidence.

Important questions for the future concern the relation between preschoolers' observation of evidence, their exploration, and learning. One topic of interest is preschoolers' explanations for evidence conflicting with their naïve theory. Siegler and Chen (2008) showed that asking primary school-aged children to explain answers affected their learning, and that explaining why incorrect answers were incorrect had an additive affect compared to solely explaining why correct answers were correct. A first question for future research is whether, besides affecting learning, explaining conflicting evidence also affects exploration. Specifically, we are interested in the question whether explaining conflicting evidence has an effect on the quality of children's exploration in addition to only observing conflicting evidence. A second question for future research is how children's explanations are related to their exploration; that is, are specific explanations related to specific patterns of play? Legare (2012) found evidence for this claim in the preschool age group. She demonstrated that children who explained conflicting evidence by referring to a problem with the functioning of an object, engaged in more variable exploration, and were more likely to show behavior consistent with a search for an internal mechanism, than children giving other causal explanations. In line with the hypothesis that explanations affect learning by making children notice explanatory variables that they had not noticed before (Calin-Jageman & Ratner, 2005; Siegler & Chen, 2008), we are interested in investigating whether this noticing of variables also guides children's play. Do children who mention a new variable in their explanation focus mostly on investigating that variable during exploration?

CHILDREN'S NAÏVE THEORIES

In Chapter 4, 6 and 7 we presented studies concerning children's naïve theories in several different areas of science. We applied an individual differences approach: based on children's response patterns to a series of items, different types of knowledge were distinguished. These qualitatively different theories were subsequently related to age. Compared to inspecting average accuracies per age group, the individual differences approach yields a more detailed description of development. We used Siegler's (1976, 1981) Rule Assessment Methodology to apply the approach, but instead of analyzing response patterns by matching observed to expected response patterns we applied a latent variable technique (e.g. McCutcheon, 1987; Rindskopf, 1987). One of the advantages of a latent variable technique over pattern matching is that the technique makes it possible to detect unanticipated response patterns, or theories (see Van der Maas & Straatemeier, 2008 for a more extended discussion). In addition, the

technique allows for disentangling different sources of variance in children's responses: variance resulting from different theories and variance resulting from children making errors in applying their theories.

In Chapter 4 we investigated primary school-aged children's naïve theories about prenatal development. Results of a forced-choice questionnaire showed that children have coherent, age-related, theories about the shape of the fetus, but not about bodily functions. The shape theories were in line with previous work on children's reasoning about natural transformations (Rosengren, Gelman, Kalish & McCormick, 1991) and constraints in representational flexibility (Karmiloff-Smith, 1992). In addition, we explored two issues related to the use of different methodologies for assessing children's naïve theories. First, we examined whether a generative task leads children to form theories "on the spot" (Vosniadou, Skopeliti, & Ikospentaki, 2004). In line with this hypothesis, we found a preceding drawing task to enhance the coherence of children's theories as measured by the questionnaire. A question for future research is whether other types of generative tasks, such as open-ended interviews, have the same effect. Second, we compared several methodologies for assessing children's naïve theories (e.g. Nobes et al., 2003; Straatemeier, Van der Maas & Jansen, 2008; Vosniadou, Skopeliti & Ikospentaki, 2004). We found the results of the drawing task not to be related to age, and the coherence of the interview to be considerably less than for the questionnaire. Therefore, we concluded that drawing tasks and interviews are suboptimal methodologies for assessing children's theories.

In Chapter 6 and 7 we investigated preschoolers' naïve theories about shadow size. In line with previous research (Chen 2009; Ebersbach & Resing, 2007; Siegler, 1981) two age-related theories were distinguished: children taking into account object size, and children taking into account both object size and the distance of an object to the light source in determining shadow size. In addition, we distinguished a group of children giving incoherent responses. However, to our knowledge, we were the first to systematically demonstrate the existence of a third theory: children taking into account the size dimension in the right direction, but the distance dimension in the wrong direction in determining shadow size (Rule 2-reversed). Learning data (see the next paragraph, "Preschoolers' causal learning") suggested that children applying this theory might be a transitional group, making them more susceptible to evidence than children in other theory groups. However, future research has to show whether this is the case. Regardless, the finding of the new theory group clearly illustrates the advantage of using a latent variable technique over pattern matching.

This work, as well as other work on children's naïve theories in areas of science (e.g. Boom, Hoijtink, & Kunnen, 2001; Jansen & Van der Maas 1997, 2001, 2002; Straatemeier, Van der Maas & Jansen, 2008), demonstrates that differences between domains exist in the development of children's knowledge. These differences might be related to available sources of knowledge: for example, some domains allow for children to have hands-on

experiences, while other domains only allow for information to be obtained through books, television or interactions with other people. However, the studies of specific domains do contribute to gaining a better understanding of knowledge development in general. Topics for future research that transcend domains concern relations between generative tasks and the coherence of knowledge, the process by which implicit knowledge gained by experience is integrated with explicit knowledge gained by interactions with others, and relations between different sources of knowledge and the coherence of knowledge (e.g. Gelman, 2009; Harris & Koenig, 2006).

PRESCHOOLERS' CAUSAL LEARNING

In Chapter 5 we investigated a prerequisite for learning from exploration: preschoolers' ability to make causal inferences form observed evidence. To our knowledge, this study was the first to apply the individual differences approach in this line of research (see Gopnik et al., 2004 for a review). To this end, we administered a series of carefully selected causal inference trials to preschoolers of a relatively broad age range. We distinguished different types of response patterns with the goal of interpreting these as types of causal inferences. Results showed a developmental pattern based on three age-related types of causal inferences. Possibly these types reflect different mechanisms for causal inference: older children responded consistent with the Causal Graphical Model framework (Gopnik et al., 2004), while younger children responded consistent with causal inference on the basis of associative models (Dickinson, 2001; Rescorla & Wagner, 1972; Shanks & Dickinson, 1987). However, as the study did not test the existence of these mechanisms directly, these interpretations should be considered preliminary. Other possible interpretations of the developmental pattern concern children's developing information processing capacities and motor abilities in combination with demands of the procedure used (Sobel & Kirkham, 2006). Future research could be aimed at further unraveling the factors underlying these individual differences by using new procedures (e.g. Beckers, Vandorpe, Debeys & De Houwer, 2009; Sobel & Munro, 2009). Studies could either focus on selecting additional procedures for distinguishing between possible mechanisms for causal inference, such as trials including information about the base rate of certain events occurring (e.g. Sobel, Tenenbaum & Gopnik, 2004), or focus on selecting procedures for minimizing the demands on abilities other than children's causal reasoning abilities (Sobel & Kirkham, 2006).

In Chapter 6 and 7 we investigated preschoolers' causal learning from exploration in the domain of shadow size. In a controlled setting (Chapter 6), we investigated relations between children's prior knowledge and learning, and between their exploration and learning. We found that children who had a Rule 2-reversed theory at the start of the experiment showed larger negative changes in knowledge on the size dimension and larger positive changes in knowledge on the distance dimension over time than children in the other theory groups.

In addition, we found that children who conducted more distance experiments during free play, showed a larger increase in knowledge on the distance dimension than children who conducted less distance experiments during free play. In a museum setting (Chapter 7) we investigated relations between parent explanation and children's learning, and between children's exploration and learning. In addition, we investigated whether attending a theater show prior to visiting the exhibition space affected children's learning. We did not find relations between parent explanation and children's learning. In contrast to the results in a controlled setting, a negative relation between children's exploration and learning was found: children who demonstrated higher mean EBS levels were less likely to learn than children who demonstrated lower mean EBS levels. Last, we found an effect of theater attendance on children's learning: children in teams that had attended the theater show were more likely to learn than children in teams that had not attended the show.

Future research could further investigate the process by which preschoolers learn from exploration in domains such as shadow size. In line with previous work on preschoolers' causal learning (e.g. Gweon & Schulz, 2008; Schulz, Gopnik & Glymour, 2007), we found only small percentages of children to show a more advanced theory after exploration compared to before. Work on primary school-aged children's science learning, suggests that the relation between exploration and learning is mediated by the hypotheses children have in mind when designing experiments and the conclusions they draw based on the results of experiments (e.g. Dunbar & Klahr, 1989; Schauble, 1990). Future studies in controlled settings could be aimed at investigating these factors in the preschool age group.

COLLABORATION UVA & NEMO: BRIDGING RESEARCH AND PRACTICE

The studies described in this thesis had the double aim of contributing to theory development on preschoolers' exploratory play, naïve theories and causal learning, and at the same time describing children's science learning in natural settings. The work was performed within the framework of Curious Minds: a program at the intersection of research and practice. In meeting the goals of Curious Minds, the UvA research group collaborates closely with science center NEMO. During the last 5 years the UvA and NEMO have collaborated on gaining experience and knowledge on young children's science learning, and sharing this knowledge with different parties in the fields of formal and informal education. As mentioned in Chapter 1, activities of the UvA and NEMO included giving workshops to teachers, writing a guide with recommendations for developing science activities for preschoolers (Franse, Van Schijndel & Raijmakers, 2010), and developing the Young explorers in NEMO exhibition (http://www.e-nemo.nl/kleutersaanzet). In addition, we have also contributed to bridging the gap between research and practice by offering advice to Dutch science museums on exhibition development, and by regular presentations on science center conferences.

The collaboration between the UvA and NEMO has proved fruitful for both parties. For the UvA the added value of the collaboration lies in the opportunity to study children's science learning in a natural setting. NEMO is visited frequently by families with young children and this allows for investigating whether research results that have been obtained in controlled settings can be replicated in a natural setting. In addition, working with NEMO on educational products, allows the researchers to gain insight on the relevance of research questions for professionals. For NEMO the added value of the collaboration lies in advancing knowledge on children's cognitive and social-emotional development. What are preschoolers' skills and knowledge in the field of science? And how can preschoolers' exploration and learning be stimulated in a museum setting? In addition, the researchers offer the museum advice on the evaluation of activities for young children. As measuring preschoolers' behavior in an informal setting can be a complicated undertaking, the UvA research group's methodological expertise comes in handy for this purpose. To conclude, looking at the advantages for both collaborating parties and the products resulting from the collaboration, the choice for performing three types of research-related activities within the framework of this thesis (studies in controlled settings, studies in natural settings, and the application of research outcomes in the practice of science education) can be considered a valuable approach.