Curious minds: stimulating parent-child interaction to foster neurocognitive functioning in four- to eight-year-olds

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CHAPTER 5

Educating parents to enhance reasoning abilities in children: A focus on verbal scaffolding

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ABSTRACT

This study investigated whether parents can be educated to improve parent-child interactions and whether this can improve children's reasoning abilities. Parents of four- to eight-year-olds were randomly assigned to a compact psycho-educational program (*N*=34) or control condition (*N*=36). Parental questioning style was observed during problem-solving interactions at home and children's scientific and social reasoning were assessed using performance-based tasks. Parents in the educational condition asked significantly more open-ended, observational and explanatory questions at post-test than controls did. More open-ended questions resulted in improved scientific reasoning in their children and more explanatory questions resulted in improved social reasoning. Educating parents to adaptively modify their parent-child interactions can positively influence their questioning style, which in turn may benefit their child's reasoning abilities.

Keywords: Parent-child interaction; parent educational program; verbal scaffolding; social reasoning; scientific reasoning

Parent-child interaction is essential in the development of children's learning and problem-solving skills. By using nondirective instructional techniques, parents can help their child engage in complex problem-solving by scaffolding the task either verbally (e.g., asking questions) or nonverbally (e.g., attention redirection behaviors) (Lewis & Carpendale, 2009). Scaffolding can be defined as the parental input during parent-child interaction promoting independent problem-solving and learning (Dieterich et al., 2006; Mermelshtine, 2017). Parents may become more involved in their children's learning when they are educated about how their child reasons and learns (Gleason & Schauble, 1999). In this sense, parents educated in reasoning development may be better equipped to recognize their child's level of competence and facilitate development by adaptively challenging their child's skills. With this increased parental understanding of their child's developmental needs, parents may thus be better able to adaptively scaffold problem-solving and thereby challenge their child's reasoning abilities.

Fluid reasoning abilities reflect the ability to think logically, detect patterns and relations, form concepts, and solve problems in novel situations (Cattell, 1987; Schneider & McGrew, 2012). Cattel (1987) conceptualized reasoning abilities as a scaffold for learning, serving as a foundation to acquire other cognitive skills. These reasoning abilities have repeatedly been shown to be predictive of school performance, especially math achievement (e.g. Floyd, Evans, & McGrew, 2003; Green, Bunge, Briones Chiongbian, Barrow, & Ferrer, 2017; Hale, Fiorello, Kavanagh, Holdnack, & Aloe, 2007; Miller Singley & Bunge, 2014). Reasoning is traditionally considered a relatively stable trait of an individual, and resistant to change through training (e.g. Carroll, 1993). However, more recently this notion has been called into question (Flynn, 2007; Nisbett et al., 2012). Specifically, reasoning abilities have been shown to be influenced by environmental factors and to be improvable (e.g. Mackey, Hill, Stone, & Bunge, 2011; Nisbett et al., 2012). Given that young children spend a substantial amount of time with their parents, this raises the question whether parents can be educated to support the early development of reasoning abilities through scaffolding.

Kuhn (2010) posited that practicing reasoning abilities in the real-life social context may be especially promising. In order to solve problems using skilled reasoning, children need to learn strategies to achieve their goals. A way to learn new strategies is through social interaction, either by being instructed specifically, by imitating others, or by collaborating. Caregivers can use verbal scaffolding such as asking questions to provide structure during a complex problem-solving task, enabling a child to gain control over his or her cognitive performance and behavior (Lewis & Carpendale, 2009). During verbal scaffolding parents provide their children with age-appropriate contingent responses (i.e. they follow the child's conversational lead), respecting the child's autonomy and stimulating explorative behavior. A specific verbal scaffolding strategy is the use of open-ended and metacognitive questioning when asking for explanations, such as "Why do you think that?" and "How are you going to figure that out?" (Hmelo-Silver & Barrows, 2006). With scaffolding, metacognitive processes involved in reasoning become externalized and available to children who are not yet able to monitor these processes on their own, in line with Vygotsky's (1978) zone of proximal development. With time, this scaffolding becomes internalized speech, which allows children to monitor their reasoning on their own (Wertsch, 1998).

A distinction in children's reasoning abilities can be discerned based on the domain of the problem that has to be unraveled, in particular problems with social content versus more logical or scientific problems (Marini & Case, 1994). Even though there is compelling evidence relating parental scaffolding to children's cognitive abilities and school achievement, studies focusing on the association between scaffolding and socio-emotional development are scarce (For a review, see Mermelshtine, 2017). The development of social understanding can be described by five successive social cognitive stages and largely takes place between preschool age and adolescence (Selman, 1980, 2003). At the first stage or egocentric level (around four years of age), children are only able to understand social interactions from their own perspective. At approximately six years of age, children are able to understand that someone else's perspective is distinct from their own (the subjective level). When children reach the self-reflective level (between eight and ten years of age) they are able to understand how someone else may view their own perspective. Around twelve years of age children are able to understand someone else's view of shared perspectives at the mutual level and adolescents are able to understand their own perspective in the context of multiple perspectives at the generalized level. These social cognitive skills are essential in understanding others during social interactions, both at the individual and the group level (Frith & Blakemore, 2006).

Around the age of four children also start developing an increasing awareness of how people obtain knowledge and begin to differentiate between assertions and reality (For reviews, see Kuhn, 2000, 2010). Furthermore, children begin to realize that perceptual information has to be correct and not just present to generate knowledge (Flavell, 2004). For instance, Flavell and colleagues (1986) showed that while three-year-olds are not yet able to make the distinction between the true color of a glass of milk and its appearance when a red filter is wrapped around it, most four-year-olds can correctly distinguish that the milk looks red but really is white. This metacognitive awareness is considered the origin of scientific thinking, as it allows children to see evidence as a source of support for a theory (Bullock, Sodian, & Koerber, 2009; Kuhn, 2010). Before the age of four, children think that mental representations are merely copies of reality, which makes it impossible for them to understand falsifiable theories, central to scientific reasoning. However, according to the ***Theory theory*** (Gopnik & Wellman, 1994), children begin to consciously revise their theories by the age of four, as they are confronted with evidence that does not match their current naïve theory. The social context plays a formative role in this conceptual change, as social experiences influence children to revise and improve their theories and conceptions of others (Hughes & Leekam, 2004).

Despite the early emergence of the metacognitive precursors of reasoning abilities, the developmental trajectory of these abilities is prolonged and requires adequate support and practice (Morris, Croker, Masnick, & Zimmerman, 2012). Even in typically developing children, considerable inter-individual differences in social understanding occurs (Repacholi & Slaughter, 2004) and differences in scientific reasoning abilities already appear during primary school (Bullock et al., 2009). As children reach primary school age, they become more active participants in interactions, which leads to parents systematically increasing their contingent instructions during parent-child interaction (Conner & Cross, 2003). Furthermore, the influence of reasoning abilities on later achievement is considered to be the strongest between ages five and ten (Ferrer & McArdle, 2004), suggesting this is an optimal age-range to stimulate the development of reasoning abilities through scaffolding. Interventions that include social interactive components aimed at supporting the development of aspects of social understanding such as theory of mind (For a meta-analysis, see Hofmann et al., 2016) or the development of scientific reasoning abilities (For a meta-analysis, see Engelmann, Neuhaus, & Fischer, 2016) have proven to be successful. Parents may be a valuable asset in supporting the early development of reasoning abilities through scaffolding. For instance, parents who ask their children questions during problem-solving help them to structure the task; a strategy which is often spontaneously imitated by children (For a review, see Morris et al., 2012). Butler and Markman (2014) showed that four-year-olds were more likely to display deeper categorization reasoning abilities when an adult was deliberately scaffolding the task, in comparison to an accidental demonstration of the task.

Parents may play an important role in supporting the development of early reasoning abilities and parent-child interaction has already been associated with reasoning abilities in kindergartners (Stright, Herr, & Neitzel, 2009) and ten- and eleven-year-old children

(Chng, Wild, Hollmann, & Otterpohl, 2014). Furthermore, parent training has been shown to be successful in improving parents' beliefs about scaffolding and the promotion of learning (Gartner, Vetter, Schaferling, Reuner, & Hertel, 2018). Nonetheless, the number of studies evaluating programs aimed at promoting parental scaffolding is still limited.

The Curious Minds parent educational program focuses on educating parents on how to support and scaffold the development of cognitive, social-emotional and self-regulatory skills necessary for adaptive behavior and learning. The aim of the educational program is twofold: (1) to educate parents about their child's developmental needs; and (2) to educate parents through home-assignments how they can stimulate self-regulation as well as explorative behavior and reasoning abilities through scaffolding that is sensitive to their child's developmental needs. A major objective of this study is to examine whether the Curious Minds parent educational program is able to improve parental questioning style in a low-risk sample of four- to eight-year-olds, and whether this can positively impact their child's social and scientific reasoning abilities. We hypothesized that parents in the educational program condition would ask more open- than closed-ended questions and more elaborative questions than parents in the control condition. Additionally, we hypothesized that parental questioning style would mediate the association between educational program condition and children's reasoning abilities.

METHOD

Participants

The current study is embedded within the Curious Minds program: a longitudinal program investigating the development of executive and social functioning in primary school-aged children in the Netherlands, and evaluating the effects of a parent and a teacher educational program (approved by the Ethical Board of the department of Education and Child Studies at Leiden University (ECPW-2010016)).

Parents of 138 4- to 8-year-old children (*M* = 6.26 years, *SD* = 1.19, 55.1% male) from the lowest four grades of two Dutch primary schools (pre-school to second grade in USA school system), from towns that are part of the Rotterdam-The Hague metropolitan area were eligible for this study and signed an informed consent letter. Children were randomly assigned to either the parent educational program condition (*N* = 69) or the control condition (*N* = 69) by drawing participant numbers from a jar. Participants were included in the analyses when their parents agreed to both home visits, when parents attended at least two sessions (educational program condition only), and when complete pre- and post-test data were available. Parents of 99 out of the 138 eligible children agreed to the home visits (response = 71.7%). To check for potential attrition bias participants whose parents agreed to the home visits were compared to those who did not agree on background variables. Groups did not significantly differ on: age, sex, school, grade, or prevalence of referral to mental health care in the past year, nor did their parents significantly differ on single parenthood status or parental education (all $p > .05$). Participants in the educational program condition who missed all ($N = 18$) or three out of four ($N = 5$) sessions were excluded from analyses and also did not significantly differ from those who remained in the educational program condition on any of the background variables (all $p > .05$). The final sample size for analysis ($N = 70$) consisted of 34 children in the educational condition and 36 in the control condition. For detailed sample characteristics, see Table 1.

Procedure

The current study uses observational data of parents' interactive behavior with their child collected during problem-solving interactions during a home visit, and child paper-and-pencil and hands-on tests to assess level of social and scientific reasoning abilities. Pre-test baseline data were collected in the period between November 2013 and February 2014 (school 1) and between May and June 2014 (school 2). Post-test data were collected in the period between June and July 2014 (school 1) and between January and February 2015 (school 2). Paper-and-pencil and hands-on performance tasks were administered in a separate room at the child's school, during two individual test sessions of approximately 60 minutes. Tests were administered by two trained junior investigators or by one of the senior investigators (AMS, MCD). All home visits were conducted by two trained junior investigators. Children were rewarded with a small token of appreciation for participation after the test session.

Curious Minds parent educational program

The content of the parent educational program was inspired by the Vygotskian principles of the Tools of the Mind curriculum for pre-school children (Bodrova & Leong, 2007; Diamond, Barnett, Thomas, & Munro, 2007), which focuses on supporting and scaffolding the development of cognitive, social-emotional and self-regulatory skills necessary for adaptive behavior and learning by using a familiar adult in a real-life setting as a change agent. The program took place at their children's school and was initiated after all baseline assessments with participating parents and children were completed. The program was provided by a skilled clinical neuropsychologist specialized in child and adolescent neurodevelopment, and consisted of four, monthly group sessions of approximately two hours each. The caregiver of each child who also participated in the home visits was asked to attend the sessions.

Table 1. *Participant characteristics and descriptive statistics (M (SD)) variables of interest at pretest.*

	EPC (*n* = 34)	CC (*n* = 36)	*p*
Age in months at T1	76.56 (14.89)	75.97 (14.32)	.87
Sex (% male)	47.06	63.88	.16
Parental education[a]			.91
High (%)	43.75	45.71	
Medium (%)	50.00	45.71	
Low (%)	6.25	8.57	
Single parenthood (%)	6.25	2.86	.60
Referral to mental health care past year (%)	6.25	8.57	.72
Number of questions per minute T1[b]			
Total questions	4.24 (1.69)	4.06 (1.87)	.68
Ratio open/closed questions	-.11 (1.10)	-.41 (1.05)	.24
Observational leading questions	.67 (.46)	.56 (.51)	.37
Procedural questions	.18 (.18)	.12 (.18)	.17
Explanatory questions	.18 (.20)	.15 (.18)	.52
Social reasoning ability T1			
Total social reasoning proficiency	32.35 (12.96)	31.97 (15.44)	.91
Identifying	7.15 (1.79)	7.36 (1.94)	.63
Discriminating	5.26 (2.11)	5.17 (2.27)	.85
Differentiating	5.59 (2.49)	4.61 (3.30)	.17
Comparing	4.21 (2.43)	4.56 (2.98)	.59
Perspective taking	3.24 (2.70)	3.33 (2.73)	.88
Scientific reasoning ability T1			
Conservation proficiency	35.50 (12.35)	36.44 (13.60)	.76
Proportional proficiency[b]	4.76 (1.26)	4.42 (1.25)	.25
Proportional complexity[b]	1.40 (.35)	1.28 (.45)	.21

[a] Background information was missing for ***N*** = 3 children due to non-response on parent questionnaire. [b] Original values before standardization. EPC = Educational program condition; CC = Control condition.

During each session, the focus was on a specific (neuro)cognitive mechanism, for which parents first received basic information on typical developmental aspects. Information about the brain-behavior developmental course at specific ages was illustrated using everyday examples of parent-child interactions. Parents also received a workbook summarizing information about the development of cognitive, social-emotional and self-regulatory skills, as well as matching home assignments to practice with their child following each session to enhance the learning experience of parents. These home assignments were discussed during the following session, allowing parents to learn from the trainer's feedback and each other's day-to-day experiences. For a more detailed description per session, see Table 2.

Measures

Demographic characteristics

Parents filled out a complementary background information questionnaire, using the online survey software Qualtrics (http://www.qualtrics.com/). The highest completed level of education by the parent who participated in the home visit was used as an indicator of educational attainment according to the Dutch Standard Classification of Education (SOI) which is based on UNESCO's International Standard Classification of Education (ISCED) ("SOI 2003 (Issue 2006/'07),"): 1. primary education (SOI level 1 to 3; at most vocational training); 2. secondary education (level 4 of SOI); and 3. higher education (level 5 to 7 of SOI; bachelor's degree or higher). Single parenthood status was established for the parent who participated in the home visit, and was defined by not having the child's other parent or a new caregiver living in the same household. Mental health care referral was assessed by asking parents whether their child had been referred, examined or treated for emotional and behavioral problems in the past year.

Parental questioning style

The parent's interactive behavior with the child was videotaped at pre- and post-test home visits during two joint activity problem-solving tasks. These problem-solving tasks consisted of a combining task and a sorting task of approximately five to ten minutes each, both based on tasks designed by Utrecht University (Corvers, Feijs, Munk, & Uittenbogaard, 2012). Parent-child dyads were alternately assigned to either task version A (N = 32, 46%) or task version B of each joint activity task (N = 38, 54%) at pre-test, which were reversed at post-test to avoid test-retest learning effects. Version A consisted of combining four different eyes and four different mouths to form 16 unique smiley faces

Table 2. *Description of the discussed topics and home assignments per session of the Curious Minds educational program.*

Session	***Main theme***	***Home assignments***
Session 1	How children learn and process new information, and how parents can help their child to explore topics in more depth by encouraging reasoning through asking questions.	e.g.: - Do science experiments with soap bubbles - Think outside the box by imagining as many different uses for a paperclip as possible. - Play sensory games, such as touching and tasting different types of food while blindfolded.
Session 2	Teaching parents how to stimulate specific aspects of AC and EF while interacting with their child. Discussion of home assignments session 1.	e.g.: - Tell two different stories to your child simultaneously, while your child focuses on one of the stories, and ask questions afterwards about its content (targeting ***attention***). - Play the game ***Yes and no are forbidden***: trick your child into answering questions with 'yes' or 'no (targeting ***inhibition***). - Play the ***Going on a trip*** game: alternately add an item to the sentence 'I am going on a trip and I am going to pack…', after recalling all items that have been mentioned (targeting ***working memory***). - Let your child come up with alternative plans when a playdate is suddenly cancelled, and observe whether your child is able to flexibly change plans (targeting ***cognitive flexibility***).
Session 3	Teaching parents how to stimulate emotion regulation and social cognition while interacting with their child. Discussion of home assignments session 2.	e.g.: - Practice and discuss a range of facial emotion expressions in front of the mirror. - Observe and address your child's emotional reactions during daily interaction and describe the reactions. - Discuss several short, illustrated stories (e.g. ***How does Billy feel when he's not allowed to play with the other kids? How do you know?***) - In a naturally occurring situation, explain why it is important to place yourself in someone else's shoes (i.e. perspective taking), using questions.
Session 4	Recap of sessions 1 through 3; parents were free to discuss what they had learned and ask additional questions. Discussion of home assignments session 3.	There were no home assignments following session 4.

and sorting different types of toy animals, and version B consisted of combining four different flower petals with four different disks to form 16 unique flowers and sorting different types of toy food. Parent-child dyads were free to sort and combine the items according to their own strategy, as long as all combinations in the combining task were different. Parents were instructed to support their child as they would normally do. The combining tasks consisted of more flower petals/disks and eyes/mouths than possible unique combinations, challenging parent-child dyads to reason about a strategy to form only unique combinations. The sorting tasks did not have a best solution, challenging parents to provide their child with age-appropriate contingent responses when they came up with a sorting rule. The videotapes were coded afterwards for parental questioning style.

The form and type of questions parents asked their children during the two joint activity problem-solving tasks were used as a measure of parental questioning style. All questions were coded from video-recordings using transcribed verbatim reports. Each question was first coded as being either (a) open-ended (e.g., ''How do you want to start?"), (b) multiple choice (e.g., ''Does a kangaroo live in the zoo or in the ocean?"), or (c) closed-ended (e.g., ''Is a cow a farm animal?"). Next, questions were coded in the following categories: (a) observational leading questions (e.g., ''What's the color of this food?", inquiring about observable aspects during the task), (b) procedural questions (e.g., ''How are you going to sort the animals?", inquiring about an action plan), and (c) explanatory questions (e.g., ''Why can the toad not be in the ocean group?", inquiring about the child's reasoning behind decisions). The form and category of each question were coded for both joint activity problem-solving tasks by three coders who were blind to other data concerning the child or the parent. All coders completed extensive training consisting of several practice and feedback sessions supervised by one of the investigators (AMS). Interrater reliability (Cohen's kappa) was large, with .84 on average for the sorting task ($\boldsymbol{N}_{\text{questions}}$ = 122) and .87 on average for the combining task ($\boldsymbol{N}_{\text{questions}}$ = 115). For each question form and category within each task, the number of questions per minute was calculated. Although parent–child dyads were randomly assigned to either joint Task Battery A or B, each task battery may have elicited a somewhat different interaction between parent and child. Therefore, we standardized the number of questions per minute within each task (sorting or combining) for each task version (A or B), followed by averaging these z-scores over the joint activity tasks.

Due to very low occurrence of multiple-choice questions (2.4%), this form was excluded from further analyses. The difference score between the standardized amounts of open- and closed-ended questions was calculated as a relative measure of question format preference during the tasks. A higher ratio score indicates that the parent asked more open-ended than closed-ended questions relative to the other parents.

Reasoning abilities

Scientific reasoning

Aspects of scientific reasoning ability, conservation and proportional reasoning, were measured with (i) the subtest Quantity of the Revised-Amsterdam Intelligence Test for children (Bleichroth, Drenth, Zaal, & Resing, 1987), a paper-and-pencil task to study conservation reasoning, and (ii) the balance scale task, a seminal task to study proportional reasoning.

Conservation reasoning

Conservation reasoning proficiency was assessed using the Quantity paper-and-pencil task that consists of 65 items (40 for four-year-olds) on relative length, weight, volume, amount, relative distance, surface area, and odds (e.g. which glass contains the most lemonade?; which rope is the longest?; which necklace has the most beads?; which cow has the most grass to eat?). Four consecutive incorrect answers resulted in aborting the task. Out of four pictures, children were asked to point to the picture with the right answer. The test-retest reliability (***r*** = .76) and internal consistency (Cronbach's alpha = .91) of this subtask are considered sufficient (Bleichroth et al., 1987). The total number of correct answers was used in analyses as a measure of conservation reasoning proficiency.

Proportional reasoning

Proportional reasoning proficiency and complexity level were assessed using a balance scale task (utilizing a beam centered on a fixed balance point with ten hanging points on both sides, and a set of 30 weights of 10 gram each). The ten hanging positions were marked with different stickers (e.g. red star, yellow smiley), similar on each side. Two parallel versions of this task were used (version A and B), each consisting of eight similar situations of increasing difficulty. A standard set of two explanatory questions was asked for the eight different test situations, resulting in a total of 16 explanations. The children were first asked to predict the end position of the balance scale before it was manipulated (i.e. before a card was placed) and to explain why. After the balance scale had been manipulated, they were asked to explain why the balance scale was in a certain position. The first four test situations focused on weight, the fifth on distance and the last three test situations on both weight and distance. The children did not receive feedback or extra assistance during the task, other than additional questions such as “what do you mean?” and “could you tell me more about that?” to reach the optimal complexity level of explanation. Administration of the balance scale task took approximately 15 minutes.

Balance scale problem tasks have repeatedly been used to assess scientific reasoning (e.g. Halford, Andrews, Dalton, Boag, & Zielinski, 2002; Jansen & van der Maas, 2002; Meindertsma, Van Dijk, Steenbeek, & Van Geert, 2012; Philips & Tolmie, 2007). The administration of the Balance scale task was recorded on video and coded by junior investigators who received extensive training, resulting in a large inter-coder reliability of .86 (ranging from .81 to .90). Predictions of the eight end positions were coded as either correct (1) or incorrect (0). The overall proficiency on proportional reasoning was calculated by summing the eight predictions, standardized within each task version (A/B). The explanations of the participants were coded using the coding scheme of Meindertsma et al. (2012), which is based on the dynamic skill theory of Fischer (1980) and Fischer and Bidell (2007). The coding of the complexity level of proportional reasoning can be found in Table 3. The overall complexity level of proportional reasoning was calculated by averaging the sixteen explanations. Mean complexity level was standardized within each task version (A/B).

Table 3. *Coding scheme for the complexity level of proportional reasoning.*

Code	Level of complexity	Content of explanation	Example
4	Representational system level	All relevant parts of the explaining mechanism and the relationships between these parts	“There is a balance because the distance on the side with one card is twice as long as the distance on the side with two cards”
3	Representational mapping level	Two or more parts of the explaining mechanism	“Because there are two cards and here only one, and because the cards are not at the same spot”
2	Single representational level	One part of the explaining mechanism	“Because they have the same weight”
1	Sensorimotor system level	Relation between action and result or an observation of the situation	“Because the card was put there”
0	Not specified	Indicates not to know an explanation	“I don’t know”

Social reasoning

Proficiency on a social reasoning task was measured with two parallel versions (A or B) of the short form of the Social Cognitive Skill Test (SCST) (Van Manen, 2007). The SCST is a semi-structured interview, based on the structural developmental approach of social cognition as proposed by Selman and Byrne (1974). Participants completed either version A or B at pre-test, corresponding to their randomly assigned A or B condition during the home visit, which were reversed at post-test. Both versions consisted of three short stories with accompanying pictures depicting different social situations in which a child is confronted with a social problem. Administration time was approximately 20 minutes. Eight questions regarding emotion recognition and perspective taking, increasing in difficulty, were asked per story, which were afterwards coded to yield either: (i) 3 points; when the answer was correct straightaway; (ii) 1 point; when the answer was not completely correct, but after a supplementary question became correct; (iii) 0 points; when the answer was incorrect from the start or still not completely correct after a supplementary question. A story was aborted after two consecutive incorrect answers. Social cognitive scale scores were calculated by summing the corresponding questions: ***(i)*** identifying; ***(ii)*** discriminating; ***(iii)*** differentiating; ***(iv)*** comparing; and ***(v)*** perspective taking, (i.e. the first question per story corresponds to identifying, the second to discriminating, etc.) The correlation between version A and B has been shown to be .84 with test-retest reliability ranging from .77 for version A to .78 for version B (Van Manen, 2007). Summed total scores were used in the analyses, as well as the five scale scores corresponding to the social cognitive stages developing at this study's age-range of four- to eight-year-olds.

Verbal ability

To assess whether associations between parental questioning style and children's reasoning ability were independent of differences in children's language skills, children's verbal ability was controlled for using the Concepts and Following Directions task of the Clinical Evaluation of Language Fundamentals (CELF-4^{NL}) (Semel, Wiig, & Secord, 2010). This task gives an indication of the child's ability to interpret and act upon spoken directions of increasing length and complexity. Children are instructed to identify in correct order a set of images that were verbally presented using time ordered prepositions. Administration took approximately 20 minutes. The task contains 49 items of increasing length and complexity. Upon reaching item 19, the task was aborted after seven consecutive incorrect answers. Administered items were afterwards coded to yield either 0 points for an incorrect answer or 1 point for a correct answer. Summed raw scores were used as a covariate in the analyses. The test-retest reliability (*r* = .76) of this subtask is considered sufficient (Semel et al., 2010).

Data analyses

Data were analyzed using IBM SPSS version 23. Demographic characteristics for both schools and educational program conditions were compared with chi-square tests, independent t-tests and Fisher exact tests. The educational effect on parental questioning style was assessed using ANCOVA controlling for corresponding pre-test values, verbal ability and age. The educational effect on reasoning through mediation by parental questioning style was assessed using bootstrapping, a nonparametric resampling procedure (Hayes, 2009). Bootstrapping with 5000 resamples was done to test for significant indirect effects using the SPSS macro developed by Preacher and Hayes (2009). Only parental questioning style variables with a significant educational program effect were included in the mediation analyses. Due to a ceiling effect of the social cognitive skill 'Identifying' (77% had one error or fewer at T1 and 93% had one error or fewer at T2), it was not considered in the mediation analyses. Unstandardized residual scores were used for parental questioning style variables in the mediation analyses, in order to control for pre-test values. Verbal ability and age were centered and controlled for in all analyses. For all significant effects, partial η^2 addressed effect size (0.04 = small effect; 0.25 = moderate effect; 0.64 = strong effect (Ferguson, 2009). Alpha for significant effects was set at $p < .05$.

RESULTS

Sample characteristics and descriptive statistics for the variables of interest are displayed in Table 1. Children in the educational program condition did not significantly differ from those in the control condition for age, sex, school, grade, single parenthood status, parental education or prevalence of referral to mental health care in the past year. Neither did the participants in the educational program condition differ from those in the control condition on the scientific and social reasoning measures at pre-test (all $p > .05$).

Curious Minds parent educational program effect

Parental questioning style

Parents in the educational program condition asked significantly more open- than closed-ended questions (η_p^2 = .10), more observational leading questions (η_p^2 = .07) and more explanatory questions (η_p^2 = .13) at post-test than parents in the control condition, while controlling for pre-test questioning style, verbal ability and age (see Table 4). Parents in the educational program condition did not ask more total questions than parents in the control condition, nor did they ask more procedural questions at post-test.

Table 4. *Analysis of covariance (ANCOVA) results comparing educational and control condition on parental questioning style at posttest, controlling for corresponding pre-test score, age and verbal ability.*

Parental questioning style	EPC *M (SE)*	CC *M (SE)*	*F (df)*	η_p^2	*p*
Total questions	.12 (.14)	.05 (.13)	.15 (65)	<.01	.70
Ratio open/closed questions	.35 (.16)	-.25 (.15)	7.35 (65)	.10	<.01
Observational leading questions	.11 (.12)	-.27 (.12)	4.82 (65)	.07	.03
Procedural questions	.17 (.13)	-.05 (.13)	1.41 (65)	.02	.23
Explanatory questions	.34 (.12)	-.19 (.12)	9.93 (65)	.13	<.01

Note. M : Marginal means. *SE:* Standard error. η_p^2*:*Partial eta squared.

Mediating effect of questioning style on scientific reasoning ability

The association between educational program condition and scientific reasoning ability was significantly mediated by the ratio score of open- versus closed-ended questions (see Table 5). Though the total effect regression coefficient between educational program condition and scientific reasoning was only significant for complexity level (*b* = .34, SE = .14, *p* =.01) and not for proficiency ($b_{conservation}$ = -2.32, SE = 2.13, *p* = .27; $b_{proportion}$ = .31, SE = .18, *p* = .08), standardized indirect effects were significant for both proportional reasoning complexity (*b* = .09, SE = .05, 95% CI [.01, .23]; see Figure 1) and conservation reasoning proficiency (*b* = 1.52, SE = .99, 95% CI [.14, 4.37]; see Figure 2). This indicates that compared to controls, parents in the educational program condition asked more open- than closed-ended questions, which resulted in enhanced scientific reasoning in their children.

Table 5. *Bootstrapping analyses results with parental questioning as a mediator in the relation between educational condition and scientific reasoning ability*

				Scientific reasoning ability (*N* = 70)								
				Conservation proficiency			**Proportional proficiency**			**Proportional complexity**		
	Direct effect	95% CI			95% CI			95% CI			95% CI	
Mediator	Program - Q	Low	Up	*b (SE)*	Low	Up	*b (SE)*	Low	Up	*b (SE)*	Low	Up
Total effect educational program				-2.32 (2.13)	-6.58	1.93	.31 (.18)	-.04	.67	.34 (.14)*	.06	.61
Covariate age				.37 (.11)*	.15	.60	.02 (.01)*	.01	.04	.01 (.01)	-.01	.02
Covariate verbal ability				.11 (.40)	-.68	.91	.03 (.03)	-.03	.10	-.01 (.03)	-.06	.05
Covariate T1 Reasoning				.48 (.13)*	.22	.74	.12 (.13)	-.13	.38	.55 (.11)*	.32	.78
Ratio questions (Ratio Q)	.55 (.21)*	.13	.98									
Direct effect program - Reasoning				-4.11 (2.21)	-8.52	.30	.29 (.19)	-.08	.67	.25 (.14)	-.04	.53
Indirect effect (mediation)				1.52 (.99)*	.13	4.18	.02 (.06)	-.09	.15	.09 (.06)*	.01	.24
Observational questions (Obs. Q)	.30 (.17)	-.05	.64									
Direct effect program - Reasoning				-2.43 (2.22)	-6.86	2.00	.33 (.18)	-.04	.70	.29 (.14)*	.01	.57
Indirect effect (mediation)				.09 (.65)	-.85	1.92	-.02 (.06)	-.18	.05	.04 (.04)	-.01	.17
Explanatory questions (Exp. Q)	.48 (.17)*	.13	.83									
Direct effect program - Reasoning				-2.76 (2.31)	-7.37	1.85	.25 (.19)	-.14	.64	.40 (.15)*	.10	.69
Indirect effect (mediation)				.39 (.99)	-1.30	2.87	.06 (.06)	-.04	.22	-.06 (.06)	-.23	.03

Note. Results based on 5000 bootstrapped samples. 95% CI = bias-corrected and accelerated confidence intervals, with p <.05 when range lower-upper CI does not include zero. Covariate T1 reasoning refers to corresponding pretest reasoning variable.

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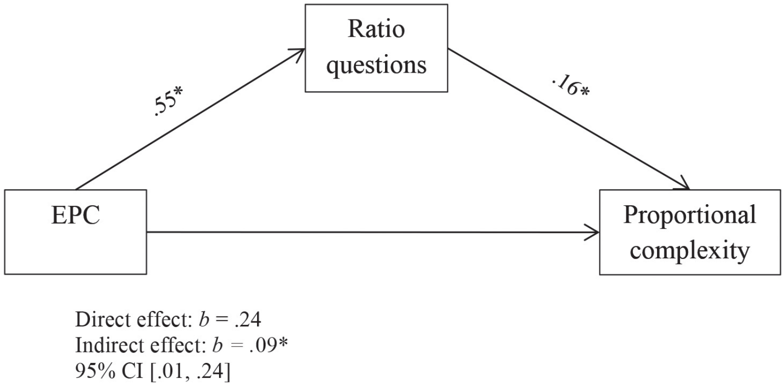

Figure 1. Unstandardized regression coefficients for the mediated association between educational condition and proportional reasoning complexity level (Balance Scale).

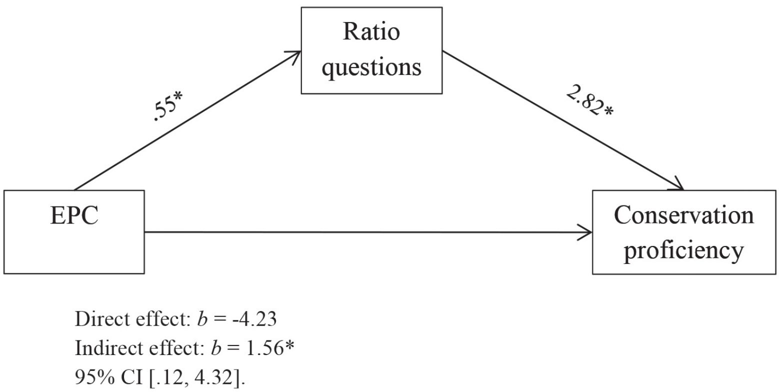

Figure 2. Unstandardized regression coefficients for the mediated association between educational condition and conservation reasoning proficiency level (Quantity task).

Mediating effect of questioning style on social reasoning ability

The association between educational program condition and social reasoning ability was significantly mediated by explanatory questions (see Table 6). The standardized indirect effect was significant for the social cognitive skill 'differentiating', corresponding to the subjective level (***b*** = .37, SE = .22, 95% CI [.06, .98]; see Figure 3). This indicates that compared to controls, parents in the educational program condition asked more explanatory questions, which resulted in enhanced differentiating skills in their children. Observational leading questions did not mediate the association between educational condition and reasoning abilities.

Table 6. *Bootstrapping analyses results with parental questioning as a mediator in the relation between educational condition and social reasoning ability.*

				Social reasoning ability (N = 69)														
				Egocentric level			Subjective level						Self-reflective level			Total proficiency		
				Discriminating			Differentiating			Comparing			Perspective taking					
	Direct effect	95% CI			95% CI			95% CI			95% CI			95% CI			95% CI	
Mediator	Program - Q	Low	Up	***b (SE)***	Low	Up	***b (SE)***	Low	Up	***b (SE)***	Low	Up	***b (SE)***	Low	Up	***b (SE)***	Low	Up
Total effect program				-.23 (.46)	-1.16	.69	.74 (.60)	-.46	1.94	.37 (.56)	-.75	1.49	-.12 (.54)	-1.20	.96	1.28 (2.22)	-3.17	5.72
Covariate age				<.01 (.02)	-.03	.04	.11 (.02)*	.06	.16	.07 (.02)*	.02	.12	.12 (.02)*	.07	.16	.54 (.10)*	.34	.73
Covariate verbal ability				-.02 (.09)	-.19	.15	.01 (.10)	-.19	.21	-.05 (.09)	-.24	.14	.09 (.09)	-.09	.28	.29 (.39)	-.48	1.06
Covariate T1 Reasoning				.14 (.12)	-.10	.38	-.09 (.11)	-.31	.12	.28 (.12)*	.04	.51	.13 (.13)	-.14	.40	.30 (.11)*	.09	.51
Ratio questions (Ratio Q)	.49 (.21)*	.08	.91															
Direct effect program-Reasoning				-.15 (.49)	-1.12	.83	.42 (.62)	-.82	1.65	.50 (.59)	-.68	1.67	.16 (.56)	-.95	1.27	1.16 (2.35)	-3.52	5.85
Indirect effect (mediation)				-.08 (.18)	-.51	.21	.30 (.23)	-.02	.91	-.12 (.23)	-.69	.26	-.26 (.21)	-.80	.04	.11 (1.00)	-1.35	2.66
Observational questions (Obs. Q)	.26 (.17)	-.09	.60															
Direct effect program-Reasoning				-.28 (.48)	-1.24	.67	.60 (.61)	-.62	1.82	.23 (.57)	-.92	1.38	-.08 (.56)	-1.19	1.04	.70 (2.28)	-3.84	5.25
Indirect effect (mediation)				.04 (.10)	-.08	.36	.13 (.17)	-.07	.65	.11 (.16)	-.06	.63	-.04 (.14)	-.46	.17	.48 (.60)	-.21	2.37
Explanatory questions (Exp. Q)	.46 (.18)*	.11	.81															
Direct effect program-Reasoning				-.32 (.49)	-1.31	.67	.37 (.62)	-.88	1.61	.23 (.60)	-.96	1.43	.10 (.57)	-1.05	1.25	.48 (2.37)	-4.25	5.22
Indirect effect (mediation)				.08 (.15)	-.18	.47	.37 (.22)*	.06	.98	.12 (.24)	-.18	.82	-.20 (.22)	-.79	.12	.73 (.87)	-.60	3.00

Note. Results based on 5000 bootstrapped samples. 95% CI = bias-corrected and accelerated confidence intervals, with p <.05 when range lower-upper CI does not include zero. Covariate T1 reasoning refers to corresponding pretest reasoning variable.

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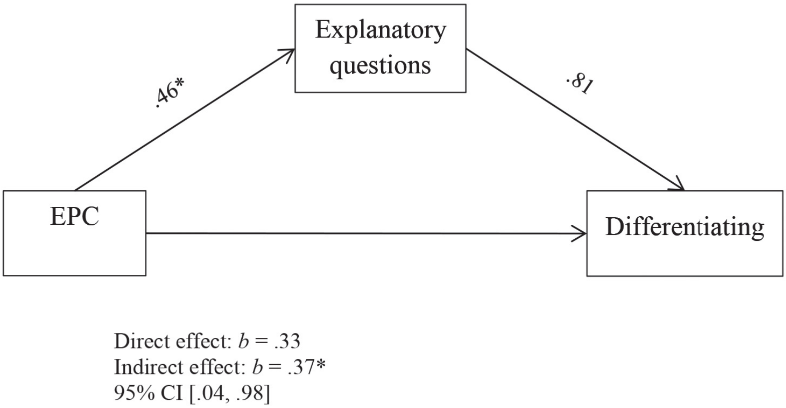

Figure 3. Unstandardized regression coefficients for the mediated association between educational condition and differentiating proficiency.

DISCUSSION

As children reach primary school age, they become more active participants in parent-child interactions, which leads to parents systematically increasing their contingent instructions to adaptively challenge their child's skills (Conner & Cross, 2003). Educating parents in reasoning development can better equip them to recognize their child's level of competence. With increased understanding of their child's reasoning and learning, parents may be better able to facilitate development through verbal scaffolding. The aim of the current study was to examine whether the Curious Minds parent educational program was able to improve parental questioning style in a low-risk sample of four- to eight-year-olds, which may positively impact their child's social and scientific reasoning abilities. The results show that parents in the educational program condition asked significantly more open-ended, observational and explanatory questions at post-test than controls did. More open-ended questions by parents in the educational program condition resulted in improved scientific reasoning in their children and more explanatory questions by parents in the educational program condition resulted in improved social reasoning.

This study has demonstrated that a compact psycho-educational parent program with home-assignments can be successful in improving parental verbal scaffolding through asking more open and elaborative questions. Our findings suggest that certain aspects of parental verbal scaffolding can indeed be improved using a compact educational program teaching parents about how their child reasons and learns, extending findings from previous studies shown to be successful in improving parents' beliefs about scaffolding and the promotion of learning (Gartner et al., 2018). Asking more open- than closed-ended questions mediated the association between educational program condition and aspects of scientific reasoning complexity and proficiency. This indicates that the enhanced scientific reasoning abilities of children with parents in the educational condition may be attributed to the improved verbal scaffolding by their parents. This is in line with the study by Butler and Markman (2014), who showed that four-year-olds were more likely to display deeper categorization reasoning abilities when an adult was scaffolding the task. However, where children showed improved reasoning ability while concurrently being scaffolded in the Butler and Markman study (2014), this study showed that children's reasoning ability was enhanced on other reasoning tasks which were not scaffolded directly. This may suggest that the scaffolded metacognitive processes involved in reasoning on these particular problem-solving tasks may have become internalized speech, allowing children to monitor their reasoning on their own (Wertsch, 1998).

Furthermore, asking more explanatory questions mediated the association between educational program condition and social reasoning proficiency, though not on all social cognitive skills. Interestingly, asking more explanatory questions only resulted in a higher proficiency on the social cognitive skill differentiating, corresponding to the subjective role taking level. This particular stage of social understanding develops between the ages six and eight and entails the ability to realize that someone else's perspective is distinct from your own or, in other words, the ability to think about others' thoughts. As parental questioning style only resulted in higher proficiency on differentiating, this may suggest that the children in our sample were in that particular developmental phase at that time. In that line of thought, the children in our sample may have already mastered the egocentric level, developing around four years of age, while the reflective level, developing between ages eight and ten, may still be a bridge too far (Selman, 1980, 2003). Tentatively, this might indicate that parental influence on the development of their children's early social reasoning abilities is subtle and depends on whether parental verbal scaffolding is adaptive to their child's developmental phase. This emphasizes the importance of an adaptive parental questioning style matching their child's zone of proximal development (Vygotsky, 1978).

In addition to reasoning proficiency, reasoning complexity level was also taken into account in this study. Research focusing on mathematical problem solving skills in preschoolers has shown that even though counting proficiency is necessary for problem solving success, especially the conceptual understanding of the counting process was predictive of math performance (Muldoon, Lewis, & Freeman, 2003). Perhaps children's reasoning complexity level reflects their conceptual understanding of reasoning, which might be more predictive of their school achievement than mere proficiency on a reasoning task. Given our findings on scientific reasoning complexity level, future studies are recommended to include complexity level when assessing children's developing reasoning ability and relating it to school achievement and social development.

As expected, educating parents to modify their daily parent-child interactions improved their questioning style and may have positively influenced the reasoning abilities of their child, which supports the notion that practicing reasoning abilities in the real-life social context using scaffolding is a promising approach to stimulate the development of early reasoning abilities (Kuhn, 2010). Our findings are in line with previous successful interventions that included social interactive components to stimulate the development of aspects of social understanding such as theory of mind (For a meta-analysis, see Hofmann et al., 2016) and the development of scientific reasoning abilities (For a meta-analysis, see Engelmann et al., 2016). Potential benefits of this compact parental group program in comparison to for instance home visiting programs targeting school readiness (For a review, see Welsh et al., 2014), include its wide employability and high cost-effectiveness.

Several limitations of the current study need to be acknowledged. Not all parents who were assigned to the educational condition participated in the program or completed all sessions, which may have biased our results due to selective drop-out. However, parents who were excluded from analyses did not significantly differ from those who remained in the educational program condition on parental education or single parenthood status, suggesting no attrition bias for these variables. Second, a no-contact control group was used, suggesting motivational issues may have arisen for parents in the control condition. However, parents in the control condition were invited to attend an informative workshop covering the topics discussed during the program after all the post-test assessments with participating parents and children were completed, possibly reducing motivational concerns. Third, during the Curious Minds program, the home assignments were not checked or monitored. Unfortunately, we do not have detailed information on the amount and quality of practice for each parent. Nonetheless, home assignments were discussed freely in each following session, possibly generating cohesiveness and social pressure to complete the assignments.

This study is among the first few to examine manners in which parents can be educated to facilitate the early development of social and scientific reasoning ability in their children through scaffolding by using a compact educational program. Strengths of this study include the objective coding with high interrater reliability of observed parental questioning style and the assessment of both reasoning proficiency and complexity level of scientific reasoning. Furthermore, parents were randomized to the educational program conditions within schools and within classes rather than assigning schools or total classes to different conditions, which limits classroom and school effects.

In sum, the current study showed that the Curious Minds parent educational program had a positive impact on the quality of parent-child interactions by improving parental questioning style compared to the control group, which may have enhanced aspects of reasoning complexity and proficiency in their children. Our findings are in line with the notion that the social environment can be an important asset in promoting early reasoning abilities (e.g. Mackey, Hill, Stone, & Bunge, 2011; Nisbett et al., 2012). Future studies should aim at examining variations in educational program responsiveness and assessing these relations over time. Furthermore, the possible moderating role of developmental phase on variations in program effects on children's reasoning ability and including reasoning complexity level when assessing long-term effects on school achievement are topics for further consideration in future studies.

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APPENDIX

Partial correlations

Table 1. *Partial correlations among observed parenting behaviors and child reasoning ability at pretest, controlled for verbal ability and age.*

	Parental questioning style				
Scientific reasoning	Total	Ratio	Observational	Procedural	Explanatory
1. Conservation proficiency	-.22†	-.09	-.09	-.06	.11
2. Proportional proficiency	-.12	-.01	-.11	-.08	-.06
3. Proportional complexity	-.03	.23†	.04	-.03	-.09
Social reasoning					
4. Discriminating	.27*	-.03	.21†	.15	.11
5. Differentiating	.07	.18	.10	.25*	-.03
6. Comparing	.07	-.09	-.04	.13	-.13
7. Perspective taking	.15	-.12	.05	.16	-.29*
8. Total proficiency	.15	.01	.09	.20	-.13

†*p* <.10; ***p* <.05; ***p* <.01.