The effects of a teacher programme on science learning, and social- and neurocognitive child factors in pupils: A pilot study

Master thesis Education and Child Studies

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Abstract

Objective This study is a pilot study to investigate the relationship between the teacher training programme of Curious Minds and science learning in pupils aged nine to twelve years. By means of a multiple mediation model it was explored whether social cognition and executive functions mediate the relation of the teacher training programme on science learning. Gain scores in mathematical performance were used to explain science learning.

Methods In this quasi-experimental research sixty-nine pupils were assigned to either the teacher training programme condition (n = 29) or the control group condition (n = 40). A *t*-test for independent samples was used to explore the unmediated effect of the teacher training programme on mathematical performances. For the mediated effect a bootstrap resampling method (n = 5000) as described by Preacher and Hayes (2004) and Hayes (2009) was used. Mediating variables are social cognition and the executive functions inhibition, cognitive flexibility and working memory. These variables were tested in thirty-eight pupils, by means of the Dutch Social Cognitive Abilities Test (SCVT; Sociaal Cognitieve Vaardigheden Test) and a computerized test battery, which is part of the Amsterdam's Neuropsychological Tasks (ANT; Amsterdamse Neuropsychologische Taken) respectively.

Results The results did not support the expectations. These data supported the view that the teacher training programme by Curious Minds significantly decreased mathematical performances. The teacher training programme had a positive effect on social cognition skills, though, no credible evidence indicated mediation.

Discussion The examinations in this study were well able to make a contribution to knowledge in the neurological and educational climate. This study provided more knowledge in contribution of a training to children's executive functions and social cognition, and hence in mathematical learning. This knowledge must be reflected in education systems, and training must be re-examined. It is advisable for future research to examine the effect of the teacher training programme on practical and explorative science aspects, where Curious Mind initially aims for.

Keywords: Curious Minds, science learning, executive functions, social cognition

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1. Introduction

1.1. Problem statement

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science" (Einstein, 1931, pp. 193-194).

Learning is mainly driven by exploring the mysterious. Already Einstein (1931) acknowledges this in the above quote, that exploring the mysterious is at the heart of learning art and science. Curiosity and motivation lead to this exploration and to an attitude of active involvement with the environment. This will in turn encourage acquisition of knowledge and skills. Unfortunately, the current school system in the Netherlands seems to focus primarily on the transfer of knowledge, rather than on a stimulation of curiosity and motivation by learning children skills of research, asking questions, exploring, and experimenting. Piaget and Inhelder (1969) described children as constructivists in nature. They argued that individuals who act and experience on a novel activity, will gain knowledge and understanding. Stimulation of curiosity and exploring is essential for the optimization of learning abilities in children, and can best be done in a supportive environment. Teachers, parents, and friends are all important role models, who can support a child in order to best acquire knowledge and skills. In addition to curiosity and exploration, neurological research examined that specific functions named executive functions, such as attention, memory, the ability to control behaviour and thoughts, ability for problem solving, and planning are also needed for learning (Gropen, Clark-Chiarelli, Hoisington, & Ehrlich, 2011). Furthermore it was argued that learning does not occur in a social vacuum and that social cognition is additionally necessary for learning (Driver, 1989). This current study utilized a teacher training programme by Curious Minds ('TalentenKracht'; www.talentenkracht.nl) which is in line with research of Bonawitz, Shafto, Gweon, Goodman, Spelke, & Schulz (2011), who concluded that precise instructions discourages curiosity and exploration in children. The teacher intervention programme by Curious Minds therefore aimed to inform teachers to create a rich learning environment which encourages exploration and propagation of knowledge and skills. This study programme cooperated with the Science and Technology Platform ('Platform Beta techniek'; www.platformbetatechniek.nl), and was initiated by a broad group of investigators with different backgrounds, from seven universities in the Netherlands and Belgium. The goal of this programme was to examine motivation and talents in science learning in pupils between the age of three and fourteen years old. This study mainly focused on the association of the teacher intervention training by Curious Minds and science learning in elementary school children. Furthermore it was examined whether this hypothesized relation was mediated by executive functions and social cognition.

Prior research provided scientific evidence supporting improvements in executive functions and academic performances after an intervention. An intervention similar to the training by Curious Minds is called Tools of the Mind, further referred to as Tools. Tools developed by Bodrova and Leong (2007) aimed for children to regulate their own behaviour and incorporate executive function training in their everyday activities. The terms self-regulation and executive function named in their study, were similar with the terms inhibition, cognitive flexibility, and working memory in this study. The goal of Tools intervention was to prepare those children for school learning. This was argued to be achieved not by discipline, though by the Vygotskian approach by giving space for play and playful learning (Bodrova and Leong, 2007; Vygotsky, 1962). Examples of the Tools curriculum were learning plans and buddy reading, where the pupils learned to plan and evaluate, and had to learn to take turns in reading and listening respectively. The effects of Tools have been widely researched. In an earlier study by Bodrova and Leong (2001) the effect of Tools on the development of literacy skills was researched. Ten kindergarten teachers participated, of which half was provided Tools teaching techniques, and half were assigned in a control group. On the pre-test both conditions showed similar literacy skills. Bodrova and Leong (2001) concluded that pupils in the training condition performed better in all literacy skills at the post-test and proceeded faster compared to the control group condition. Also Diamond, Barnett, Thomas, and Munro (2007) researched the Tools curriculum. In this study the intervention Tools was compared with a district’s version of Balanced Literacy curriculum, further referred to as dBL (Diamond et al, 2007). Authors stated that both add-on curriculums contained alike academic themes, though executive function and self-regulation development was not addressed in the dBL curriculum. It was concluded that on all measures pupils in the Tools condition outperformed pupils in the dBL condition. A disadvantage of this study is that prior differences between the two conditions were not researched as pre-testing was not administered (Diamond et al, 2007).

Other interventions widely studied were computerized interventions. The most well-known is CogMed designed by Klingberg and his colleagues (2005). Cogmed training is a computerized working memory training developed for children with ADHD. The training consisted of visual-spatial working memory tasks and verbal working memory tasks, which had to be done daily (Klingberg, Fernell, Olesen, Johnson, Gustafson, Dahlström, Gillberg, Forssberg, & Westerberg, 2005). By means of randomly assigning children to adaptive working memory training or a similar, though non-adaptive training, the effects of CogMed were researched. The authors concluded that children in the adaptive working memory training outperformed children in the control group on visual-spatial working memory performance. Additionally, effects were generalised to improvement in inhibition and concentration (Klingberg et al, 2005). Recently a computerized training based on CogMed called Braingame Brian was developed (Prins, Ten Brink, Dovis, Ponsioen, Geurts, De Vries, & Van der Oord, 2013). This training was dissimilar from CogMed namely first that besides working memory, also inhibition and cognitive flexibility were trained, and second the training tasks contained more gaming elements. The training was done at the computer at home, where the child explored the game world. In this study children were randomly assigned to either the Braingame Brian condition or a waiting list condition. In conclusion the authors stated that positive effects on ADHD-symptoms and executive function deficits were found in the Braingame Brian condition. Though, training effects will be further evaluated with larger samples (Prins et al, 2013).

1.2. Science learning

As mentioned earlier, exploration helps the acquisition of knowledge and skills. These knowledge and skills are stored in a schema, which is a cognitive framework with organized sets of knowledge (Piaget & Inhelder, 1969). The constructivist view of Driver and Bell (1986) defined that what pupils learned from an experience is not dependent on the nature of the activity, though on the knowledge schemes that was brought to this task by the pupil. In a later study Driver (1989) elaborated on the other hand when the pupil experiences a new task, the knowledge schemes change as a result. He further stated that as this is a process of using and testing ideas in a novel situation, curiosity and active involvement are necessary to relate present schemes to new tasks. For that reason, learning science is associated with progressive development and restructuring the pupil's knowledge schemes.

As science can be defined in different fields, this study clarified science learning by the definition of Wilkening and Sodian (2005) namely "the ability to generate, test, and revise theories and hypotheses, and to reflect on this process" (p. 137). Theory formation and the full complexities of evaluation are beyond the grasp of children, however, the basics of hypothesis testing and reflection are within their means (Gropen et al, 2011). According to this study the building blocks for the ability of children to test and revise hypotheses depend critically on attention, memory, the ability to control behaviour and thoughts, ability for problem solving, and planning. These abilities are associated with executive functions, further referred to as EF. Additionally, science learning does not occur in a social vacuum (Driver, 1989). In this study he argued that social interaction and social skills, such as empathy and the ability to imagine and relate to other persons, are also building blocks for science learning as social cognitive skills allow the pupil to see a problem from different perspectives. While extensive research is present on the predictive value of executive functions on science learning (Gropen et al., 2011; Raver et al., 2011), a literature gap exists in research on the predictive value of social cognition on science learning.

Understanding the cognitive processes that are at the root of science learning can help teachers and parents to determine which support can provide the best aid to pupils.

1.3. Executive functions

Multiple definitions of executive functions exist depending on different fields of studies. At first the concept executive function was described by Baddeley and Hitch (1974) as the central executive, which he described as a mechanism responsible for the regulation of the cognitive processes. Simultaneously, Luria (1973) described various functional regions of the brain and connected the functions of the frontal lobe to executive functions. Later did Lezak (1982) name this control mechanism executive functions and defined them as “the mental capacities necessary for formulating goals, planning how to achieve them, and carrying out the plans effectively” (p. 281).

Although the concept executive function is still vague, there is consensus among researchers, psychologists, and other experts that executive functions can be described as multiple psychological processes underpinned by the frontal lobes, which cooperate in analysing situations, planning, focussing and maintaining attention and problem solving (Barkley, 2001; Diamond, 2002; Stuss & Benson, 1986; Zelazo, Craik, & Booth, 2004). At a more fine-grained level these cognitive capabilities can be divided into three core executive functions, namely inhibitory control, cognitive flexibility, and working memory (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). Miyake et al. (2000) emphasized in the study that numerous studies on frontal lobe deficits after brain injury examined the role of the frontal lobe in executive functioning to be prominent. Russell and Edin (1948) proposed that the maturation of the frontal lobes, are among the latest developing regions in the brain and most important during childhood years. Zelazo et al. (2004) examined executive functions across life span and concluded that a systematic improvement exists during childhood into adolescence and that performances on executive functions also decline by old age. This study suggested that the development of executive functions follows an inverted U-shape developmental curve.

1.3.1. Inhibition

Inhibition is often defined as the capacity to supress certain stimuli or impulses, so that other cognitive and behavioural processes are not obstructed (Barkley, 1997). This concept is also called self-control. Barkley (1997) distinguished three processes associated with inhibition, namely first a prepotent response on an event. In other words the suppression of an incorrect response in order to make the good response. Second, to be able to stop an already initiated response, and third the suppression of a contrary response. The latter is referred to as interference control. Impairments in inhibition can manifest in impulsivity. This can lead to inappropriate behaviour and/or attention deficits disorder (Barkley, 1997).

The development of inhibition starts at an early age. Diamond (2002) described that, though at a base, children of twelve months can inhibit. He argued that further development continues in late childhood, which peaks at an age between six and twelve years old.

1.3.2. Cognitive flexibility

Cognitive flexibility can be defined as the ability to plan, think, and adjust behaviour in changing situations and circumstances (Miyake et al., 2000). Also the ability to adapt fast and switch between strategies in order to optimize the information process is included. When cognitive flexibility is underdeveloped it expresses itself in rigid and stereotype behaviour (Lezak, 1982). These characteristics are common among individuals with an autism spectrum disorder (Hill, 2004).

The development of cognitive flexibility starts between the third and fifth years of life, and the strongest progress can be seen between seven and nine years (Miyake et al., 2000). This is in contrast to inhibition as cognitive flexibility is still developing in adolescence.

1.3.3. Working memory

The term working memory is evolved from the term short-term memory, and are often used interchangeably. Although, in the current study working memory referred to the combination of storage and manipulation, while short-term memory solely referred to information storage (Baddeley, 2012). Specifically, working memory is defined as temporary storage and mentally handling, updating and using information (Miyake et al., 2000). In particular, this requires an active revision of incoming information that is important for a specific task, and then accurately amends the information held in working memory from old, no longer relevant information to newer, more relevant information (Morris & Jones, 1990). A well-known cognitive framework that has been associated with working memory is Baddeley's and Hitch's (1974) influential multicomponent model of working memory. This model distinguished three component of working memory. Two of which are the phonological loop and the visuospatial sketchpad, respectively for auditory-based information and visual and spatial information. These components of the model are often called 'slave systems' as they are subordinate to the third component the central executive. The central executive controls the attention and information flow in both loops. Baddeley (2000) expanded the model with a fourth component, namely the episodic buffer. This system integrates information from the phonological and visual-spatial loop in order for the information to be understandable. This ensures that individuals can solve problems and evaluate prior experiences based on new knowledge.

The development of working memory becomes most evident in the first three years in a child's life, as they start retaining information (Miyake et al., 2000). When impairments are present in working memory, it will express in difficulties in following instructions and retain information.

Miyake et al. (2000) argues that children with working memory difficulties are in general easily distracted and loose their thoughts quickly whilst another replaces it.

1.4. Social cognition

In addition to EF, there is evidence that the prefrontal cortex is involved in social cognition (Blakemore & Choudhurry, 2006). In this study social cognition in pupils is defined as the cognitive processes for understanding thoughts, feelings, motives, and behaviours in order to navigate efficiently in the social world (Shaffer & Kipp, 2010). Shaffer and Kipp (2010) explained this concept by dividing this in the child's self-concept and their impression on other people. The self-concept is explained as the recognition of the self and the development of self-esteem, while the impression of other people can, for example, be explained by the theory of mind. The theory of mind, further referred to as ToM, is regarded as the ability to relate to the belief, thoughts, desires, and intentions of others (Baron-Cohen, Leslie, & Frith, 1985). Baron-Cohen, Leslie and Frith (1985) further explained that among ToM components such as recognizing and understanding emotions, distinguishing between reality and fantasy and the ability to empathize with ideas and expectations of others, are influential in science learning.

An influential model, which is regularly used to describe the individual differences in terms of adaptive or maladaptive social cognition, is the Social Information Processing model, further named the SIP-model (Crick & Dodge, 1994). This model differentiates steps of social information processing. Social information processing, and with that the cognitive processes underlying social interactions, involves a series of six steps namely: "(1) Encoding of clues (both internal and external); (2) Interpreting the cues (think of causal attributions, intent attributions, and other interpretative processes); (3) Clarification of goals (arousal regulation); (4) Response access or construction (either from memory or formulation of new response possibilities); (5) Making a response decision (including: response evaluation, outcome expectations, self-efficacy evaluation, and response selection); and (6) Behavioural enactment" (Crick & Dodge, 1994, p. 76). During the first three steps it is tried to get an inference of the situation and the intention of a person with whom interacting, while in the last three steps the possible responses and selecting the most favourable response at that time, are assessed. According to this model, the way pupils encode information and interpret cues of a particular social situation (partly) influences how they will generate goals and respond to that same social situation.

Children develop these competencies by collaborating with teachers, parents, and peers. The belief that social interaction contributes greatly to cognitive growth is a cornerstone of the sociocultural perspective on cognitive development by Vygotsky (1962). Recent neuropsychological studies have shown that brain injuries disrupt social cognitive processes. When impairments in social cognition are present, this can present itself by problems in emotional responses to social stimuli, problems in imagination, and not being able to reflect to different perspectives (Shaffer & Kipp, 2010).

1.5. Executive functions and social cognition

Evidence is mounting that executive functions and social cognition are connected in development (Benson & Sabbagh, 2013; Diamond et al., 2007; Hala, Pexman, Climie, Rostad, & Glenwright, 2010). First it was argued that executive functions and social cognition were both mainly driven by the frontal lobes (Luria, 1973; Blakemore & Choudhurry, 2006). This was concluded as the studies on brain deficits in the frontal lobes after brain injuries or after a frontal lobe removal examined impairments in executive function and social cognition to be prominent. Second, marked advances of EF and social cognition both take place in the preschool years as this develops with the maturation of the frontal lobes (Russell & Edin, 1948). Although, it is reasonable to suggest that brain development, and therefore the development of executive functions, does not exist in a social vacuum (Driver, 1989). It can be argued that EF is causally implicated in social cognition and that advances in EF are needed for development of social cognition aspects (Moses & Tahiroglu, 2010). Namely, in order to understand the false belief task of ToM assessment for social cognitive abilities, recognizing the conflict between the protagonist's mental state and the true state is necessary. This involves shifting attention away from the true state and questioning the first impression and thoughts (Moses & Tahiroglu, 2010). It is hence crucial to view the relationship of executive function and social cognition as support for each other’s development.

1.6. Objectives

The purpose of this study was to get more knowledge of the social cognitive and neurocognitive child- and teacher factors which are required for optimal science learning, and in order to stimulate the development of the child in the best possible way. In order to put children, with their wonder and approach to things, as a central starting point, it is expected to know more about the way children think, reason, and learn. This knowledge must be reflected in education systems. Towards this goal definitions of the social cognitive and neurocognitive factors were reported, by means of elaborating on the terms social cognition, executive functions, and mathematical performance as science learning.

1.7. Research question and hypothesis

This study has, by means of a quasi-experimental design, elaborated on the relation between the teacher training programme by Curious Minds and the difference in mathematical performance as science skills in elementary school pupils. Additionally was examined whether this relation could be explained by mediating variables, which was caused by the teacher training programme and was a cause for mathematical skills. The question examined in this study reads:

Does the teacher training programme improve science skills, and is this relations mediated by social cognitive and neurocognitive child factors, respectively social cognition and executive functions?

It was hypothesized that the teacher training programme developed by the Curious Minds study has a positive effect on mathematical performance in elementary school pupils and that this relation is partly or fully mediated by social cognitive and neurocognitive factors.

1.8. Scientific and social relevance

This study provided information on science learning in pupils, and is relevant in both the scientific and the social field. Earlier a literature gap on the relation of social cognition and science learning was described. This study aimed to contribute to the knowledge on possible manners to improve science learning in elementary classrooms. Additionally, science and technology need more priority in the curriculum for elementary school children. By 2020 every child in elementary school will participate in science classes according to one of the twenty-two established action points of the Technology pact (Techniekpact) (Rijksoverheid, 2013). This national pact has been introduced by the Dutch government on 13 may 2013 in order to improve the connection between education and the labour market in the technology sector and thereby reduce the shortage of technical staff. The technology pact unites the aspirations of existing plans and initiatives, but aims to achieve their goals faster (in 2020) and with more vigour (Rijksoverheid, 2013). The Dutch government assigned the Science and Technology Platform to achieve these goals. The intention of the pact is based on the assumption that society needs to have an expanding knowledge of science and technology. Additionally, it is expected that more children will choose a job in a technical domain, if enthusiasm for science is increased at a young age (Rijksoverheid, 2013).

2. Methods

2.1. Sample

This study employed data obtained by Curious Minds. Six elementary schools in different areas of the Netherlands applied at the Science and Technology Platform in order to participate in the research for talent development coordinated by Curious Minds. The research focused on the talents of pupils aged three to fourteen years in the science and technology context and was conducted by the department Neuropedagogics of Curious Minds from Leiden University. Each school started its own study programme and obtained funding for it. Because each school had its own area of focus, different tests were conducted depending on the school's research question. By means of an information letter the particular schools invited pupils for this programme through their parents. To minimize compounds solely pupils who were at least two months registered at school, were Dutch speaking and whose parents were able to read Dutch were accepted in the programme. Of those six elementary schools a total of 918 pupils were recruited in this study. A written consent was given by all participants and ethical approval was provided by the board of Leiden University.

The current study is a quasi-experimental design. For the purpose of this study additional inclusion criteria were set. For this study it was required that at the school a test battery for social cognition was conducted and that executive functions were administered by a computerized test battery. Two elementary schools, namely the Bisschop Ernstschool in Delft and the Freinet school in Goes met the criteria. The second criterion for this study was that there must be a teacher intervention programme and a control group. At the Bisschop Ernstschool all teachers were provided with an intervention programme and focused on the questions whether pupils from a Plus class have better developed neurocognitive building blocks for science learning than pupils of the same age in a situation without having been offered the Plus class. Pupils from a Plus class are basically gifted pupils from grades 5 to 8 that need extra challenge in their curriculum. Placement in this class occurs according to the guidelines of the gifted-protocol of the school. The Freinet school included a parent intervention programme with a control group and had their area of focus in investigating whether 'enquiry-based learning' encourages scientific learning. For the purpose of this study, participants of the Bisschop Ernstschool were included as an intervention group and solely the participants of the Freinet school whose parents did not receive training as a control group. A sample of 158 pupils in total was utilized in this study of which 50.6% boys and 49.4% girls (mean age = 10.30 years; SD = .75). Furthermore, 31.0% of the pupil's teachers received intervention training, while 69.0% of the pupil's teachers received no training at all.

2.2. Procedure

The participating pupils were individually tested by two undergraduate students, during school hours. Between 8.30 a.m. till 3.15 p.m. pupils could be taken out of the class for approximately two hours excluding breaks. The students were trained beforehand at the Leiden University and instructed to administer the test in the same manner for all pupils. The pupils were removed twice from the classroom, for the pre-test and the post-test. The pre-test took place in September 2012 and the post-test in the period between April to June 2013. During the post-test it was attempted to do the same measurements in the same manner as was done at the pre-test in September 2012. The tests were carried out in a separate and quiet room.

In between the period of the pre-test and post-test the teacher training programme provided by Curious Minds was given. This intervention programme is a training aimed to inform teachers how to create a rich learning environment which encourages exploration and the propagation of knowledge and skills (Swaab, Noordam, Munk, Van Dongen, & Sjoers, 2012). Each training session consisted of three meetings with a theoretical and practical part. The theoretical part was provided by Prof. Hanna Swaab, clinical neuropsychologist and clinical psychologist at the Leiden University and Leiden Institute for Brain and Cognition. The practical part was guided by the Haagse Hogeschool. The sessions included the basic elements of the theory of information processing, the ABC model of understanding and managing behaviour, executive functions, and social-cognitive skills (Swaab et al., 2012).

2.3. Measurement instruments

Science learning was the dependent variable in this study and was measured by using the mathematic Cito-scores of the primary schools. In order to measure the three components of executive functions, namely inhibition, cognitive flexibility and working memory, a series of computer tasks, which are part of the Amsterdam's Neuropsychological Tasks (ANT; Amsterdamse Neuropsychologische Taken) (De Sonneville, 2005) were used. Social cognition was measured with the Dutch Social Cognitive Abilities Test (SCVT; Sociaal Cognitieve Vaardigheden Test), which is a screening for the development of social capabilities in children (Van Manen, Prins, & Emmelkamp, 2007). Underneath an elaboration is provided of these measurement instruments.

2.3.1. Science Learning

Elementary schools in the Netherlands can provide skills in basic mathematics, physics, and chemistry. Of those subjects solely the mathematical performances are systematically assessed, hence these performances will be used in order to inquire science skills. In order to measure this the Cito-test was used. The organization Cito is internationally recognized as an expert in conducting examinations and tests, where the range of services and products for education is broad and is focused on contemporary forms of testing and tracking the pupil's learning development in elementary schools (Janssen, Verhelst, Engelen, & Scheltens, 2010). By means of this test an identification of the level of the students' skills can be given, which can be compared with a nationwide group. The Cito-test is a paper-and-pencil test and consists of three parts, namely language, mathematics and study skills. In addition, there is an optional part which is world orientation. The subtest mathematics of June 2012 and June 2013 was used to identify the level of science learning in this study for respectively the pre-test and post-test. The subtest included percentages, fractions, money, mental arithmetic, measures, time and weight (Janssen et al., 2010). Twice a year the teacher conducts the Cito-test for the whole class at the same time. The duration of the subtest mathematics is 40 to 45 minutes. The reliability coefficients are invariably high to very high, since they vary between .91 and .97 (Janssen et al., 2010).

This study focused on the development curve of the child between the Cito-scores at pre-test and post-test. Because every test was dissimilar for every grade in content, length and difficulty, the raw scores of total correct answers could not be used as a reference. In order to give more meaning to those scores, Cito came up with the 'skill score' which makes it possible to compare test results with each other (Hollenberg & van der Lubbe, 2011). In that manner both a comparison of the child's personal development and a comparison to other pupils was possible. However, still these tests were distinctive tests and measure diverse skills. Therefore Cito has developed a separate skill level for each test. In order to define an improvement or decline, levels were connected to the skill scores for each test. The skills score of each child was compared with the scores of all pupils in the Netherlands, resulting in levels from E to A with an additional level of A+. The levels have the following percentiles: 10% (E) – 15% (D) – 25% (C) – 25% (B) – 15% (A) – 10% (A+). This means that when a child scores in the level E, the child scores in the weakest 10% of the pupils in the Netherlands, though when in the level A+, the child belongs to the 10% best scoring pupils in the Netherlands. This study used the adjusted Cito national standards from September 2013.

2.3.2. Executive functioning

The concept executive functioning was evaluated by measuring inhibition, cognitive flexibility, and working memory. Those three executive functions were the mediating variables. In order to measure cognitive abilities the Amsterdam's Neuropsychological Tasks (ANT; Amsterdamse Neuropsychologische Taken), a computerized test battery, was utilized (De Sonneville, 2005). All test stimuli were presented at a computer screen and to respond, pupils were asked to click on the mouse button. Prior to each task, the pupils were given a verbal instruction and visual representation of each task and the tasks were briefly practiced. In total five tasks have been conducted, though two were used for this current research. These are the shifting attentional set – visual (SSV) for inhibition and cognitive flexibility and the spatial temporal span (STS) for working memory. Test-retest reliability of the reaction time varied depending on task and interval between .70 and .84 (De Sonneville, 2005).

2.3.2.1. Inhibition and Cognitive flexibility

In order to determine inhibition and cognitive flexibility the subtest shifting attentional set - visual was conducted. Regardless of hand preference, the pupil was asked hold the right index finger on the right mouse button, and the left index finger on the left mouse button. In this task, the pupil saw a coloured block jumping at random from the right to the left. The task consisted of three conditions. In the first condition a green block jumped at random from the right to the left. In the first condition pupils were instructed to respond with the left index finger to a left visual stimulus, and to respond with the right index finger to a right visual stimulus. This is called the spatially compatible response (De Sonneville, 2011). In condition two, the block was red in colour and jumped back and forth. The pupils were instructed to do precisely the opposite of what the block does. If a right visual stimulus was shown response with the left index finger on the mouse button was expected, if a left visual stimulus was shown response with the right index finger on the mouse button was expected. This is known as the spatial incompatible response (De Sonneville, 2011). In the second condition the pupils had to inhibit a prepotent response. The third condition constituted of a combination of the conditions before. A red or green block jumped at random to the right and left. The colour showed whether the pupil should give a compatible or incompatible response (De Sonneville, 2011).

This task measured the ability to inhibit prepotent responses and, on the basis of the incoming information, change the response behaviour whenever was needed (De Sonneville, 2011). The first one quantified inhibition while the latter one evaluated cognitive flexibility. It is universally true that the compatible condition is easier than the incompatible condition, hence should be done faster and more accurate. Inhibition was assessed by the difference in the amount of errors made on the incompatible tasks in trial two and the amount of errors made on the compatible task in trial one. Cognitive flexibility on the other hand was evaluated by the difference in the amount of errors made on the compatible tasks in trial three and the amount of errors made on the compatible task in trial one.

2.3.2.2. Working memory

The task spatial temporal span from the ANT was used to determine working memory (De Sonneville, 2005). This task showed a growing complex pattern in a grid of nine blocks which was designated by the computer. The pupil was asked to remember which pattern was designated and to click on the blocks with the mouse in exactly the same order (De Sonneville, 2011). The task contained two conditions of each sixteen trials in increasing difficulty of which two till eight blocks could be designated. Each amount of blocks designated was offered twice. When the pupil failed to remember the pattern and clicked on the incorrect blocks twice in the same amount of blocks designated, the task was stopped. In the first condition the pupil had to click the blocks in the same order, in the second trial the pupil had to click the blocks in a backwards order as was originally designated. The backwards condition has a great appeal on working memory. The working memory of the pupil was assessed by the difference of the amount of backwards condition and the amount of correct backwards condition. A low score on this measure indicated more functional impairments in working memory (De Sonneville, 2005).

2.3.3. Social cognition

A Dutch screening was used named the Social Cognitive Abilities Test (SCVT; Sociaal Cognitieve Vaardigheden test) in order to measure social cognition (Van Manen et al, 2007). The pupil was read a small story based upon a cartoon. Three stories were read, and after each story eight question were asked which relate to the eight social cognitive skills. These social cognitive skills included identification, discrimination, differentiation, comparing, coordinating, relating, perspective-taking and taking into account different perspectives (Gerris, 2006). 'Identification' was divided into recognizing, and naming of perspectives. In order to judge if those perspectives were similar, is within the scale of 'discrimination'(Van Manen et al, 2007). 'Differentiation' was the comprehension that two or more persons in similar or different situations do not necessarily have the same perspective. Additionally, 'comparing' was an extension of the skill differentiation, where the child realizes that both similarities and differences between perspectives can exist. The following scale was 'coordination', where the pupil is able to relate with the third person position. The scale 'relating', though, referred to the ability to make causal relations between perspectives, where 'perspective taking' was the ability for a child to place oneself in the perspective of another person. Lastly, there was the scale 'taking into account different perspectives', where the pupil is aware of the possibility of influencing the perspective of someone else (Van Manen et al., 2007). For every question zero, one or three points could be scored. One point was given if the child gave a wrong answer, one point if the child answered correctly after an alternative question or helping question, and three points were submitted if the child answered correctly. These scores were added and by means of standard tables standard scores were derived. In this study the standard scores of the social cognitive abilities were used.

The reliability of the test is good, where the internal consistency of the entire SCVT is .96. However, two skills have an alpha below .70, namely discrimination (.52) and differentiation (.62). All the rest of the skills are above .70 (Van Manen et al., 2007).

2.4. Statistical analysis

In order to guarantee the quality of the data and to come to reliable analysis, a data inspection is executed.

2.4.1. Data inspection

Statistical software Statistical Package for Social Studies (SPSS) version 22 was used to provide diagnostic statistics to evaluate the data. The missing value analysis indicated that missing values were distributed over several tests, and these cases were excluded from analysis. According to requirements from Field (2005) numeric variables showed no evidence for outliers. Graphically three outliers were brought to attention. Values for Cook's distance and DFBeta statistics were below 0.154 (4/(n-k-1)) and 1 respectively and therefore gave no evidence outliers were influential in the analysis. Hence, no further adjustments were made to the data set. Normality of the variables was examined by means of descriptive statistics, graphical analysis, and statistical tests for normality.

In this study the amount of learning efficiency in science learning was analysed after an intervention of a teacher training course (2 levels: yes or no) as independent variable, and social- and neurocognitive child factors as mediating variables. This analysis followed a multiple mediation analysis, as is illustrated in figure 1.

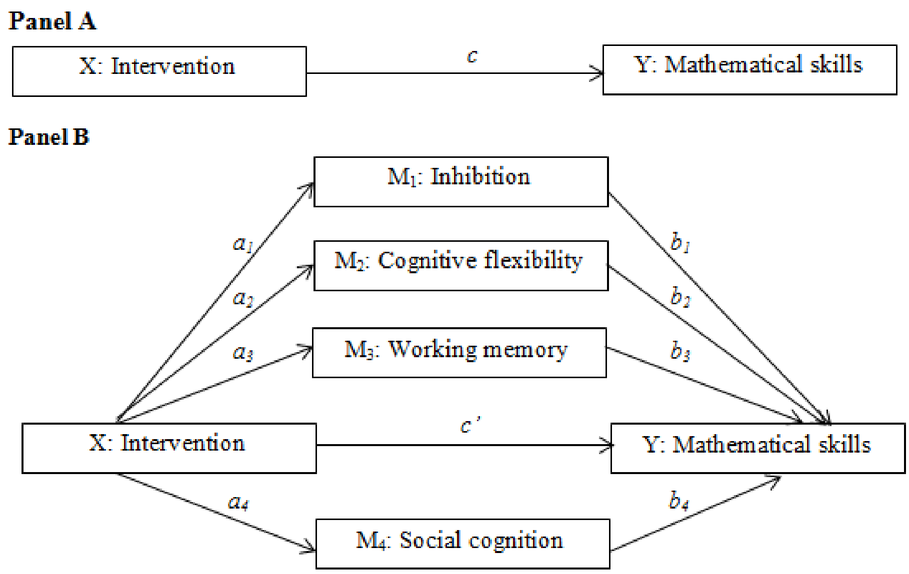

Figure 1. Multiple mediation model being tested (based on Preacher & Hayes, 2008).

This multiple mediation model was based on prior research by Preacher and Hayes (2008). Path c in panel A is the total effect in the unmediated model, which illustrates the relation between the teacher training programme (X) and mathematical skills (Y). In panel B the mediated model is shown, where was examined if this relation could be explained by mediating variables (M_{1-4}) which were caused by the teacher training programme (X) and was a cause for mathematical skills (Y). Path c' is called the direct effect. When complete mediation occurred, X no longer affects Y, after M_{1-4} is controlled. The path c' would hence be zero (Preacher & Hayes 2008).

First was examined whether the teacher training programme by Curious Minds had a positive effect on mathematical skills, while mediating variables being ignored *(path c)*. This was done with an independent sample *t*-test. For significant effects (*t*-test, $p < .05$) the effect size was further examined. An effect size between .50 and .80 could be considered as a moderate effect while an effect size of .80 and higher could be seen as a large effect (Cohen, 1988).

Second was examined, as can been seen in panel B in figure 1, to what extend the teacher training programme influenced the mediating variables *(path a)*. These mediating variables included social cognition and executive functions such as inhibition, cognitive flexibility, and working memory. The following step in this path analysis explored whether the mediating variables were related to mathematical skills, while controlling for teacher training *(path b)*. Finally, was studied whether the teacher training programme was still related to mathematical skills, while controlling for the mediating variables *(path c')*. All analyses were analysed by means of a regression analysis. In order to test the hypothetical mediating role of social cognition and executive function, a mediation analysis by means of a bootstrap resampling method (n = 5000) as described by Preacher and Hayes (2004) and Hayes (2009) was used. For this method normality was not assumed.

3. Results

The results of the study are discussed in this chapter. The first section includes a brief descriptive analysis of the variables. The second section discusses the statistical analyses used to test the hypotheses.

3.1. Descriptive analysis

Demographic characteristics are illustrated in table 1. The final sample for the unmediated model consisted of 69 pupils of which 42% pupils had a teacher participating in the intervention group, while 58% of the pupils had a teacher in the control group. The mean age of the pupils from the intervention group and control group was respectively 10.01 and 10.18 years.

The mediated model had a final sample of 38 pupils of which 76% of the pupils had a teacher participating in the intervention group, while the remaining 24% had a teacher who did not participate in the intervention group. The mean age for the pupils in the intervention group and control group was respectively 10.01 and 10.72 years.

Table 1. Demographic characteristics

	Analysis for unmediated model (n = 69)		Analysis for mediated model (n = 38)	
	Intervention group (n = 29)	Control group (n = 40)	Intervention group (n = 29)	Control group (n = 9)
Gender				
Boys	45% (13)	55% (22)	45% (13)	44% (4)
Girls	55% (16)	45% (18)	55% (16)	56% (5)
Age				
Mean age	10.01	10.18	10.01	10,72
Minimum	9.15	9.15	9.15	10.10
Maximum	11.43	11.37	11.43	11.12

3.2. Statistical analysis

In the sections underneath statistical analysis is described. First the unmediated model will be analysed, and thereafter the mediated model.

3.2.1. The unmediated model

The unmediated model illustrated in figure 1, panel A describes the effect of the teacher training programme on mathematical skills (n = 69). An independent-samples *t*-test was conducted to compare mathematical skills in the teacher training programme and no teacher training programme conditions. A significant negative effect in the mathematical skills for the teacher training programme (M = -.66, SD = 1.29) and no teacher training programme (M = -.05 SD =1.04) conditions; $t(52) = 2.09$ $p = .04$ was found. As illustrated in figure 2, mathematical skills decreased over time. Additionally, pupils in the condition teacher training programme produced significantly worse mathematic scores than the control group condition. The calculated effect size measured 0.52 which is a medium effect according to the criteria by Cohen (1988).

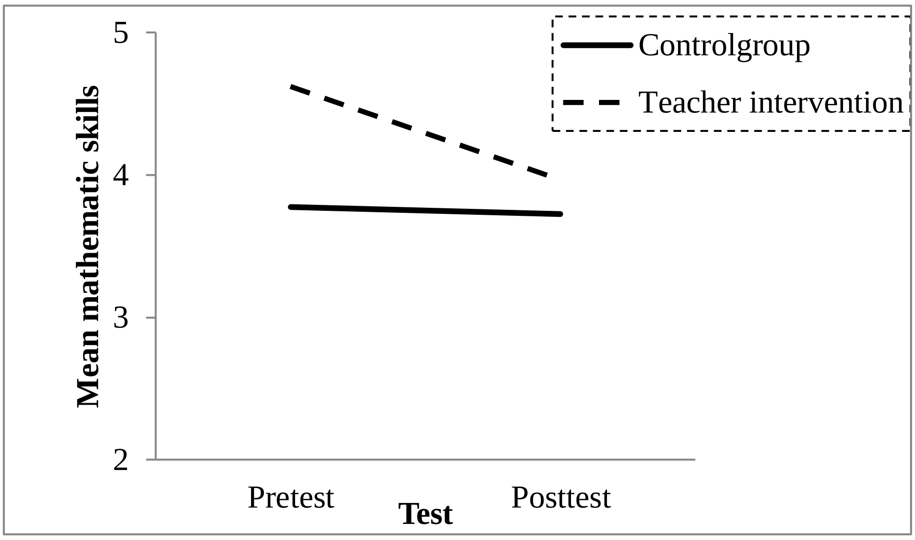

Figure 2. Difference in mathematical skills for intervention and control group (N = 69)

3.2.2. The mediated model

The mediated model illustrated in figure 1, panel B describes the effect of the teacher training programme on mathematical skills, while controlling for mediating variables executive functions and social cognition (n = 38). A multiple mediation analysis was conducted by means of a bootstrap resampling method to compare mathematical skills and mediating variables in the teacher training programme and no teacher training programme conditions.

First, the total effect (path c) was examined, which explored the relation between the teacher training programme and mathematical skills while ignoring the mediating variables. No significant results were found here. Second, the direct effect (path c') was researched, which illustrated the relation between the teacher training programme and mathematical skills while controlling for the mediating variables. Results remained non-significant. Third, the total indirect effect (path ab) was studied, which embodied the relation between the teacher training programme and mathematical skills through the mediating variables. Results showed no significant evidence for total indirect effects, as zero was included in the interval (point estimate .0818; 95% BC bootstrap CI of -.4693 to .5945). Lastly, specific indirect effects were explored (path a or path b). There was a significant positive effect in social cognition for teacher training programme condition and no teacher training programme condition (F(1, 36) = 4.94, p < .05). Significantly 12% (R^2 =.12) of variance in social cognition scores were explained by the teacher training programme. This difference in social cognition score for intervention and control group is displayed in figure 3.

By means of contrasts the specific indirect effects were compared, to check for differences in significance (William & MacKinnon, 2008). As illustrated in table 3, zero was included in the 95% BC interval, meaning that the effect of the teacher training programme on social cognition scores was not significantly different from the other effects. For that reason the earlier mentioned significant effect in social cognition scores could not be discriminated in terms of a valid effect.

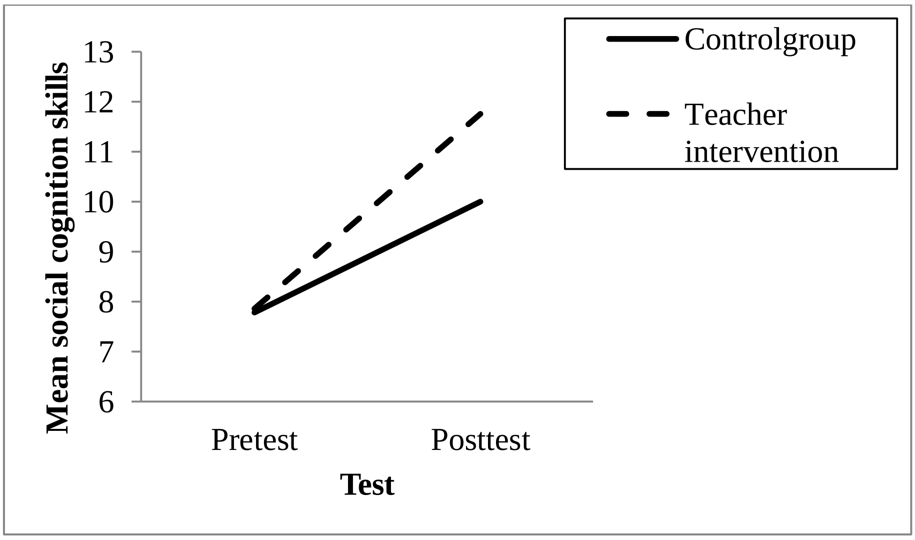

Figure 3. Difference in social cognition skills for intervention and control group

Table 2. *Multiple mediation results for direct effects*

Predictor variable	Outcome variable	*β*	*SE*	*t*	*p*	95% CI Lower	95% CI Upper
Path a							
Training	Inhibition	2.6322	1.5564	1.6912	.0994	-.524	5.789
Training	Cognitive flexibility	-4.7893	3.5832	-1.3366	.1897	-12.056	2.478
Training	Working memory	-4.1533	3.0014	-1.3838	.1749	-10.240	1.934
Training	Social cognition	1.6743	.7531	2.2232	.0326*	.147	3.202
Path b							
Inhibition	Mathematical skills	-.0482	.0505	-.9542	.3471	-.151	.055
Cognitive flexibility	Mathematical skills	.0078	.0221	.3531	.7263	-.037	.053
Working memory	Mathematical skills	-.0004	.0278	-.0135	.9893	-.057	.056
Social cognition	Mathematical skills	.1460	.1085	1.3460	.1878	-0.75	.367
Path c							
Total effect		-.2107	.4531	.-4650	.6447	-1.130	.708
Path c'							
Direct effect		-.2926	.5138	-.5694	.5731	-1.339	.754

Note. N = 38; 5000 bootstrap samples. S.E. = Standard error. CI = Confidence interval.

*indicates statistically significant difference, *p*-value <.05, in observed cases.

Table 3. *Bootstrapped results for indirect effects*

		Product of Coefficients	Bootstrapping			
			Percentile 95% CI		BC 95% CI	
	Point Estimate	*SE*	Lower	Upper	Lower	Upper
Indirect effects						
Inhibition	-.1268	.1378	-.4485	.0974	-.5597	.0408
Cognitive flexibility	-.0373	.0984	-.2751	.1310	-.3605	.0858
Working memory	.0016	.1315	-.2540	.2960	-.2901	.2616
Social cognition	.2444	.2056	-.1237	.7007	-.0985	.7397
Total	.0818	.2588	-.4126	.6396	-4693	.5945
Contrasts						
Inhibition vs. cognitive flexibility	-.0895	.1838	-.4727	.2759	-.5458	.2209
Inhibition vs. working memory	-.1284	.1776	-.4988	.2216	-.5026	.2160
Inhibition vs. social cognition	-.3713	.2496	-.9004	.0884	-.9651	.0384
Cognitive flexibility vs. working memory	-.0389	.1659	-.4004	.2756	-.3816	.2897
Cognitive flexibility vs. social cognition	-.2818	.2436	-.8328	.1607	-.8595	.1349
Working memory vs. social cognition	-.2429	.2675	-.8252	.2631	-.9121	.1818

Note. N = 38; 5000 bootstrap samples. S.E. = Standard error. CI = Confidence interval. BC = bias corrected

Confidence intervals containing zero are interpreted as not significant. (Preacher & Hayes, 2004).

4. Discussion

In this pilot study the efficacy of teacher support training by Curious Minds on mathematical skills was investigated. In the unmediated model sixty-nine children were assigned to the teacher training programme (n = 29) or to control group (n = 40), while in the mediated model thirty-eight children participated in the teacher training programme (n = 29) or control group (n = 9). Treatment outcome was assessed on the difference between the Cito-tests mathematics at pre-test and post-test. This chapter will first elaborate on the findings of the current study. Then the second and third sections consider the theoretical implications and the practical implications, respectively. Lastly, limitations and strengths of the study and suggestions for future research are provided.

4.1.Findings

Within this study the question *does the teacher training programme improve science skills, and is this relation mediated by social cognitive and neurocognitive child factors, respectively social cognition and executive functions?* was tried to be answered. It was expected that teacher training programme was effective in improving mathematical skills. Explorative, it was investigated whether this effect was mediated by executive functioning and social cognition. It was hypothesized that these concepts partly mediated the abovementioned relationship.

Surprisingly, the unmediated model showed a significant negative effect in mathematical skills for the teacher training programme (M = -.66, SD = 1.29) and no teacher training programme (M = -.05 SD = 1.04) conditions; $t(52) = 2.09$, $p = .04$. Meaning that the teacher training programme condition produced significantly worse mathematic scores over time than the control group condition. This was measured with a moderate effect according to criteria by Cohen (1988). In the mediated model neither credible evidence indicated that this relationship was mediated, nor evidence was found that the relationship was suppressed by one of the mediating variables. A significant indirect effect was found on social cognition ($F(1, 35) = 4.207$, $p = .048$) across different groups of teacher training programme. When the effect of the teacher training programme on social cognition scores was compared with other specific indirect effects, otherwise called contrasts, no significant results became evident either.

4.2 Theoretical implications

The visibility of the process in which the effect of the teacher training programme in mathematical skills was investigated, and the results of the present study, provide an important contribution to the literature. In pupils was found that the teacher training programme decreased mathematical skills six months after the training. This training though, did improve social cognition skills.

Most studies, including research on Tools and CogMed, found significant improvement in executive functions and academic performance after an intervention was provided (Bodrova & Leong, 2001; Klingberg et al, 2005). The current study did not find the similar effects, and thus provides a major implication on the efficacy of different interventions in different age groups. One explanation could be that the population investigated was dissimilar, as prior studies focussed on preschool children. Earlier was described that the development of inhibition and cognitive flexibility peaks only at six and twelve years old, and seven and nine years old respectively. Apparently, when children's executive functions are further developed, the teacher training programme will not improve these skills anymore. Furthermore was argued in this study that science learning does not occur in a social vacuum. Prior research studied neither the mediated effect of executive functions and social cognition, nor the mediated effect for social cognition alone, on teacher training programmes and science learning. For that reason, this study contributed to the address the literature gap in education and child studies.

4.3 Practical implications

This study provided more knowledge on the way children think, reason, and learn. Pupils in this study did not improve in executive function and decreased in mathematical skills, which contrasts prior research severely. Social cognition improved due to the teacher training programme, though this had no further effect on mathematical skills. This knowledge must be reflected in education systems, and training must be re-examined and focus more on executive function improvement.

4.4 Limitations and strengths

The examinations in this study were well able to make a contribution to knowledge in the neurological and educational climate. Nevertheless, this study also had some limitations. Because some limitations severely influenced the study, this study had to be regarded as a pilot study. The intention was to make a basis for a more complete research in the future. The main limitation on the content concerned the variable science learning. Although, mathematical skills were within the definition of science, this study hoped to contribute to a richer environment in classrooms in order for pupils to develop interests in science. Mathematics are within the curriculum of elementary schools for many years, though the science learning in this study initially aimed to emphasize on the novel, practical and explorative aspects of scientific learning. These aspect should have been assessed by practical and explorative tests in order to see the best possible improvements. A methodological limitation of the study concerned the availability of the data. Because each school had its own area of focus, different tests were conducted depending on the school's research question. This resulted into less available data. Additionally, a limitation involved time availability to investigate for longitudinal improvement within a sample. Namely, time was constrained by the due date of the thesis.

Strengths of the research were that both a pre-test and post-test was administered and a control group was included. This will give the possibility to conduct a longitudinal study and increases reliability. Furthermore, a strength of this study was the use of a multiple mediation model. This model enabled to explore effects simultaneously, which more directly studies the mediation hypothesis, than multiple single regression analyses. This model made it also possible to incorporate several executive functions and social cognition as mediating variables. Lastly, an important strength is that the programme Curious Minds was implemented by a broad group of scientists with very different backgrounds, such as neuroscientists, developmental psychologists, physicists, and linguists. This caused a true exchange of knowledge and experience.

4.5. Suggestions for future research

In future research on the neurological and educational climate it is advisable to take into account a number of the above limitations. In content the study would improve significantly when the effect of teacher training programme is examined on the practical and explorative science aspects, where Curious Mind initially aims for. This can be done by replacing the paper-and-pencil- test by the Cito with a practical test where pupils have to solve a scientific problem. The platform for Science and Technology also advocates for such ideas (Rijksoverheid, 2013).

Methodological limitations concerning lack of available data can be resolved by demanding the participating schools to have next to their specific research question, obligatory test assessments for the research for Curious Minds. Although this might cost more time and effort to administer the extra tests, less data will be missing and more representative distributions and examinations can be derived from the sample. For a master thesis a longitudinal study might be too comprehensive, for future research more time devotion to the same sample might give more insight in de hypothesized improvement in science learning.

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