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Creative problem solving in primary school students

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A R T I C L E I N F O

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A B S T R A C T

Aims: Two studies are reported to give insight in the nature of creative problem solving in primary school students. Study 1 focused on the process and aimed to determine to what extent behaviors in response to a task matched the Creative Problem Solving model (CPS model; Isaksen et al., 2011; Treffinger, 1995). Study 2 focused on the product and aimed to determine the relations among creative problem solving outcomes and the overlap of these outcomes with divergent thinking and academic achievement outcomes.
Sample: 13 fourth graders participated in Study 1; 594 fourth, fifth, and sixth graders participated in Study 2.
Methods: In study 1, students were asked to think aloud while completing a structured task. Their behaviors were coded based on the CPS model. In study 2, students completed similar tasks for three problem situations. Students' ideas were rated on four CPS indicators. A measurement model and structural model were tested.
Results: Study 1 showed that behaviors could be described with the CPS model. All elements were found: understanding the challenge, generating ideas, preparing for action, and planning your approach. The number of utterances within elements and the sequence of the creative problem solving processes varied across students. Study 2 showed that the relations of the creative problem solving indicators corresponded with theory and with relations found in earlier studies.
Conclusions: The CPS model can be applied in the primary school context and creative problem solving capability is already evident in primary school students.

1. Introduction

Our society changes rapidly. Consequently, children grow up with many possibilities and challenges (Craft, 2011). To meet these challenges, creative products are needed. As commonly used definitions point out, something can be considered creative when it is both original and useful (Plucker et al., 2004; Runco & Jaeger, 2012; Stein, 1953). This definition implies that not only artistic expressions, such as paintings or poems, can be regarded as creative products. Creative products can also be ideas that are both original and useful, such as those generated by primary school students in response to an everyday problem presented to them as part of a task. These ideas are often referred to as expressions of everyday creativity, also known as 'little-c creativity' (Craft, 2011), and are viewed as the result of a creative problem-solving process (Brophy, 1998; Isaksen et al., 2011). *Creative problem solving* can, as such, be defined as a real-life creative strategy, in which creativity and domain knowledge are combined to solve problems in original but useful ways (Isaksen & Treffinger, 2004; Long, 2014). Most earlier research focused on the positive effects of creative problem solving on various outcomes such as divergent thinking, subject matter learning, and exploration (e.g. Kashani-Vahid et al., 2017; Kim et al., 2019; Poddiakov, 2011; Saxon et al., 2003). However, little is known about the *nature* of creative problem solving in primary school students. The aim of this research therefore is to gain a better understanding of how primary school students solve problems creatively.

As a framework to study creativity at different levels, Rhodes (1961) proposed the Four P's of creativity: the Person (i.e., individual characteristics associated with creativity), the Process, the Product, and the Press (i.e., the creative environment or context). To better understand the nature of creative problem solving in primary school students, this study zooms in on two P's: the *Process* and *Product*. Here, the creative problem solving process refers to a set of distinct creative problem solving behaviors (Brophy, 1998; Isaksen et al., 2011). Because the CPS model of Treffinger, Isaksen and colleagues (Isaksen et al., 2011;

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Treffinger, 1995) described such a set of behaviors and was specifically designed for education, this model was applied in this study. A creative problem solving process may eventually results in a product: a set of (potentially) creative ideas to solve a problem (Isaksen et al., 2011; Runco, Plucker, & Lim, 2000 – 2001–2001). These ideas can be scored on multiple indicators to determine the level of creativity of the ideas. More insight into the nature of creative problem solving processes and products in primary school students may help teachers to foster the creative problem solving abilities of students from an early age on and may ultimately support students in navigating future challenges and possibilities.

1.1. The Creative problem solving process

In his seminal work on creative problem solving, Guilford (1957) postulated that a creative problem solving process involves both divergent thinking (i.e., ideation) processes and convergent thinking (i.e., evaluation) processes. Furthermore, according to Guilford, a certain level of domain knowledge is required to be able to fully understand the problem and to come up with creative ideas to solve it (Runco & Chand, 1995; Wiley, 1998). Generally, creative problem solving processes are described as a set of iterative activities (Brophy, 1998; Isaksen et al., 2011). Although these activities may primarily focus on either divergent or convergent processes, one may still alternate divergent and convergent thinking while iteratively solving the problem (Brophy, 1998; de Vink et al., 2022; Runco & Chand, 1995; Webb et al., 2017). Several scholars have developed frameworks to describe these creative problem solving activities, which help in their application in specific domains (e.g., Altshuller, 1996; Finke et al., 1992; Mumford et al., 1991). Treffinger, Isaksen, and colleagues (Isaksen et al., 2011; Isaksen & Treffinger, 2004; Treffinger, 1995) adapted models for creative problem solving to the educational context. Their creative problem solving model (i.e., CPS model) includes four main elements: (1) understanding the challenge, (2) generating ideas, (3) preparing for action and (4) planning your approach (Fig. 1). 'Understanding the challenge' includes three activities: (a) the construction of opportunities by generating broad, brief, and beneficial statements that help set the principal direction for the problem-solving efforts, (b) exploring data by generating and answering questions that pin-point key information, feelings, observations, impressions and questions about the task and (c) framing problems by seeking a specific or targeted question (problem statement) on which to focus subsequent efforts. 'Generating ideas' includes the ability to diverge and think of many, varied and unusual options for responding to the problem.'Preparing for action' includes the evaluation of ideas and the identification of the most creative solution to the problem. This element entails (a) the development of solutions by analyzing and refining promising options and (b) the identification of potential sources of assistance and resistance in practice and other factors that may influence successful implementation of solutions (Isaksen et al., 2011).

Creative problem solving activities do not need to follow a fixed sequence (Lubart, 2001). Therefore, the first three main elements of the CPS model should be understood as flexible and dynamic in their ordering: students could apply these in iterative ways switching back and forth between them while solving a problem (Isaksen et al., 2011; Treffinger et al., 2008). Isaksen et al. (2011) therefore added the fourth 'planning your approach' element to the model that includes all efforts to plan and monitor the creative problem solving process.

To gain insight in how creativity in primary school students was studied in the past decades, Kupers et al. (2019) conducted a systematic review of recent literature on primary school students' creativity. They concluded that most studies conceptualized and measured children's creativity as a static, aggregated construct (i.e., the macro level), whereas the number of studies focusing on students' behaviors that emerge while working on a task (i.e., the micro level) is limited. According to Kupers et al., an even smaller number of studies (5%) combined and connected the micro and macro level. The dominant focus on the macro level is problematic because (a) creativity measures at the aggregated or group level cannot be generalized directly to the individual and (b) research with a focus on the macro level will not reveal *how* creative ideas are formed. Therefore, in order to enhance primary school students' creative problem solving outcomes, it is important to examine their creative problem-solving processes first.

The creativity studies with a micro focus, even though limited in number, do provide information on how creative ideas are formed on the individual level. For instance Pringle and Sowden (2017) studied creative problem solving in adults and described that shifts and combinations of divergent and convergent thinking are indeed beneficial for creative products. The work of Bai et al. (2021; 2023) is of specific interest to the present study. Bai et al. studied divergent thinking processes in young children and concluded that similar processes are involved in idea generation among both children and adults. However, a complete understanding of how children solve everyday problems creatively is

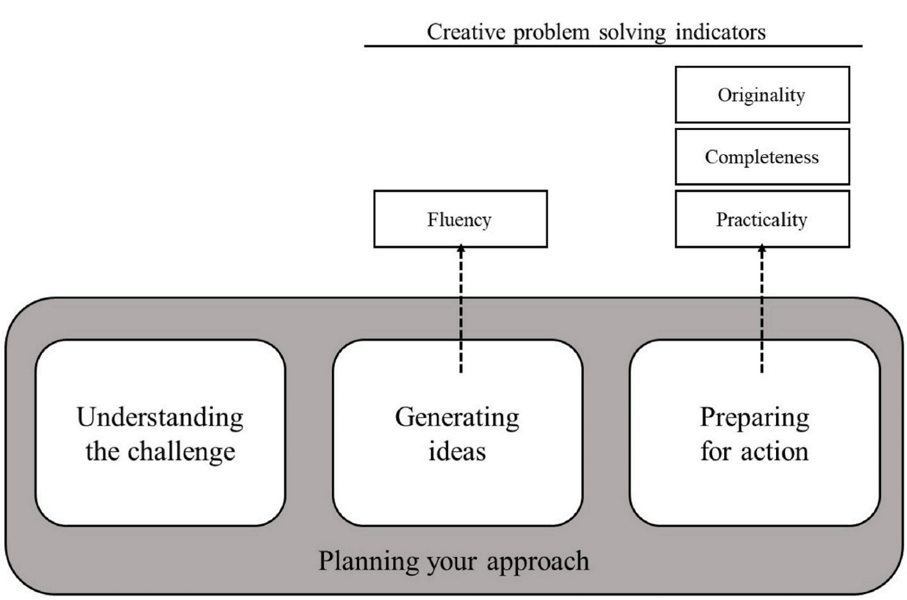

Fig. 1. The Four Elements of the CPS Model (Understanding the Challenge, Generating Ideas, Praparing for Action and Planning Your Approach; Based on Isaksen et al., 2011) and the four Creative Problem Solving Indicators (Fluency, Origfinality, Completeness, and Practicality).

still lacking. Although children's creative problem solving processes may resemble those found in adults, they may also differ due to the ongoing development of executive functions, which can affect planning and monitoring in particular (Diamond & Lee, 2011). Therefore, Study 1 explored whether and how the CPS model (Isaksen et al., 2011; Isaksen & Treffinger, 2004; Treffinger, 1995) applies to creative problem solving processes in primary school children.

1.2. The creative problem solving product

When students engage in creative problem solving processes, they may develop ideas to solve problems. These ideas can be regarded as the outcome or the *product* of a creative problem solving process (Rhodes, 1961). To determine how creative these ideas actually are, several indicators can be applied. In the first version of the Torrance Test of Creative Thinking (TTCT; Torrance, 1966), four factors were derived from Guilford's (1957) Structure of the Intellect Model and used to determine the creativity of ideas. These factors included fluency, flexibility, originality and elaboration. Fluency refers to the ability to produce many different ideas, flexibility refers to the ability to come up with ideas from different perspectives or categories, originality refers to the uniqueness of ideas, and elaboration refers to the amount of detail the ideas have. When creativity was assessed in later work, the flexibility factor was less frequently applied because of its strong correlations with fluency (Kim, 2006; Reiter-Palmon et al., 2019).

More recently, in line with the 'standard definition' of creativity (e.g., Stein, 1953), authors emphasized that creative ideas should not only be original, but should also be appropriate, useful, effective, or should fulfil a certain purpose (Corazza, 2016; Runco & Charles, 1993; Runco et al., 2005; Runco & Jaeger, 2012). Therefore, multiple studies assessing creative products included measures of usefulness, sometimes instead of measures of elaboration (e.g., Reiter-Palmon et al., 2019). For creative problem solving in specific, ideas can be considered useful when they are well thought out and applicable in practice. In other words, the creative problem solving products of students should not be solely assessed in terms of quantity and originality but also in terms of how complete and practical ideas are (Long, 2014). To summarize, the number of ideas a student generates during 'idea-finding' is often viewed as an indicator of fluency (Isaksen et al., 2011; Reiter-Palmon et al., 2019, Fig. 1). Solutions that a student ends up with after a creative problem solving process are usually regarded as creative when they are original, complete and practical (Byrne et al., 2010; Corazza, 2016; Isaksen et al., 2011; Okuda et al., 1991; Piffer, 2012; Reiter-Palmon et al., 2009).

To fully understand creative problem solving in primary school students, it is important to know how the creative problem solving indicators are related. Drawing on the work on creative cognition and divergent thinking of Guilford (1957) and Torrance (1966, 1972a), originality and fluency may be regarded as distinct but related constructs: generating more ideas may increase the odds of finding original ones. Indeed, throughout the years, many authors found substantial correlations between originality and fluency (e.g., Dumas & Dunbar, 2014; Hocevar, 1979; Silvia, 2008). Results of other studies, however, indicated that fluency and originality may come at the expense of one another (Benedek, et al., 2006) and are more separable when originality outcomes are corrected for the number of ideas students come up with (Silvia et al., 2008). Nevertheless, studies that assessed fluency and originality with divergent thinking tasks in children generally regarded them as related concepts (de Vink et al., 2022; Shah & Gustafsson, 2021) and found positive relations between the two (Bai et al., 2021; Runco & Albert, 1985).

Although products can only be considered creative when they are original *and* practical (Cropley, 2006; Plucker et al., 2004; Runco & Jaeger, 2012; Stein, 1953), indicators of originality and measures of practicality do not tend to go hand in hand (Mueller et al., 2012). In fact, originality and practicality might even be inversely related, because original ideas tend to be more difficult to apply in practice (Cropley, 2006; Rietzschel et al., 2009). In the creative problem solving context, Reiter-Palmon et al. (2009) used multiple measures of both originality and quality (encompassing both completeness and practicality) to rate ideas generated in a creative problem solving task in a study with an adult sample. They found that when fluency increases (i.e., more ideas are generated), the number of ideas rated highly on originality increases as well. Between fluency and measures of quality, Reiter-Palmon et al. (2009) found some small negative correlations. In addition, measures of originality correlated more strongly with each other than with quality measures, suggesting that originality and quality can be seen as distinctive indicators.

The relations between the creative problem solving indicators discussed here are mainly based on research conducted with adult samples or found with data from divergent thinking tasks. The question is whether the same relations (i.e., a positive relation between fluency and originality, a small negative relation between fluency and measures of completeness and practicality, and a negative relationship between originality and practicality) will also be found with creative problem solving data from primary school students.

1.2.1. Creative problem solving, divergent thinking and academic achievement

To fully understand creative problem solving in the primary school context, it is important to study to what extend creative problem solving outcomes overlap with outcomes from commonly used creativity tests and measures of academic achievement. In previous research and in education, divergent thinking tasks are often used to get an indication of primary school students' creative potential (Acar & Runco, 2019; Reiter-Palmon et al., 2019; Runco & Acar, 2012). In divergent thinking tasks, students are, for example, asked to think of alternative uses for an object like a brick or a paperclip. A critisism of such tasks has been that they focus on divergent thinking processes in the form of idea generation in isolation, rather than also on processes demanding both divergent and convergent thinking that are explicitly part of a creative problem solving task (Brophy, 1998; Cropley, 2006; de Vink et al., 2022; Runco & Chand, 1995; Van Hooijdonk et al., 2020; Webb et al., 2017). Nevertheless, outcomes of a divergent thinking task have been widely recognized as an indicator of creative potential (Runco & Acar, 2012) and, as Guilford (1968) pointed out, "most of most of our problem solving in everyday life involves divergent thinking" (p. 8). Indeed, decades of research have shown that creative problem solving interventions enhanced divergent thinking processes in children (e.g., Kashani-Vahid et al., 2017; Kwon et al., 2006; Scott et al., 2004; Torrance, 1972b; Torrance & Torrance, 1972), suggesting that divergent thinking and creative problem solving are related in primary school students. To study to what extent creative problem solving and divergent thinking outcomes overlap, we investigated how they are related in primary school students.

While some authors contend that creativity and academic achievement should be positively correlated since both require domain-specific knowledge (e.g., Beghetto, 2016; Cropley, 2006; Guilford, 1968; Schoevers et al., 2020), other authors argue that current academic achievement tests administered in schools offer limited opportunities for creativity since these tests often require a single correct answer on standardized test tasks (Beghetto, 2010; Solomon, 2009). This implies that creativity and academic performance may not or even be negatively related. To address this debate, Gajda et al. (2017) performed a meta-analysis on 120 studies across diverse age groups. They found significant but relatively modest correlations between academic achievement and creativity tests (e.g., $r = 0.23$ - 0.30). The studies included in the meta-analysis used a variety of creativity tests such as divergent thinking tasks, drawing tasks, and questionnaires, but the relationship of academic achievement with creative problem solving outcomes in primary school students remains unclear. Therefore, we studied how the creative problem solving indicators are related to academic achievement as well in Study 2.

1.3. The present studies

To determine whether the nature of creative problem solving processes in primary school students corresponds with the theoretically assumed elements of the CPS model (Isaksen et al., 2011; Isaksen & Treffinger, 2004), we observed primary school students' processes during working with a creative problem solving task. Because the think-aloud method is especially suitable for studying complex cognitive processes (Sowden et al., 2020; Van Someren et al., 1994), we used this qualitative approach to answer our first research question in Study 1:

(1) To what extent do the CPS elements appear when primary school students solve problems creatively?

In a larger-scale quantitative study, students applied creative problem solving with similar structured tasks in three different problem situations. Students' ideas were rated on the four creative problem solving indicators (see Fig. 1) and a quantitative measurement model and structural model were tested in Study 2 to answer the second and third research question:

(2) How are the creative problem solving indicators related in primary school students?
(3) How do these creative problem solving indicators relate to outcomes from a divergent thinking task and to academic achievement?

Hypotheses. For RQ1, Because of the explorative nature of this study, no specific hypotheses were defined.

For RQ2, which focusses on the relations among the creative problem solving indicators (i.e., the measurement model), we expected, in line with creativity theory and earlier findings (e.g., Bai et al., 2021; Guilford, 1957; Mueller et al., 2012; Reiter-Palmon et al., 2009; Runco & Albert, 1985; Torrance, 1966, 1972a), that fluency and originality are distinct but positively correlated constructs. We also expected small negative relationships between fluency and completeness and practicality. Apart from that, we expected originality and practicality to have a negative relationship.

For RQ3, the external relations (i.e., the structural model), we expected in line with theory and earlier findings (Guilford, 1968; Kashani-Vahid et al., 2017; Kwon et al., 2006; Runco & Acar, 2012; Scott et al., 2004; Torrance, 1972b; Torrance & Torrance, 1972) that creative problem solving fluency would be positively related to divergent thinking fluency, creative problem solving originality would be positively related to divergent thinking originality, and that creative problem solving completeness would we be positively related to divergent thinking elaboration. We expected creative problem solving originality to be positively related to divergent thinking fluency as well. In line with the meta-analysis of Gajda et al. (2017), we expected academic achievement to have a positive small to moderate association with the creative problem solving originality, completeness and practicality indicators. Moreover, we expected the relations between academic achievement and completeness/practicality to be stronger than the relation between academic achievement and originality, because both academic achievement and completeness/practicality tend to rely on convergent thinking processes (de Vink et al., 2022; Webb et al., 2017).

In both studies, structured tasks were used to trigger students creative responses to a problem. We first describe these tasks before proceeding to the methods and results of the qualitative study (Study 1; section 3) and the quantitative study (Study 2; section 4).

2. The structured creative problem solving tasks

2.1. Problem situation construction

A structured task was constructed and used in Study 1 and Study 2. In general, creativity is considered to be a partly domain-specific ability (Plucker & Beghetto, 2004; Silvia et al., 2009) and a variety of factors such as creative self-efficacy, prior knowledge and task characteristics tend to influence creativity scores (e.g., Redifer et al., 2021; Reiter-Palmon et al., 2009). Consequently, determining the creative problem solving performance of students with a single task may be difficult, as it relates to only one domain. Therefore, the goal was to construct three different everyday problem situations, related to three different domains, to be solved by the participants. Because the scientific, interpersonal and entrepreneurial domains were found to be distinct creativity domains in several studies (Kaufman, 2012), two problem situations for each of these three domains were selected from Treffinger's practice problems (2000). Based on vignette theory (Poulou, 2001), we modified the six problem situations to fit our research purposes and the age group. As with vignettes, the problem situations described hypothetical scenarios which, although being realistic, did not involve the respondent personally. Six criteria were used to design the problem situation descriptions: (1) The problem situations are open and non-directive, enabling the participant to form his/her own interpretation of the described situation, which is important for creativity; (2) They are concrete and specific about the situation, precisely delineating the situation under investigation; (3) The characters and story are realistic; (4) They evoke imagination, feelings and thoughts at the same time; (5) They are written in the third person and contain about the same number of words; (6) They are easily understood and contain short sentences, and the choice of words is suitable for children between 9 and 12 years old.

To select the three problems for our study, five 9-year-old students (4th grade, 3 boys, 2 girls) were asked to rank the six constructed problem situations on complexity, importance, realism, problem-based efficacy (i.e., whether they thought they could solve the problem), and experience (e.g., Reiter-Palmon et al., 2009). The three problems that were selected ranked lowest on complexity, but highest on realism, efficacy, and experience.

The selected science problem described Lisa and Tom buying ice cream on a hot day, which melted on the way home. The selected social problem referred to a classroom situation, in which Simon gets distracted by his friend Julian all the time. The selected entrepreneurial problem described Aron who desperately wants a new bicycle, but only owns a two-euro coin.

After this step, we asked three experts in educational research to evaluate the three problem situations on the six design criteria. Their feedback was used to enhance the formulation of the problems. In brief, a few sentences were rewritten or shortened and a few words were altered to make the problem situation less specific and easier to understand. The final problem situations included a short story about the problem, and were presented written on paper as well as read aloud to the students by the test administrator.

2.2. Creative problem solving steps

The structured task included a general introduction of what creative problem solving is and an explanation of the steps of the task. Then, the problem at hand was read aloud to the students. Next, the students were guided through four pre-structured steps of the task (see Appendix A for the task).

In the first step, students were instructed to explore their knowledge relevant to the problem by listing the knowledge elements they could think of (e.g., the box, the ice, the distance, the temperature for the science problem; cf. Barak, 2013) in a simple mind map. Here, students were told they could list as many elements as they liked. In the second step, students were asked to frame the problem at hand by writing down the problem statement in the form of a question in the middle of the mind map. In the subsequent third step, students received 10 min to list as many different and original ideas to solve the problem as they could. Students received a sheet of paper with 18 boxes in which to write their ideas, and were told they could list more ideas on the back of the paper if they wished to do so. Because instructions influence creative outcomes (Di Mascio et al., 2018; Nusbaum et al., 2014), the students were explicitly asked to come up with ideas of which nobody else would think. To minimize time pressure, students were not notified about the time left to complete the task. To stimulate the use of knowledge in idea finding, students were asked to look back at their mind map to see what elements they could use in the construction of more ideas. In the final step of the task, top scoring was applied (Silvia et al., 2008). Rather than rating each of a student's ideas (and consequently rating a different number of ideas for each student), the method of top scoring has been developed to assure a fixed number of ratings for every student and a fluency-independent measure (Benedek et al., 2013; Silvia et al., 2008). Students themselves therefore selected their three most creative ideas, which were then considered for scoring. The administrator stated: *"A creative idea is an original idea nobody has thought of before, it is complete and solves the problem and can be easily applied in practice."* The students were asked to label their self-perceived top three of ideas by numbering them on their sheet of paper, for which purpose there were small boxes beside each idea box.

3. Study 1: The creative problem solving process

In a small-scale think aloud study, the structured task featuring the science problem situation was used to examine the extent to which primary school students demonstrate the theoretically assumed CPS elements when solving problems creatively.

3.1. Material & methods

3.1.1. Participants

The students that were invited to participate in the study were independently selected by two teachers of two 4th grade classes (N = 42) of one sub-urban school in The Netherlands. Although the structured task was developed for 4th to 6th grade students, we selected 4th graders for the think aloud study: we reasoned that if it proved possible to elicit creative problem solving processes with 4th grade students, then it was likely 5th and 6th grade students would show these processes as well. Teachers were asked to select students with well-developed verbal communication skills. Although this might imply that these students were slightly more intelligent or creative compared to the rest of their class (i.e., potentially introducing a systematic bias; Batey & Furnham, 2006; Sternberg, 2000), the ability to verbalize thinking processes is regarded as a prerequisite for participating in a think aloud study (Van Someren et al., 1994). Seventeen students were selected (9 boys, 8 girls) and were consequently invited to participate in this study. The parents and the students were informed about the study and asked for their consent with a written consent form. Parents had two weeks to decide and were reminded once of the study after the first week. In the end we received consent for 13 students (7 boys, 6 girls; M age = 9.08; SD = 0.49). These students were included in the study.

3.1.2. Procedure

In order to study whether the students engaged in the processes as described by the CPS model, we asked the students to complete one creative problem solving task while thinking aloud. The think aloud method is the most common approach in studies using problem-solving tasks because problem solving combines two types of reasoning that are relatively easy to verbalize: constructing solutions and constructing justifications for these solutions (Van Someren et al., 1994). Think aloud is regarded as a form of concurrent verbal reporting (Ericsson & Simon, 1980): within a think aloud study, students are individually assessed and instructed to verbalize their thoughts while performing a task. During the administration, it is important that the participants are instructed to report verbal content, but are not asked to explain their thinking (Ericsson & Simon, 1980). If these conditions are satisfied, it is argued that researchers are able to identify the spontaneous use of processes. Although thinking aloud may slightly slow down those processes, the concurrent verbalization of one's thoughts will most likely not interfere with the ongoing thinking processes (Bannert & Mengelkamp, 2008; Ericsson & Simon, 1980), making think aloud a suitable method to study creative problem solving processes.

Because original solutions tend to be scarce by nature, we chose to use the science problem situation, as it elicited the most original solutions in an earlier pilot study (N = 140; Van Hooijdonk et al., 2020). Furthermore, this problem was easily understood by students.

Three trained assistants administered the task. The students were seated outside the classroom in a quiet area. The whole procedure took about 30 min for every student. Before starting the task, the students were shortly trained in thinking-aloud with a simple mathematical word problem (Van Someren et al., 1994; Marc saves money for a new drum set with new drumsticks. He has already saved 559 euros. The drum set costs 1450 euros and the drum sticks 29 euros. How many euros does he still have to save?). The researcher explained that thinking aloud includes saying everything you think while doing a task. The researcher gave an example, e.g.: "I think I need to write down first how much he needs in total, and how I need to compute that.". During the mathematical word problem, the researcher prompted the student (e.g., Keep on talking, Please tell me what you think? Please describe what you think now). The word problem task took about 5 min. Then, the researcher asked whether the concept of thinking aloud was clear before proceeding to the task.

During the creative problem solving task, the role of the administrator was a restrained one: interference only occurred when the student stopped talking. The students were prompted to continue thinking aloud when they were silent for 5 s or more by using one of four prompts (Please tell me what you think; keep on talking; what are you thinking? what are you thinking about?) or by repeating the last sentence or last few words the student expressed. The students were not asked for clarifications or elaborations to reduce interference with the cognitive processes involved in creative problem solving (Van Someren et al., 1994).

3.1.3. Analysis

The 13 think-aloud protocols were audio-recorded, transcribed, anonymized, and then segmented into utterances. One utterance included one meaningful expression about a (sub)topic. When the student changed topics or when a new element was added, a new segment started. We applied the directed content analysis technique because this method is used to validate or extend a theoretical framework or theory (Hsieh & Shannon, 2005). In our case, we aimed to study whether and to what extent the primary school students' verbalized thinking showed evidence of the elements as described by Isaksen et al. (2011) in the CPS model. A coding scheme was therefore prepared, which was used to code the thinking processes of the students (Appendix B). For the four main elements (understanding the challenge, generating ideas, preparing for action, and planning your approach) of the model of Isaksen et al. (2011), we defined categories describing the behaviors to be observed. Next, operational definitions for each coding category were defined using the CPS theory (see Appendix B). In a last step, specific descriptions of the utterances belonging to each coding category were defined in line with Isaksen et al. (2011). Segments of 8 protocols were coded with this coding scheme in a first phase. The program NVivo version 12 Pro was used to code all protocols.

Across the 8 protocols that were coded first, 22 segments (6.4%) could not be coded with the initial coding scheme. 17 of these 22 segments could be regarded as task-related processes, such as remarks or questions about the task. For these segments, the category 'task-related' was defined within the 'planning your approach' element. From the remaining 5 segments without a code, 2 segments included students asking questions about spelling, 2 segments included a personal story, and 1 segment was a remark about children playing outside. These segments were defined as irrelevant segments and were as such excluded from further analysis. The extended coding scheme was used to code the remaining 5 protocols. All remaining segments could be coded with this scheme. The 13 protocols contained 22 to 85 segments (M = 43). A second coder coded 4 randomly selected protocols (student 3, 7, 8, and 11; 156 segments in total). A Cohen's Kappa of 0.85 indicated that the raters largely agreed in their assignment of codes (Landis & Koch, 1977).

3.2. Results

Findings are presented and discussed for each of the four CPS elements as well as for the separate categories (Table 1). With regard to the first element 'understanding the challenge', all students made utterances belonging to the 'exploring data' category. This means that all students expressed information, feelings, observations, impressions or questions about the melting popsicle problem situation: *"I also know that they are not completely melted, they are mostly soft"* (student 3), *"And that they feel sad as well"* (student 1*), "Maybe it's also because of the ice cream itself. How they are packaged. So … But also … How they froze up, how they are made."* (student 5). The amount of information explored differed across students, the number of utterances ranged from 4 to 18 (M = 9.07). For the 'framing problems' category, 12 out of 13 students showed 1 to 3 utterances. Only one student expressed 7 utterances of that category. Utterances from this student for instance included: "*That their ice pops are melting. So why are the ice pops melting is the question?*"; *"How did the ice pops melt that quickly?"*; *"And what could help them?"*. In other words, all students attempted to seek a problem statement on which to focus subsequent efforts. Although the students were not specifically instructed to 'construct opportunities', 7 students did show utterances that belonged to this category. The brief statements belonging to this category included a wish or an obstacle that shaped the principal direction for problem-solving efforts, for instance: *"Yeah right. So the ice pops should not melt. So they have to stay cold. An ice pop that does not melt."* (student 2).

With regard to second element 'idea generation', all students showed utterances including ideas to solve the problem. Examples for instance included: *"Maybe you can make a bicycle. Then you have a basket in front and then you can see, for example if you are going to eat somewhere in between, you can. If you want it to be heated, you can heat it and if it must remain cold, you can program it to be cold."* (student 9), *"We could also invent a rain or snow cloud to put above an ice cream box or ice pop. And then it can simply be delivered. So then you get on your bike and then a cloud comes behind you from above the ice cream shop. So when you go to buy it at the store, they ask if you want a rain cloud or a snow cloud. And then you can take it with you. Above your bike or above your bag and then it stays cold."* (student 2). The number of ideas generated seemed to vary widely: the students generated a minimum of 2 ideas and a maximum of 24 ideas (M = 10.15). 8 out of 13 students continued their idea in later utterances. These ideas were for instance interrupted by questions about spelling (e.g., *"They can call a fantasy animal with magica … How do you write that?"* student 7), utterances including knowledge or previous experiences (e.g., *"You can light a fire with it. With such a thing and then you think wow! If you put it in the muffler of the car, no more CO_2 comes out of the muffler. And then there is an explosion. I know because I once put a pebble in the muffler and then someone found out and they said wow, this can light a fire. So ice in the muffler and then fire."*, student 10) or by the researcher that stimulated the student to continue talking.

With regard to third element 'preparing for action', all students showed some form of evaluation of their ideas to identify their most creative ones. Three students even included some form of refinement (e.g., *"It may be, even if it takes a long time, but it can be made. And I don't think other people will come up with a machine that you can put on your bike. And it is practical. And it says, a machine that keeps ice pops cool. And I will add to that, to put it on your bike so that is clear as well."* (student 1). The number of utterances describing this developing solutions category ranged from 1 to 14 utterances (M = 6.31). Although students were not asked to 'build acceptance' for their solutions, four students searched for potential sources of assistance and resistance and identified possible factors that may influence successful implementation of solutions. For example, student 8 said: *"Or you can melt chocolate and you add it to it. No, I don't think that will taste good"* and student 11 said *"Ice pops that never melt would be nice because with hot days at the beach, if it melts and your entire hand is covered, that's not really fun"*.

For the fourth element 'planning your approach', no students showed utterances belonging to the 'appraising tasks' category, meaning no students seemed to question whether or not CPS was a suitable choice for the task. However, all students did show utterances that could be categorized as belonging to the 'designing process' category, indicating that metacognitive actors are an integral part of the creative problem solving process. These utterances for instance included questions about revising information (e.g., *"Can I read the story again?"*; student 1), statements that they knew more ideas or were finished thinking about ideas, (e.g., *"Oh yes, I know something else. An ice cream that. Designing an ice cream that never melts. Uh. Now I don't know anything anymore."*; student 12) or utterances including they were ready to move to the next step (e.g., *"Now I just have to put the numbers down for the ideas"*; student 12). The number of utterances belonging to this category ranged from 3 to 10 utterances (M = 5.31). Aside from this, 11 out of 13 students showed utterances that were categorized as task-related processes. Here, the number of task-related utterances seemed to vary greatly as well (1–24 utterances; M = 4.55). Utterances for instance included task-specific questions (e.g., *"Do I have to write that here?"*, student 10) and clarification requests.

Our data indicated that processes occurred in different sequences. Only two students showed a completely 'linear' process (student 4 and 9), meaning that they first showed processes of *understanding the challenge* (i.e., exploring data and framing problems), then generated ideas, and finished with *preparing for action* with evaluating and selecting ideas. Two students (student 3 and 13) explored additional data while generating ideas. One student (student 12) questioned the acceptance of

Table 1
Number of utterances per category for every student and in total.

Main CPS process	Category	Student Number													Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	
1. Understanding the challenge	1a. Constructing opportunities	1	12	–	–	–	4	–	1	–	1	1	–	1	21
	1b. Exploring data	12	5	8	4	9	15	9	4	9	18	5	4	16	118
	1c. Framing problems	7	2	1	2	1	3	2	2	2	3	3	2	3	33
2. Generating ideas	2a. Generating ideas	10	24	6	8	2	12	8	9	8	18	9	8	10	132
	2b. Idea continued	–	1	–	1	–	19	9	3	2	6	–	2	–	
3. Preparing for action	3a. Developing solutions	14	6	6	6	5	14	8	3	6	4	3	6	1	82
	3b. Building Acceptance	–	–	–	–	–	–	–	1	–	6	1	3	–	11
4. Planning your approach	4a. Appraising tasks	–	–	–	–	–	–	–	–	–	–	–	–	–	0
	4b. Designing process	8	3	4	3	5	6	10	3	3	6	6	5	7	69
	4c. Task related	3	3	1	–	–	2	7	1	1	23	1	5	3	50
Total number of segments		55	56	26	24	22	75	53	27	31	85	29	35	41	559

an idea (i.e., prepared for action) during idea finding. Five students (student 1, 6, 7, 8, and 10) did both: they alternated idea generation with the exploration of additional data and processes of analysis and selection. One of these students (student 8) already generated one idea at the beginning of the task, during fact finding. One student (student 2) started with generating ideas and wishes (i.e., expressed opportunities; Appendix B), then defined the problem and then continued the idea-wish process. Every student ended with defining their top 3 and thus ended with developing solutions. Furthermore, every student showed designing and task related processes throughout the task.

Despite these differences in sequences between students, the main finding of this think aloud study was that every student showed creative problem solving processes belonging to each of the four main elements of the CPS model (understanding the challenge, generating ideas, preparing for action, planning your approach; Isaksen et al., 2011).

4. Study 2: The creative problem solving product

To study the creative problem solving *product* in primary school students, three tasks were administrated in a second larger-scale quantitative study. Here, the aim was to determine how the creative problem solving indicators (i.e., fluency, originality, completeness, & practicality) relate to each other. Associations with academic achievement and divergent thinking outcomes were investigated to explore to what extend creative problem solving outcomes from this young age overlap with other creativity and achievement tests administrated at school.

4.1. Material & methods

4.1.1. Participants

Because of the complexity of the model and the hierarchical structure of the data (students nested in classes), an a-priori sample size of 575 students (30 predictors*15 observations; Stevens, 2012) and 25 classes was determined. Therefore, twenty-five classes of 4th and 5th grade students (n = 629; mean age = 10.67) of 14 Dutch primary schools participated in our study. Teachers were asked to participate directly or via their schoolboard and were selected based on their willingness to participate. We deliberately asked teachers of a variety of schools to participate, resulting in a sample of 5 urban schools, 4 sub-urban schools, and 4 more rural schools.

4.1.2. Procedure

This second study was part of the larger 'Creative Problem Solvers' data collection effort. This paper describes the first analyses performed on these data. The institutional ethical review board approved the methods and procedures in March 2018 (Number: FETC16-05). Teachers were informed about the studies' goals and were asked to read and sign a consent form including three statements. Because the study was non-intrusive, passive informed consent was applied for parents. All parents were however informed with a written message including our contact details. This message included notice that teachers and students would be asked for consent and that parents and students could withdraw from the study at any point. Every school also received information about the project for a newsletter. The students were asked whether they were willing to participate before the start of the data collection. Two parents requested their child not be included in the study and 13 students opted out. The data collection took place in April, May and June 2018, over two sessions. All data were collected at school in the regular classrooms, during school days. Data were collected by the first author and a trained research assistant using an administration protocol. In session one, students completed two structured creative problem tasks (with problem situations from the science and social domain, provided to the students in a random order). In session two, students completed the third creative problem solving task (from the entrepreneurial domain) and a divergent thinking task.

4.1.3. Measures

4.1.3.1. Creative problem solving. For the originality, completeness, and practicality indicators, two raters rated the top-three ideas as selected by the students on each of the three structured tasks. The originality, completeness, and practicality of the ideas were evaluated using a modified version of the Consensual Assessment Technique (CAT; Amabile, 1996) on a 5-point scale (0–4). The post-graduate raters received 16 h of training to understand the tasks, the indicators and the rating schemes involved. Pilot data of 70 students not included in this study were rated and discussed to establish sufficient inter-rater agreement.

4.1.3.1.1. Originality. If the idea was very predictable and commonly known, it received 0 points (e.g., use a cool bag). If the idea clearly reflected an imaginative approach and was completely new, it received 4 points (e.g., make an umbrella that protects you from the sun and has little fans built-in that blow cold air).

4.1.3.1.2. Completeness. If the problem at hand was ignored or just repeated in the idea, it received 0 points (e.g., don't eat ice-cream, make sure it does not melt). If all the steps of the idea were explicitly described, it received 4 points (e.g., put a fridge on your bike that is powered by a dynamo and put the ice in when you leave the supermarket and cycle home).

4.1.3.1.3. Practicality. If the idea was impossible in practice, it received 0 points (e.g., go to a wizard to refreeze the ice-cream with magic). If the idea could be implemented in practice right away, it received 4 points (e.g., purchase a new ice pop and eat it immediately on a bench just outside the store).

The ratings for originality, completeness, and practicality were averaged across the two raters. Intraclass correlation coefficients (consistency; single measures; Cicchetti, 1994) were calculated for the top 1 to top 3 scores for all three indicators to check for inter-rater agreement. The ICCs for originality ranged from 0.75 to 0.87, indicating excellent agreement. The ICCs for completeness ranged from 0.68 to 0.80, indicating good to excellent agreement. The ICCs for practicality ranged from 0.79 to 0.89, again indicating excellent agreement.

4.1.3.1.4. Fluency. To assess fluency, two raters counted the total number of different ideas listed. Ideas that could not be interpreted or were listed twice, were excluded. Because the raters disagreed in less than 1% of the cases, these cases were discussed to gain a single fluency measure for every student.

4.1.3.2. Divergent thinking. One divergent thinking task from the Runco Creativity Assessment Battery (rCAB; Runco, 2011) was applied in this study. This assessment battery is comparable to other divergent thinking assessments such as the TTCT (Torrance, 1966). The task included a picture of a toothbrush and a page full of lines for writing. Students were asked to list as many different uses for a toothbrush as they could. Again, students were explicitly asked to come up with ideas of which nobody else would think. The task lasted 8 min and students were not notified about the time they had for the task.

4.1.3.2.1. Fluency. To obtain scores for divergent thinking fluency, the total number of different ideas listed was used. If ideas were listed twice, the second idea was excluded.

4.1.3.2.2. Originality. To obtain scores for divergent thinking originality, a lexicon was created. In this lexicon, the common ideas were clustered to determine which ideas deserve points for being more unique. Ideas were clustered when they (1) had the same meaning, (2) they meant the same but were written as an action and an object respectively, (3) objects could be replaced with an object from the same category that could be regarded as unique for the student's situation, or (4) when they had the same meaning but differed in the amount of detail. A second researcher independently checked whether ideas were correctly clustered. After this check, 18 out of 570 categories (3.15%) were included in a different cluster. Clusters mentioned by fewer than 1% of the students received 1 originality point. To obtain a fluency-independent measure, the originality score was divided by the number of ideas (Reiter-Palmon et al., 2019).

4.1.3.2.3. Elaboration. To obtain scores for divergent thinking elaboration (i.e., how detailed the ideas were), we counted the total number of words a student used for all the ideas and divided it by the total number of ideas (fluency score).

4.1.3.3. Academic achievement. Scores from two standard Dutch achievement test batteries (Cito and Boom; Janssen et al., 2010; Tomesen et al., 2019; Van Vugt, De Vos, Milikowski, & Milikowski, 2019) were used as a measure for academic achievement. Tests for mathematical ability and reading comprehension were selected because they give a broad image of a student's academic achievement and were administrated at every school in our sample.

We calculated learning efficiency percentage scores for the tests for mathematical ability and reading comprehension by dividing the student's test score by the national mean test scores for every grade (as provided by the test developer) and multiplying this by 100. This means that a student that scored exactly average for his/her age received a learning efficiency percentage of 100%.

4.1.4. Analysis

4.1.4.1. Measurement model. To study how the creative problem solving indicators (i.e., fluency, originality, completeness, & practicality) relate to each other, we conducted a Confirmatory Factor Analysis (CFA) to test our measurement model with Mplus 8.5 (Muthén & Muthén, 2012). The separate top-three scores for originality, completeness and practicality were first loaded on the three indicators (i.e., first order latent factors) of creative problem solving within the tasks. The separate top 1, 2, and 3 scores for originality, completeness, and practicality came from one and the same idea. As a consequence, these scores were expected to show shared method variance (Cole et al., 2007). As such, residual errors belonging to the scores of the same selected ideas were allowed to covary. Next, the first-order latent variables for originality, completeness, and practicality were loaded on the second-order factors of originality, completeness, and practicality across tasks (Fig. 2). The students' fluency scores on the three tasks were also loaded on a latent fluency factor across tasks. Correlations of the four main latent factors (fluency, originality, completeness, and practicality) were included in the specification of the model to determine whether the creative problem solving indicators related to each other as expected.

As is often the case in creativity studies, highly original ideas were relatively scarce and practical ideas were relatively common within the current study. As a result, the distribution of these variables was non-normal. To take this non-normality and the clustering of students in classes into account, type = COMPLEX was applied in Mplus as the method of analysis. The Robust Maximum Likelihood (MLR) estimator used with this method is robust to non-normality and non-independence (Byrne, 2013).

The measurement model was assessed based on the following goodness-of-fit indices: the comparative fit index (CFI), the Tucker-Lewis Index (TLI), the root mean square error of approximation (RMSEa), the standardized root mean square residual (SRMR), and the chi square/df ratio (Hu & Bentler, 1999; Marsh et al., 2004).

4.1.4.2. Structural model. To determine how the creative problem solving indicators related to divergent thinking and academic achievement scores from primary school students, we tested a structural model that was based on the measurement model. The scores for mathematics and reading comprehension were first loaded on the latent academic achievement factor (Fig. 3). Next, the creative problem solving fluency factor was correlated with the divergent thinking fluency score. The creative problem solving originality factor was correlated with the divergent thinking fluency score, the divergent thinking originality score, and the latent academic achievement factor. The creative problem solving completeness factor was correlated with the divergent thinking elaboration score and the latent academic achievement factor as well. Creative problem solving practicality was only correlated with academic achievement. Because the divergent thinking measures were taken from the same divergent thinking task, these variables were allowed to covary. Again, we assessed model fit with the CFI, TLI, RMSEA, SRMR and chi square/df ratio indices. Standardized regression coefficients and explained variance (R^2) in the creative problem solving variables were reviewed as well.

4.2. Results

4.2.1. Missing data

Though 627 students and their parents were invited to participate in the study, partly to fully available data of 594 students could ultimately be used in the analysis. Thirty students did not consent, stopped the administration during the first assignment or were a absent or ill during both days of the administration. Additionally, data of 6 students were excluded due to behavioral problems that interfered with the assignment or due to unscorable tasks. A small group of students (1.59–2.75% per task) did not define a top-3, or their top-3 could not be interpreted. Pilot study results indicated that students were quite able to define a top 3 themselves (Van Hooijdonk et al., 2020). Therefore, we defined a top-3 for these tasks ourselves. The top 3 scores of these tasks were rated by the same two raters as in Study 1. Some students were only able to think of 1 or 2 ideas. This resulted in a slightly different sample size for every

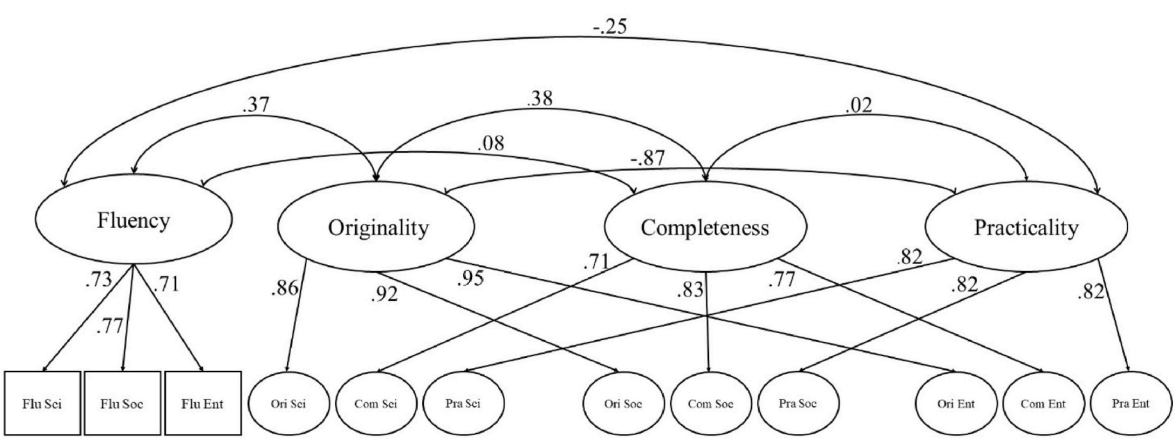

Fig. 2. Results Creative Problem Solving Measurement Model. *Note.* Flu = Fluency; Ori = originality; Com = completeness; Pra = Practicality; Sci = Science problem situation; Soc = Social problem situation; Ent = Entrepreneurial problem situation.

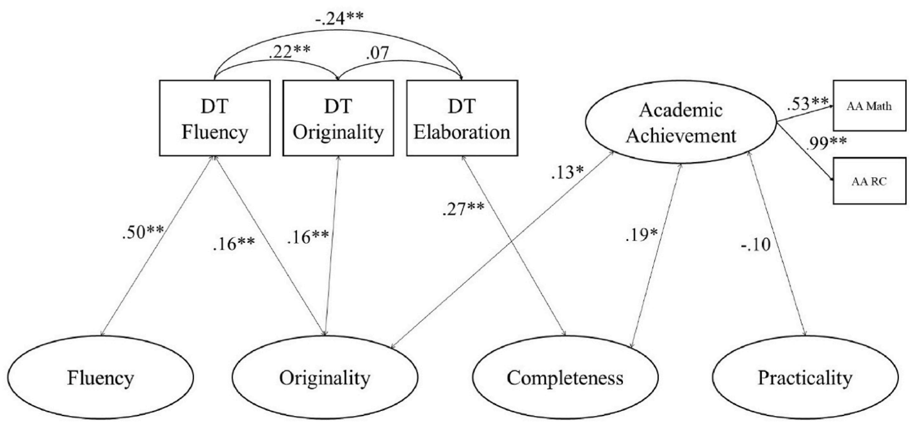

Fig. 3. Results Structural Model for the Relations between the Creative Problem Solving Indicators, the Divergent Thinking (DT) outcomes and the latent Academic Achievement (AA) factor. *Note.* *$p < .05$, **$p < .001$; Math = Mathematics; RC = Reading Comprehension.

measure (Table 2; Table 3). Academic achievement data was missing for math for 15 students (2.51%) and for reading comprehension for 21 students (3.53%). No outliers were detected. The MLR estimator used for the analyses enabled us to estimate the model using all the available data.

4.2.2. The measurement model

The CFA of the measurement model with nine first-order and 4 s-order latent variables showed an adequate to good fit between the model and the observed data (CFI = 0.95; TLI = 0.94; RSMEA = 0.03, 90% CI [0.03–0.04]; SRMR = 0.05; chi square/df ratio = 568.24/363 = 1.57). No post-hoc modifications were conducted. Standardized and unstandardized parameter estimates for within-task first-order latent originality, completeness, and practicality variables and residual correlations are provided in Appendix C. The residual errors and correlations were checked. No negative residual errors were detected. The patterns of the residual correlations corresponded within the tasks, illustrating the presence of shared method variance (see appendix C). Standardized factor loadings and correlations of the latent fluency factor and the second order (across-task) latent variables are provided in Fig. 2.

All within-task creative problem solving factors loaded significantly on the across task second order latent factors ($p < .001$ for all factor loadings). The Fluency measures of the three tasks loaded statistically significant on the latent Fluency factor as well ($p < .001$). Overall, correlations between the factors were mostly in line with what we expected based on the literature. Positive moderate correlations were found between Fluency and Originality and Originality and Completeness ($r = 0.37$, $p < .001$ and $r = 0.38$, $p < .001$ respectively). A large negative correlation was found between Originality and Practicality ($r = -0.87$, $p < .001$). A small negative correlation was found between fluency and practicality ($r = -0.25$. $p = .001$). No significant correlations between fluency and completeness ($r = 0.08$, $p = .25$) and completeness and practicality ($r = 0.02$, $p = .86$) were found.

Table 3
Creative problem solving fluency scores for the science, social, and entrepreneurial tasks, divergent thinking scores, & academic achievement scores.

	N	M	SD	Min	Max
Creative Problem Solving Fluency					
Science	572	5.73	2.97	1	17
Social	568	5.75	3.31	1	16
Entrepreneurial	550	6.76	3.51	1	17
Divergent Thinking					
Fluency	558	11.27	6.85	0	36
Originality	547	0.10	0.12	0.00	1.00
Elaboration	547	2.75	1.31	1.00	12.00
Academic Achievement					
Mathematics	585	98.51	11.70	51.09	135.63
Reading Comprehension	579	97.59	25.49	12.50	209.38

4.2.3. Structural model

The analysis of the structural model also showed an adequate to good fit between the model and the observed data (CFI = 0.93; TLI = 0.92; RSMEA = 0.03, 90% CI [0.03–0.04]; SRMR = 0.06; chi square/df ratio = 817.82/510 = 1.60). Again, no post-hoc modifications were conducted. Standardized regression coefficients and factor loadings for the academic achievement factor ($p < .001$ for both academic achievement factor loadings) are provided in Fig. 3.

Divergent thinking Fluency was related to the latent creative problem solving Fluency factor ($r = 0.50$, $p = <.001$). This correlation can be classified as large (Cohen, 1988). Further, creative problem solving

Table 2
Mean top scores for creative problem solving originality, completeness, and practicality across raters for the science, social, and entrepreneurial tasks.

		Originality				Completeness				Practicality			
	N	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max
Science													
Top 1	566	2.07	1.05	1.00	5.00	3.24	0.81	1.00	5.00	4.48	0.86	1.00	5.00
Top 2	553	1.97	0.99	1.00	5.00	3.14	0.69	1.00	5.00	4.60	0.78	1.00	5.00
Top 3	499	1.94	0.91	1.00	5.00	3.05	0.73	1.00	5.00	4.60	0.78	1.00	5.00
Social													
Top 1	565	2.02	0.95	1.00	5.00	3.29	0.68	1.00	5.00	4.27	0.85	1.00	5.00
Top 2	540	1.93	0.89	1.00	5.00	3.23	0.62	1.00	5.00	4.30	0.82	1.00	5.00
Top 3	496	1.93	0.84	1.00	5.00	3.15	0.61	1.00	4.50	4.33	0.76	1.00	5.00
Entrepreneurial													
Top 1	546	2.02	0.95	1.00	5.00	3.21	0.74	1.00	5.00	3.78	0.93	1.00	5.00
Top 2	538	1.93	0.89	1.00	5.00	3.11	0.68	1.00	5.00	3.82	0.86	1.00	5.00
Top 3	515	1.93	0.84	1.00	5.00	3.04	0.69	1.00	4.50	3.89	0.83	1.00	5.00

Originality was related to divergent thinking Fluency, divergent thinking Originality and Academic Achievement ($r = 0.16$, $p < .001$; $r = 0.16$, $p < .001$; $r = 0.13$, $p = .032$ respectively). These correlations can be classified as small (Cohen, 1988). Finally, creative problem solving completeness was related to divergent thinking elaboration and academic achievement ($r = 0.27$, $p < .001$; $r = 0.19$, $p = .002$). These correlations can be classefied as small as well (Cohen, 1988). No statistically significant relation was found between creative problem solving practicality and academic achievement ($r = -0.10$, $p = .26$).

5. Discussion

Schools need to foster creative problem solving skills in students from primary education onwards to meet the growing demand for creative problem solvers in modern society. In order to do so, more insight is needed in the nature of creative problem solving in this young age group. Two studies on the creative problem solving process (Study 1) and the creative problem solving product (Study 2) were therefore conducted.

The main finding of Study 1 was that each student engaged in all the creative problem solving processes belonging to the four main elements of the CPS model (understanding the challenge, generating ideas, preparing for action, planning your approach; Isaksen et al., 2011). However, the number of utterances within elements and the sequence of the creative problem solving processes seemed to vary across students. Still, this indicates that despite potential developmental differences between children and adults - such as not fully developed executive functios (Diamond & Lee, 2011) - the CPS model and its main elements (Isaksen et al., 2011; Isaksen & Treffinger, 2004; Treffinger, 1995) can be used to describe creative problem solving processes in primary school students.

For Study 2, we conducted a larger scale quantitative study to investigate fluency, originality, completeness, and practicality as indicators of a creative problem solving product, specifically the ideas generated by students. The main findings were that these four creative problem solving indicators were distinguishable in the ideas of primary school students, Furthermore, the relations between these indicators and those with divergent thinking and academic achievement outcomes largely matched with relations found in earlier studies.

In specific, the moderate positive correlation ($r = 0.37$) between fluency and originality and the strong, negative relation ($r = -0.87$) between originality and practicality were in line with creativity theory (Guilford, 1957; Torrance, 1966, 1972a), with the relations other authors found with divergent taks in both younger and older samples (Bai et al., 2021; Dumas & Dunbar, 2014; Hocevar, 1979; Runco & Albert, 1985; Silvia, 2008), and also with creative problem solving tasks in adults (Reiter-Palmon et al., 2019). This suggests similar structural relations of the creative problem solving indicators for primary school students. Within this study, we applied top scoring. As a consequence, the originality scores were based on a fixed number of ideas (Silvia et al., 2008). Still, we found a significant, positive relationship between fluency and originality. This implies that fluency and originality as assessed with a creative problem solving task in primary school students, can be regarded as distinct but related constructs, just like divergent thinking fluency and originality.

Overall, we conclude that both the CPS model (Isaksen et al., 2011; Isaksen & Treffinger, 2004; Treffinger, 1995) and the creative problem solving indicators, can be used to describe creative problem solving in primary school students.

In line with Rhodes' (1961) 4P model (i.e., the person, process, product and press or environment) we studied creativity at the level of the process and the product. This model is still influential in today's creativity research and, as such, helps creativity researchers in structuring their work. Nevertheless, the four P's cannot be compartmentalized: they constantly inform each other and should therefore be regarded as interactive (Glă;veanu, 2013; Kupers et al., 2019). In fact, in some domains of creativity, the creative process and product may be the same thing, such as in improvisation performance (Sawyer, 2000). That this distinction between person, process, product, and press (or environment) is not so clear cut, is also apparent in our study. For instance, we used fluency to describe both the creative process (i.e., describing the number of utterances belonging to the idea generation element) and the product (i.e., as one of the creative problem solving indicators). Dumas et al. (2022) describe fluency as primarily describing processes, i.e., how fluently ideas come to mind. A fluent process may even be regarded as a condition for creativity; the likelihood of generating original ideas may increase with a fluent idea generation process (e.g., Bai et al., 2021; Hass, 2017; Reiter-Palmon et al., 2009). Although fluency is often taken as an outcome measure of creative potential (e.g., Reiter-Palmon et al., 2019) and showed to be a useful criterion to base educational interventions on (e.g., Fink, Reim, Benedek, & Grabner, 2020), researchers applying the fluency indator should be aware of this process-product ambiguity.

One way in which the eventual product and the process may be impacted by the environment in our study is through task instructions. In the instructions of our creative problem solving task, students were instructed to explore many knowledge elements, but were asked to formulate only one problem statement. As a consequence, the amount of information students explored that belonged to the 'exploring data' category of the understanding the challenge element, varied greatly. For the 'framing problems' category, the variation was much smaller: only one student showed more than 3 expressions within this category. In other words, external task instructions may impact creative problem solving processes and, as a consequence, the creative problem solving product that is assessed (Di Mascio et al., 2018; Nusbaum et al., 2014). In future research, it is therefore important to pay attention to how demands from the environment, such as variations in task instructions, impact creative problem solving processes and the outcomes that are assessed.

Our studies also illustrated the importance of studying creativity at the level of the person (Rhodes, 1961). Although a larger-scale study is important to determine differences between the moment-to-moment activities that primary school students exhibit while completing a creative problem solving task (e.g. Barbot et al., 2016; Kupers et al., 2019; Lubart, 2001), our data indicated that the sequences of the students' creative problem solving varied. This may have impacted the eventual product that was assessed. In Study 1, students generated more ideas on average (M = 10.15) while thinking aloud, compared to Study 2 (M = 5.73), where they only recorded their ideas on paper. This differences may be explained by the selection of students with sufficient verbal skills for the think aloud study, or it could be the case that in Study 2 students did not write every single idea down during the execution of the task. When a person's sequence of creative problem-solving activities does not match the task structure (e.g., a student generates ideas at the beginning of the task), some ideas may not be recorded on paper. Consequently, these ideas are not evaluated in the final product. An in-depth study of how the sequence of creative problem-solving processes affects the final product may yield insights into the interconnection between the person, process, and product.

In many previous creative problem solving studies in older age groups, the completeness and practicality indicators were assessed as one single construct to measure overall quality or effectiveness (see e.g., Reiter-Palmon et al., 2009). Within the current study, the completeness and practicality indicators were assessed separately to obtain distinct measures for the level of detail and the practical feasibility of the ideas. Interestingly, practicality was negatively related to fluency and originality (as was expected based on earlier research; Cropley, 2006; Rietzschel et al., 2009), but completeness showed a moderate positive correlation with originality. This indicates that, at least in our sample of primary school students, the completeness and practicality indicators can be regarded as relatively distinct creative problem solving aspects. Consequently, they may be best measured separately in this young age group. An alternative explanation is that primary school students did not take practicality into account when they selected their top-3 of most creative ideas, as was suggested in an earlier study on creative problem solving with primary school students (Van Hooijdonk, et al., 2020). More work focusing on the process (i.e., micro) level on *how* students select their most creative ideas is necessary to explore this.

5.1. Limitations

Where most earlier studies focused on the macro-effects (i.e., aggregated outcome level) of being involved in creative problem solving on various outcomes (Kupers et al., 2019), we combined a micro and macro approach to study the nature of creative problem solving processes in primary school students. This makes this project unique in its kind. However, because the sample in Study 1 was relatively small, conclusions should be drawn with caution. Furthermore, the young age of the students in Study 1 might have made it difficult for them to verbalize every thought during the think aloud study. Although we put effort into maximizing the students' ability to achieve this by selecting students with good verbal skills, by practicing thinking aloud with a word problem, and by reminding them to verbalize throughout the task, findings should still be interpreted with care.

Although a strong correlation ($r = 0.50$) between fluency on the creative problem solving task and divergent thinking fluency was found, the other correlations of the creative problem solving indicators (originality and completeness) with the corresponding divergent thinking outcomes (originality and elaboration) were rather small. Measurement-specific factors may play a role here (see e.g., Barbot et al., 2019). Our conceptualization and measurement of fluency in the creative problem solving context were largely in line with how fluency is commonly assessed in the divergent thinking tasks (i.e., counting the number of ideas generated). This probably resulted in more overlap and thus explained variance. For originality and completeness, our individual-response qualitative way of conceptualizing and scoring with the consensual assessment technique, differed from this quantitative response-set ways of scoring originality and elaboration of the divergent thinking tasks. This probably resulted in less shared variance. In other words, the selection of the creative constructs, the tasks, the indicators for scoring and scoring procedures may have impacted the eventual results. In future creativity studies, it is therefore important to align the selected creativity constructs with the chosen creativity measures. To assist authors in making and warranting these choices, Reiter-Palmon et al. (2019) wrote an extensive review about what choices to consider when selecting and scoring divergent thinking tasks, that we recommend authors to consult.

In the quantitative study (Study 2), top-scoring was applied. Although this method was validated in multiple studies (Benedek et al., 2013; Silvia et al., 2008) and tested with primary school students (Van Hooijdonk et al., 2020), it could still be the case that students missed creative ideas in their selection, which, as a consequence, were not considered for scoring. In addition to that, only the first two structured tasks in Study 2 were provided to the students in a random order. While the third structured task (administered during the second assessment occasion) was from the entrepreneurial domain and may have required different domain knowledge, a learning effect may still have occurred regarding the process of solving this type of task. To limit the impact of this effect on future results, the three structured tasks should be randomized.

5.2. Practical implications

A structured task was utilized to trigger creative problem solving processes in primary school students across three problem situations. These types of tasks can be a valuable addition to the creative activities available to primary school students, as they are directly related to everyday life (Piffer, 2012; Zeng et al., 2011) and explicitly embed both divergent and convergent thinking processes (Brophy, 1998; de Vink et al., 2022; Runco & Chand, 1995; Van Hooijdonk et al., 2020; Webb et al., 2017). Our findings suggest that creative problem solving and academic achievement are related but distinct from each other, requiring different cognitive processes. While more comprehensive research is needed to determine the specific differences and overlap between creative problem solving and academic achievement, our results suggest that incorporating creative problem solving tasks into the curriculum does not lead to unnecessary overlap with other academic activities. In fact, it may provide a low-stakes alternative to high-stakes testing since these tasks require the exploration of multiple solutions rather than a single correct answer (Baer & Garrett, 2017; Runco et al., 2017). By regularly engaging in whole-group tasks like these with primary school students and reviewing their outcomes, teachers may be better able to determine and ultimately foster students' individual creative problem solving abilities. As a result, teachers can better integrate creative problem solving and suitable individual interventions into their daily teaching practices (Beghetto, 2013; Kaufman et al., 2016). Regularly providing primary school students with creative problem solving activities can help them develop the ability to apply their knowledge in flexible and creative ways from an early age.

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Data availability

The data that supports the findings can be found at https://doi.org/10.34894/LALWP0.

CRediT authorship contribution statement

Mare Van Hooijdonk: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Tim Mainhard:** Conceptualization, Methodology, Validation, Writing – original draft, Writing – review & editing, Supervision. **Evelyn H. Kroesbergen:** Conceptualization, Validation, Writing – original draft, Writing – review & editing, Supervision. **Jan Van Tartwijk:** Validation, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.learninstruc.2023.101823.

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