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Creative Problem Solving in Primary Education: Exploring the Role of Fact Finding, Problem Finding, and Solution Finding across Tasks

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ABSTRACT

Interest in fostering creative problem solving (CPS) from primary education onwards is growing. However, embedding CPS in Education seems to be a challenge. One problem is that generating creative ideas (idea finding) is often taught in isolation, rather than also including processes such as exploring knowledge (fact finding), defining the problem (problem finding) and comparing ideas to identify the most creative ones (solution finding). In the current study, we prepared CPS tasks for primary education that represent this more complete CPS model and studied whether successful fact finding and problem finding were positively associated with the creativity of the ideas found. Additionally, we studied whether solution finding is doable for these young students and how they select the most creative ideas. Bayesian analyses indicated a positive association of fact finding and problem finding with the number of ideas generated and the originality of these ideas. In addition, problem finding seemed to be positively associated with the completeness of ideas, whereas fact finding seemed not. We also found that primary school students were able to identify their most creative ideas. Students did not seem to undervalue certain aspects of creativity when applying solution finding. Our results indicate that when aiming for more and original solutions, teachers could embed fact finding and problem finding in their CPS teaching practices. Our results also indicate primary school students are able to recognize creativity.

1. Introduction

Modern society requires people to be able to solve problems in a creative way (Craft, 2011). As such, educational systems need to produce creative problem solvers that try to understand everyday challenges, generate multiple creative ideas and select the most creative ideas to put into practice (Isaksen, Dorval, & Treffinger, 2011). An idea is seen as creative when it is original, well-thought out (i.e., complete) and transferrable to practice (Corazza, 2016; Okuda et al., 1991; Reiter-Palmon et al., 2009). Multiple scholars created frameworks to describe the CPS process and to support finding these creative ideas (e.g., Altshuller, 1996; Finke et al., 1992; Mumford, Mobley, Reiter-Palmon, Uhlman, and Doares, 1991; Simon, 1969; as cited in Rowe, 1987). Among others, Treffinger and colleagues (Isaksen et al., 2011; Isaksen and Treffinger, 2004; Treffinger, 1995) continued to develop this framework. Their CPS model includes three main components: (1) understanding the challenge (2) generating ideas, and (3) preparing for action. The goals of the understanding the challenge stage are orientation, preparation, and the construction of opportunities to kick-start idea

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generation and to retain focus at the same time (Isaksen et al., 2011). Within this first stage, students apply *fact finding* by exploring and defining their knowledge on the problem. In addition, they apply *problem finding* by identifying the problem at stake. In the second idea generation stage, students are asked to diverge and come up with creative ideas to solve the problem (Isaksen et al., 2011). This stage is also called *idea finding*. In the last preparing for action stage, students need to evaluate their ideas and identify their most creative ones (Isaksen and Treffinger, 2004). This is also called *solution finding* and is seen as a last step before the ideas can be transferred to practice (Isaksen et al., 2011).

Interest in CPS from primary education onwards is growing, because it can be easily connected to the problems a student may face in daily life as well as to factual knowledge learned in school (Runco and Acar, 2012). Besides this, engaging in CPS showed to be beneficial for primary school students' divergent thinking, attitudes towards creativity, active learning and exploration (Kashani-Vahid et al., 2017; Saxon et al., 2003). However, embedding CPS in education seems to be a challenge. Only in a few studies, the translation of the full CPS process to educational practice and to primary education in particular was investigated (e.g., Arreola and Reiter-Palmon, 2016; Okuda, et al., 1991). Besides this, when teaching CPS teachers often focus on divergent thinking and idea finding (Cropley, 2006; Piffer, 2012). This means students are often immediately asked to think of multiple creative ideas to solve a problem at the expense of processes demanding both convergent and divergent thinking such as fact finding, problem finding, and solution finding processes (Isaksen et al., 2011). We do however not know whether fact finding and problem finding may help primary school students to think of more creative ideas in the idea finding stage. Additionally, we do not know whether solution finding is doable for these young students and how they select the most creative ideas. Besides this, CPS outcomes showed to differ across CPS tasks suggesting that CPS processes and how they are interrelated might differ across CPS tasks as well (Reiter-Palmon, et al., 2009). In the current study, we therefore prepared two CPS tasks for primary school students that next to idea finding explicitly embedded and scaffolded fact finding, problem finding, and solution finding processes. We explored whether successful fact finding and problem finding are, as the CPS model would predict, positively associated with idea finding and whether primary school students are able to apply solution finding by identifying their most creative ideas.

1.1. Fact finding

In the fact finding stage, students are asked to explore their knowledge on the problem and to describe or list all the knowledge elements they can think of (Isaksen et al., 2011). Fact finding is of particular importance because factual knowledge can be regarded as a precondition for inferencing and high-level reasoning (Yekovich et al., 1991). Besides this, it is seen as the source of creative ideas (Cropley, 2006). Fact finding may especially affect the ability to come up with many ideas (fluency), because listing the knowledge connected to a problem may highlight more solution opportunities (McCaffrey, 2016). Barak (2013) found that a systematic search of the knowledge involved was beneficial for high schoolers' creative outcomes. For undergraduates, length of time spent on factual information was also positively associated with generating ideas of higher quality and originality (Mumford et al., 1996a). Length of time spent on factual information also mediated the relationship between problem construction engagement and creativity, next to the quantity and the breadth of information viewed (Harms et al., 2018). Although there is no evidence available that fact finding also helps primary school students in generating ideas, in line with findings from Barak (2013) and Mumford et al. (1996a) we hypothesize that successful fact finding is positively associated with idea finding. We especially expect fact finding to be positively associated with the number of ideas a student comes up with (i.e., fluency scores).

1.2. Problem finding

Students are asked to think about the problem at hand and describe it in the problem finding stage (Isaksen et al., 2011). This could help in providing focus when applying idea finding. Mumford et al. (1996b) found that problem finding ability explained differences in CPS performance of high schoolers, even after controlling for general intelligence and divergent thinking ability. In primary education, problem finding was beneficial for students when solving novel problems in mathematics (English, 1997) and was predictive of creative accomplishments (Ma, 2009; Okuda, et al., 1991). However, problem finding was also a challenge for primary school students (Van Harpen and Sriraman, 2013). Nonetheless, the positive effects of problem finding for this group are not completely clear. Arreola and Reiter-Palmon (2016) found a positive association of problem finding and idea finding outcomes of undergraduates, but this association was different across different problem tasks. For one task, problem finding quality predicted idea finding quality, whereas for another task the quality of the problems found predicted both idea finding quality and originality. Although several researchers asked participants to come up with multiple possible problems (e.g., Arreola and Reiter-Palmon, 2016; Mumford et al., 1996b), we asked primary school students to identify one single problem to keep our CPS task as simple as possible. We hypothesize problem finding is positively associated with idea finding, but especially for measures of completeness because we think the provided focus helps students to develop well-rounded solutions. We will explore whether this hypothesis is true across two CPS tasks to screen for potential task differences.

1.3. Solution finding

During solution finding, students are asked to evaluate their own creative ideas and select the most creative ones. In the past years, the number of studies investigating the identification of creative ideas as a feature of creative metacognition (CMC) in education has grown (e.g., Benedek et al., 2016; Grohman, Wodniecka, and Klusak, 2006; Kaufman et al., 2016; Pretz and McCollum, 2014; Silvia, 2008; Sternberg, 2012; van de Kamp, Admiraal, van Drie, and Rijlaarsdam, 2015). In primary education, Runco (1991) found that students' evaluative abilities of divergent thinking tasks can be measured and that evaluative skill is related to divergent thinking ability. However, the popularity of ideas was more accurately judged than the creativity of ideas. Grohman, Wodniecka, and Klusak (2006) conducted an exploratory study on whether primary school students' self-ratings of creativity aligned with external ratings of creativity on a visual, verbal, and scientific task. Results showed students were able to differentiate their performance across creativity domains and across quality levels. Besides this, their scores were positively associated with creativity scores given by experts. Within this study of Grohman and colleagues (2006) creativity of the ideas was reviewed as a whole. The aspects of creativity can however be separated to explore whether specific creativity aspects are valued more in the solution finding process than others. This will give us more insight in whether all aspects are valued by students when solution finding is applied in education and will gives us more detailed advice on how to train solution finding. Rietzschel, Nijstad, and Stroebe (2010) found in their study with undergraduates that when doing CPS, even with explicit training, it seemed to be difficult to both appreciate originality and effectiveness of their ideas. Blair and Mumford (2007) found in their study with undergraduates that evaluation criteria and time pressure influenced what creativity aspects were valued most by students. The question is whether primary school students are able to select ideas scoring high on all three aspects of creativity across CPS tasks, or ignore certain aspects such as originality. We hypothesize students are able to apply solution finding by selecting the most creative ideas. Because less is known about what aspects of creativity are valued most by primary school students, we will not formulate specific follow-up hypotheses here but explore whether the separate aspects are valued or undervalued.

1.4. The Present Study

To enhance CPS in everyday educational practice, we need to gain more insight in whether the different CPS stages help these young students to generate and recognize creative ideas. In the current study, we therefore prepared CPS tasks for primary education that represent the CPS model (Isaksen et al., 2011) and embed fact finding, problem finding, and solution finding alongside idea finding. Within this explorative study, we will answer two sets of questions:

Question 1. Are successful fact finding and problem finding positively associated with idea finding of primary school students across CPS tasks?

Question 2. Can primary school students select ideas scoring high on multiple aspects of creativity across CPS tasks, or they do they ignore certain aspects such as originality?

Answering these questions will not only give us insight in how we can foster CPS from primary education onwards, it will also help us to develop interventions to enhance primary school students' ability to generate and recognize creative ideas across problem situations.

2. Method

2.1. Sample

Six classes of 4th and 5th grade students (N = 148; mean age = 10.38, SD = 0.72; 72 girls, 76 boys) of three Dutch primary schools (one urban, one sub-urban, one village school) participated voluntarily in the study. Parents were informed about the study and all messages to parents included an anonymity statement. Parents and students were told students could withdraw from the study at any point. Five students did not participate due to illness on the day when the students completed the tasks. Before the start of the CPS tasks, three students asked whether they could withdraw, and were as such excluded from the study. All remaining students (N = 140) were randomly divided in groups of eight to eleven students and were individually seated outside the class in a quiet study area. Tasks of three students turned out to be unscorable in the rating phase. As such, data from these students was excluded as well (N = 137).

2.2. Procedure

Every student completed two CPS tasks individually. Because the science and interpersonal domains were found as different creativity domains in several studies (Kaufman, 2012; Kaufman et al., 2009; Oral et al., 2007), we selected one problem situation for each of these domains from Treffinger's practice problems for many ages (Treffinger, 2000). With vignette theory (Poulou, 2001), we modified the problem situations to fit our research purposes and the age group. Vignettes are short descriptions of hypothetical situations (or persons) that include the required information for the participants to reason with (Poulou, 2001). As with vignettes, the problem situations described hypothetical scenarios which, although they were very realistic, did not involve the respondent personally. They were constructed to attract the interest of the students and stimulate their imagination and written in third person to avoid personal biases such as personal experiences with the problem. The problem situations were open and non-directive since they enable the participant to form his/her own interpretation of the described situation, important for creativity. Furthermore, they were clearly written to make sure they were easily understood by the respondents. The problem situations were discussed with two teachers to check whether they were fit for purpose. Two sentences were shortened and one sentence was rewritten to improve readability. The final problem situations included a short story about the problem, and were presented written on paper as well as read to the students by the researcher. The science problem described Lisa and Tom buying ice cream on a hot day (Fig. 1). The social problem referred to a classroom situation, in which Simon gets distracted by his friend Julian all the time (Fig. 2).

The weather is very hot. Lisa and Tom feel like eating ice cream. They cycle to the supermarket and buy a colored cardboard box with ice pops. However, when they get home and open the wrapper, the ice pops appear to be completely soft. The ice drips slowly down the stick. The ice pops started to melt in the box!

Fig. 1. Problem situation 1, stemming from the science domain.

Simon sits next to his friend Julian in class. Julian likes to talk to Simon and often bothers him when he is busy with his work. Sometimes Julian distracts Simon, making him miss an important part of the lesson. Today, Simon does not get his work done once again because Julian interferes with him. However, Julian is also a very good friend of Simon, and he really likes hanging out with him.

Fig. 2. Problem situation 2, stemming from the social domain.

Students received a short explanation of the CPS steps involved during the first CPS task (science). First, students applied fact finding by listing the knowledge elements they could think of (e.g., the box, the ice, the distance, the temperature; cf. Barak, 2013). Students were told they could list as many elements as they liked. Then, students applied problem finding by writing down the problem statement in the form of a question. Subsequently, students received ten minutes to list as many different and original ideas to solve the problem as they could. Because instructions influence creative outcomes (Nusbaum et al., 2014; Runco et al., 2005), the students were explicitly asked to come up with ideas nobody else would think of. Besides this, students were not notified about the time. Although the authors state that the CPS process can have different starting points and routes (Isaksen et al., 2011; Treffinger, Selby, & Isaksen, 2008), we choose to apply these components as stages in a particular order to be able to scaffold the CPS process of the young creative problem solvers. However, to stimulate the use of knowledge and the problem when applying idea finding, students were stimulated to look back at their first stages to see what they could use in the construction of more ideas.

In the final step of the procedure, students chose their three most creative ideas. Silvia and colleagues (2008) proposed a method that facilitates solution finding: top-scoring. Within this procedure, participants are asked to choose a specific number of most creative ideas, which are then considered for scoring or evaluation (e.g., Benedek et al., 2013). To come to this top three within our study, students were asked to take originality, completeness and practicality into account: 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 transferred to practice."* The students were asked to put one number one, one number two, and one number three at their selected ideas to highlight their top 3.

2.3. Measures

Two raters (trained teachers and involved in educational research; one graduate, one post-graduate) were used to rate the CPS tasks. They received at least 8 hours of training to understand the CPS tasks, the CPS concepts and the ratings schemes involved. Pilot data of 20 students was rated and discussed to establish sufficient inter-rater agreement. Because every student received ratings from these two raters and scores were averaged, the two-way mixed average score Intra Class Correlation (ICC) was calculated to check the inter-rater agreement.

2.3.1. Fact finding

Fact finding was scored as the number of different knowledge elements listed. Elements that were mentioned twice and elements that could not be considered as knowledge elements (e.g., "this is a problem"), were excluded from scoring.

2.3.2. Problem finding

The quality of the identified problem was evaluated using a modified version of the consensual assessment technique (CAT; Amabile, 1996). Problem finding was defined as the quality of the identified problem and scored by the two raters (ICC = .84 indicating excellent agreement; Cicchetti, 1994) on a five-point scale. For instance, when the problem identified was not or marginally related to the situation involved, it received 0 points. (e.g., warmth). When the problem identified was stated in the form of a question, was complete, accessible for solution and shaped the focus of the CPS process, it received 4 points (e.g., How can we keep ice from melting on a hot day, when we are buying it in the supermarket?).

2.3.3. Idea finding

Four idea finding measures were used: fluency, originality, completeness, and practicality.

To assess fluency, the method commonly used to score divergent thinking tasks was applied (Runco and Acar, 2012). The fluency score consisted of the total number of different ideas listed. Ideas that could not be interpreted or were listed twice were excluded.

Originality was rated with a rating scheme by the two raters (ICC = .83, indicating excellent agreement; Cicchetti, 1994) on a five-point Likert scale. 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).

Completeness was rated by the two raters (ICC = .67, indicating good agreement; Cicchetti, 1994) on a five-point Likert scale. If the problem at stake 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 multiple steps towards a solution were included in the idea, it received 4 points (e.g, put a fridge on your bike that is powered by a dynamo, put the ice in when you leave the supermarket and cycle home).

Practicality was rated by the two raters (ICC = .90, indicating excellent agreement; Cicchetti, 1994) on a 5-point Likert scale. 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 transferred to practice right away, it received 4 points (e.g., buy new ice-cream and eat the ice-cream just outside the store on a bench.) The scores for originality, completeness, and practicality of the entire set of generated ideas were averaged across raters to get scores for idea finding next to the fluency scores.

2.3.4. Solution finding

By averaging the scores for originality, completeness and practicality across the top-scores, we gained measures for solution finding. Because the number of ideas was too low (< 4) for some students, we compared the top-1 and the top-3 score with the mean score across all ideas within these samples. Findings of the top-1 and top-3 analysis were compared (Table 3).

2.3.5. Analysis

Within this study, Bayesian statistics were used instead of conventional Null-hypotheses tests (Van de Schoot et al., 2014). Bayesian statistics were used because we held specific, informed hypotheses (e.g., that problem finding has an even larger influence on completeness than fact finding) rather than uninformed, null hypotheses. Furthermore, Bayesian statistics are less sensitive for problems with normality (e.g., relatively scarce original ideas) and eliminate the risk of alpha inflation when conducting multiple tests. Bayesian statistics give researchers the chance to include prior knowledge when conducting their analyses (Klugkist et al., 2011). Within a Bayesian analysis, informed hypotheses are compared with each other and with an unconstrained hypothesis to correct for poorly chosen hypotheses (Kluytmans et al., 2012). The analyses produce Bayes Factors (BFs), indicating the support for the hypothesis from the data. A BF larger than 1 indicates marginal support for the hypothesis, BFs from around 3 can be regarded as positive evidence, and when BFs of 6 and bigger are found, evidence can be regarded as strong (Hoijtink et al., 2016; Kass and Raftery, 1995). BFs can be divided by one another, to calculate the likeliness of one hypothesized model compared to another. In addition, posterior model probabilities (PMPs) can be calculated by dividing the BF of the chosen model by the sum of BFs of all models of interest. This PMP represents the relative support for a specific hypothesis within a set of competing hypotheses (Klugkist et al., 2011).

The analyses were performed with the program BIEMS (Mulder et al., 2012). Because no previous outcomes are available, an informed prior could not be set. That is why we used the standard prior in BIEMS. This approach is based on using a subset of the data for automatic prior specification (Mulder and Wagenmakers, 2016; Nathoo and Masson, 2016).

2.3.6. Question 1: Fact finding and Problem finding

To investigate whether fact finding and problem finding are positively associated with idea finding, we applied Bayesian Linear Regression. We regressed our four measures for idea finding (fluency, originality, completeness and practicality) on fact finding and problem finding. Because we hypothesized that fact finding and problem finding were beneficial for idea finding, our hypothesized H_1 model included a positive influence of both predictors (fact finding = ff, problem finding = pf): H_1: $\beta_{ff} > 0, \beta_{pf} > 0$. For fluency, we expected fact finding to have an even larger influence than problem finding, so a second hypothesized model was added: H_{2a}: $\beta_{ff} > \beta_{pf} > 0$. For completeness, we expected problem finding to be most beneficial, so here we also added a second hypothesized model H_{2b}: $\beta_{pf} > \beta_{ff} > 0$. These hypotheses were compared with the unconstrained model (H_{unc}: β_{ff}, β_{pf}), which assumes no specific direction. The BFs will be interpreted alongside the standardized regression coefficients (betas) to draw conclusions on whether fact finding and problem finding are positively associated with idea finding. Findings were compared across the two tasks to screen for potential task differences.

2.3.7. Question 2: Solution finding

To investigate whether students were able to identify creative ideas, we conducted a Bayesian paired sample t-test for the top-1 and the top-3 score for originality, completeness and practicality of the ideas together (multivariate). Because we were interested in whether students are in general able to identify creative ideas, we hypothesized all top-scores for the separate aspects (originality, completeness, practicality) were larger than the overall scores, resulting in the hypothesized model H_1: $\mu_{top\text{-}ori} > \mu_{all\text{-}ori}, \mu_{top\text{-}com} > \mu_{all\text{-}com}, \mu_{top\text{-}pra} > \mu_{all\text{-}pra}$.

Because we were interested to see on which CPS aspects students tend to base their selection of top ideas, we compared two additional competing hypothesized models per aspect: (1) H_1: Students choose ideas with a relatively high score on originality/ completeness/practicality and as such are able to detect this aspect ($\mu_{top} > \mu_{all}$), and (2) H_2: Students undervalued a certain aspect when they choose their best ideas ($\mu_{top} < \mu_{all}$). These models were compared to the unconstrained model (H_{unc}) assuming no specific direction: students tended to choose ideas neither high nor low on creativity (i.e., appeared to pick an idea randomly; $\mu_{top,}$ μ_{all}).

3. Results

3.1. Question 1: Fact finding & Problem finding

To investigate whether fact finding and problem finding are positively associated with idea finding, we regressed our four measures for idea finding (fluency, originality, completeness and practicality) on fact finding and problem finding. Descriptive statistics of the dependent and independent variables are provided in Table 1.

For fluency, the first hypothesized model, including a positive effect of fact finding and problem finding ($\beta_{ff} > 0$, $\beta_{pf} > 0$), resulted in BFs of 3.09 (science task) and 2.91 (social task; Table 2), which means this model was about three times more likely to be true than the unconstrained model. However, the additional H_{2a} model, which included a positive effect of both as well as a larger effect of fact finding ($\beta_{ff} > \beta_{pf} > 0$), resulted in BFs of 6.12 (science task) and 5.21 (social task; Table 2). This indicated that this model was about 5 to 6 times more likely to apply than the unconstrained model and about 2 times more likely than the H_1 model. The positive posterior betas of fact finding (.37 and .24) and problem finding (.06 and .05; Table 2) illustrate the relevance of this model. Overall, these results indicated a positive association of both fact finding and problem finding with fluency, with the largest positive association of fact finding. A similar trend occurred across the two CPS tasks.

For originality, the proposed hypothesized model, which included a positive effect of fact finding and problem finding ($\beta_{ff} > 0$, $\beta_{pf} > 0$), resulted in a BF of 3.79 (science task) and 3.70 (social task; Table 2). This means that both models are almost four times more likely than the unconstrained model respectively, indicating a positive association of fact finding and problem finding with originality. Again, this is illustrated by the positive posterior betas. A similar trend occurred across the two CPS tasks.

For completeness, the H_1 model, which included a positive effect of fact finding and problem finding ($\beta_{ff} > 0$, $\beta pf > 0$), resulted in BFs of 0.84 (science task) and 0.79 (social task; Table 2), implying that this model was not supported by the data. However, the additional H_{2b} model including a positive effect of both, plus a larger effect of problem finding ($\beta_{pf} > \beta_{ff} > 0$) resulted in BFs of 2.61 (science task) and 2.55 (social task; Table 2) implying marginal support from the data. This indicated that, based on the data, this model was about two-and-a-half times more likely than the unconstrained model and about three times more likely than the H_1

Table 1
Descriptive Statistics of Fact finding, Problem finding and Idea finding Measures (N = 137).

	Science CPS task				Social CPS task			
	M	*SD*	*Min*	*Max*	*M*	*SD*	*Min*	*Max*
Fact finding	5.77	2.61	0	16	5.79	3.26	0	14
Problem finding	2.40	0.84	0	4	1.92	0.97	0	4
Idea finding								
Fluency	8.29	3.79	2	21	6.67	3.70	2	18
Originality	0.56	0.43	0	1.9	0.37	0.42	0	1.67
Completeness	2.42	0.46	1.3	3.9	2.31	0.34	1.63	3.30
Practicality	2.70	0.57	0.80	3.63	3.25	0.56	1.22	4.00

Table 2
Results Bayesian Regression Analyses (N = 137).

	Science		Social			Science		Social	
	β_{ff}	β_{pf}	β_{ff}	β_{pf}	Hypotheses	BF	PMP	BF	PMP
Fluency	.37	.06	.24	.05	H_{unc}	1.00	.10	1.00	.11
					H_1: $\beta_{ff} > 0, \beta_{pf} > 0$	3.09	.30	2.91	.32
					H_2: $\beta_{ff} > \beta_{pf} > 0$	6.12	.60	5.21	.57
Originality	.14	.10	.14	.13	H_{unc}	1.00	.23	1.00	.22
					H_1: $\beta_{ff} > 0, \beta_{pf} > 0$	3.33	.77	3.56	.78
Completeness	−.07	.18	−.07	.15	H_{unc}	1.00	.22	1.00	.23
					H_1: $\beta_{ff} > 0, \beta_{pf} > 0$	0.84	.19	0.76	.18
					H_2: $\beta_{pf} > \beta_{ff} > 0$	2.61	.59	2.55	.59
Practicality	−.14	−.09	−.07	.08	H_{unc}	1.00	.81	1.00	.62
					H_1: $\beta_{ff} > 0, \beta_{pf} > 0$	0.11	.09	0.62	.38

Note: β_{ff} = beta for fact finding, β_{pf} = beta for problem finding, BF = Bayes Factor, PMP = Posterior Model Probability. H_{unc} hypothesized no specific direction, H_1 ($\beta_{ff} > 0$, $\beta_{pf} > 0$) hypothesized a positive influence of both fact finding and problem finding, H_2 for fluency ($\beta_{ff} > \beta_{pf} > 0$) hypothesized a positive influence of both fact finding and problem finding, with the highest influence of fact finding. H_2 for completeness ($\beta_{pf} > \beta_{ff} > 0$) hypothesized a positive influence of both fact finding and problem finding, with the highest influence of problem finding.

Table 3
Posterior Sample Means and Variances of Top-1 and Top-3 Scores and Overall Scores on Originality, Completeness, and Practicality.

	Science CPS Task				Social CPS Task			
	Top-1 M(SD)		Top-3 M(SD)		Top-1 M(SD)		Top-3 M(SD)	
	Top	All	Top	All	Top	All	Top	All
Originality	0.66 (0.01)	0.57 (0.00)	0.62 (0.00)	0.57 (0.00)	0.47 (0.00)	0.37 (0.00)	0.47 (0.00)	0.40 (0.00)
Completeness	2.63 (0.00)	2.43 (0.00)	2.54 (0.00)	2.42 (0.00)	2.41 (0.00)	2.31 (0.00)	2.35 (0.00)	2.29 (0.00)
Practicality	2.81 (0.00)	2.69 (0.00)	2.77 (0.01)	2.66 (0.00)	3.27 (0.00)	3.24 (0.00)	3.21 (0.01)	3.20 (0.00)

Note: Top-1 N = 124; Top-3 N = 99.

model. This seems to indicate that problem finding tends to have a larger positive association with completeness than fact finding. This is illustrated by the posterior betas of -.07 for fact finding and 0.15/0.18 for problem finding (Table 2). Findings were again similar across the two tasks.

For practicality, the hypothesized model including a positive effect of fact finding and problem finding ($\beta_{ff} > 0, \beta pf > 0$) resulted in in a BF of 0.11 (science task) and 0.62 (social task; Table 2). This means this model did not receive support from the data, especially for the science problem. This is illustrated by the negative betas of fact finding and problem finding for the science task, and the negative beta of fact finding for the social task.

3.2. Question 2: Solution finding

Data of thirteen students were excluded due to a missing or unreadable top rating. These students varied in terms of gender, age and class. This resulted in a top-1 sample of 124 students. Because for the top-3 analysis a fluency score of at least 4 ideas for both tasks was necessary because otherwise the students could not make a selection, 25 students needed to be excluded from this analysis. Therefore, for the top-3 analysis, the sample consisted of 99 students. Posterior sample means and variances for the two different samples are provided in Table 3.

To see whether the students were able to apply solution finding and identify the most creative ideas, we conducted a Bayesian paired sample t-test for the top-1 and the top-3 score for the aspects together (overall creativity; Table 4). The hypothesized model (H_1: $\mu_{top\text{-}ori} > \mu_{all\text{-}ori}, \mu_{top\text{-}com} > \mu_{all\text{-}com}, \mu_{top\text{-}pra} > \mu_{all\text{-}pra}$) assuming students were able to identify their most creative ideas, indicated by relatively high top-scores compared to the overall scores on all three aspects, resulted in BFs ranging from 4.40 (social task, top-3) to 7.06 (social task, top-1; Table 4). This indicated our hypothesis is supported.

BFs coming from our analyses on the separate aspects are also provided in Table 4. The BFs larger than 1 (but lower than 3) for all three aspects indicated marginal support for our hypothesis that students valued the aspect (H_1: $\mu_{top} > \mu_{all}$). The BFs smaller than 1 for all three aspects indicate there is no support from the data for our model proposing student undervalue specific aspects (H_2: $\mu_{top} < \mu_{all}$). For originality, the H_1 model is almost ten times more likely than the H_2 model. Here, we see a similar trend across the

Table 4
Results Bayesian (Multivariate) T-tests.

		Science				Social			
		Top-1 (N = 124)		Top-3 (N = 99)		Top-1 (N = 124)		Top-3 (N = 99)	
	Hypotheses	BF	PMP	BF	PMP	BF	PMP	BF	PMP
Creativity	H_{unc}	1.00	.13	1.00	.18	1.00	.12	1.00	.19
	H_1: $\mu_{top\text{-}ori} > \mu_{all\text{-}ori}, \mu_{top\text{-}com} > \mu_{all\text{-}com}, \mu_{top\text{-}pra} > \mu_{all\text{-}pra}$	6.64	.87	4.71	.82	7.06	.88	4.40	.81
Originality	H_{unc}	1.00	.33	1.00	.33	1.00	.33	1.00	.33
	H_1: $\mu_{top} > \mu_{all}$	1.82	.61	1.79	.60	1.90	.63	1.92	.64
	H_2: $\mu_{top} < \mu_{all}$	0.18	.06	0.21	.07	0.10	.04	0.09	.03
Completeness	H_{unc}	1.00	.33	1.00	.33	1.00	.33	1.00	.33
	H_1: $\mu_{top} > \mu_{all}$	2.01	.67	2.00	.67	1.94	.65	1.97	.66
	H_2: $\mu_{top} < \mu_{all}$	0.00	.00	0.00	.00	0.06	.02	0.04	.01
Practicality	H_{unc}	1.00	.33	1.00	.33	1.00	.33	1.00	.33
	H_1: $\mu_{top} > \mu_{all}$	1.85	.62	1.93	.64	1.33	.44	1.22	.41
	H_2: $\mu_{top} < \mu_{all}$	0.14	.05	0.07	.03	0.69	.23	0.78	.26

Note: Top-1 N = 124, Top-3 N = 99. BF = Bayes Factor, PMP = Posterior Model Probability. H_{unc} hypothesized no specific direction, H_1 for overall creativity ($\mu_{top\text{-}ori} > \mu_{all\text{-}ori}, \mu_{top\text{-}com} > \mu_{all\text{-}com}, \mu_{top\text{-}pra} > \mu_{all\text{-}pra}$) hypothesized a higher top-score versus the overall score for all three aspects. H_1 for originality, completeness and practicality ($\mu_{top} > \mu_{all}$) hypothesized a larger top score than the overall score for this aspect, whereas H_2 ($\mu_{top} < \mu_{all}$) a larger overall score than the top score for this aspect.

two tasks. For completeness, the H_1 model (BFs around 2) is from 32 to at least 200 times more likely than the H_2 model (BFs ranging from 0.00 to 0.06). Again, there was a similar trend across the tasks, although the support for H_1 in the science task is even more convincing. For practicality, the H_1 model received about 13 times more support than H_2 for this task. For the social task, there was only about 1.5 times more support for H_1 compared to H_2. In other words, for all three aspects there is more support for the H_1 hypothesis. Compared to the H_2 hypothesis, the support for H_1 is largest for completeness.

4. Discussion

In line with the CPS model (Isaksen et al., 2011), two CPS tasks for primary education that represent the CPS model were prepared that explicitly embedded the exploration of knowledge (fact finding), defining the problem (problem finding), and the identification of creative ideas (solution finding) alongside the generation of ideas (idea finding). First, we examined whether successful fact finding and problem finding were positively associated with idea finding of primary school students across CPS tasks. Second, we explored whether primary school students were able to select ideas scoring high on multiple aspects of creativity across CPS tasks, or ignored certain CPS aspects.

4.1. Question 1: Fact Finding & Problem Finding

Regarding the first research question, a successful exploration of knowledge and a high-quality problem definition were positively associated with students' ability to find more and more original ideas. More specifically, the exploration of knowledge seemed especially positively related to the number of ideas a student thought of. This suggests that exploring knowledge on the problem may indeed kick-start the idea finding stage by activating *more* solution opportunities, as was hypothesized (Isaksen et al., 2011; McCaffrey, 2016). At the same time, we found that a successful exploration of knowledge and a high quality problem definition were not positively associated with students' ability to find *complete* and *practical* ideas to tackle the problem. Our results did however suggest that defining the problem helped with finding complete ideas, whereas fact finding might even hamper it. It might be the case that the exploration of knowledge leads a student away from finding complete ideas because it highlights too many opportunities and as such withholds students from focusing on one idea and elaborating on it. Defining the problem might on the other hand assist in finding completing ideas, because it may provide focus in the idea finding stage, as was found by Arreola and Reiter-Palmon (2016). Although more research is needed to further support this hypothesis, discussing the benefits of focus and reflecting on the problem when students do CPS might help them to prepare ideas that are complete. The exploration of knowledge and defining the problem are possibly not helping or even impeding students' ability to find practical ideas because they stimulate students to think outside the box and not to use things that are convenient to use. However, this may differ across CPS tasks, as was indicated by the different results we found across the two CPS tasks we used in our study.

4.2. Question 2: Solution Finding

With regard to our second research question, results indicated that in general primary school students are able to identify their most creative solutions. We did not find any indications that aspects such as originality, completeness, practicality were undervalued by the students when defining their top 3. Results did however indicate that the primary school students were much more likely to value rather than disregard completeness. It is possible that students did take all aspects into account but pick the complete ideas first because these ideas took most cognitive effort and time. It could also be the case that students struggle with taking all aspects of solutions into account at once and that completeness is the most salient to them as was found by Rietzschel and colleagues (2010). To gain insight in whether students really appreciate all aspects of creativity or not, a more qualitative approach zooming in on how these solution finding processes take place would be worthwhile.

4.3. The influence of Tasks

We used two CPS tasks situated in two different domains to explore whether the results could differ across tasks. Although Reiter-Palmon and colleagues (2009) found differences across CPS tasks, our findings tended to be quite in line across the two CPS tasks. Reiter-Palmon and colleagues (2009) did however manipulate the complexity of the tasks, whereas we tried to develop CPS tasks that were different in domain, but comparable in complexity. A small difference between the tasks appeared with regard to how the exploration of knowledge and identification of the problem were associated with the practicality of ideas. It could be the case that due to still existing small differences in complexity one task evoked more practical ideas from students than the other, as is illustrated by the fact that the mean practicality scores differed across the two CPS tasks we used (see Table 1). Future research may provide more insight in the relation between how students perceive the complexity of a task, the application of fact finding and problem finding, and the eventual practicality of ideas.

4.4. Limitations

For the top-3 scoring procedure, we had to deal with a relatively small sample size ($N = 99$). However, the similar findings for the top-1 and top-3 scores suggested this smaller sample size did not negatively influence the results. Additionally, to keep the CPS task simple we asked students to come up with only one problem statement. In other studies, students are asked to generate multiple problem statements and select one problem statement to work with in the next steps (Ma, 2009; Reiter-Palmon, 2017). This might improve the quality of the problem statements and its influence on the idea finding process (Arreola and Reiter-Palmon, 2016). In future studies, it would be interesting to investigate how constructing multiple problem statements impacts idea finding in primary school students. Furthermore, originality, completeness and practicality were rated by external judges. Although students chose ideas that were rated relatively high on creativity as scored by these judges, we do not know why students selected these ideas and whether they completely agree with the scores the judges assigned. A more qualitive, in depth examination about how they evaluate their own ideas would give us more insight into this process. Although this study showed associations between outcomes from different CPS processes, this does not imply causation. Therefore, the results should be interpreted with care.

4.5. Practical Implications

Our findings show that when students struggle to find multiple or original ideas to solve problems, teachers may be able to stimulate students to explore their knowledge on a problem in order to enhance the generation of ideas. When students struggle to find complete ideas, it might be helpful for students to explicitly define the problem at stake. For this study, we developed two CPS tasks for primary education that embedded and scaffolded these processes of fact finding and problem finding, next to idea finding and solution finding processes. Because the CPS stages might not follow this order in practice and students probably switch between stages multiple times while solving a problem (Isaksen et al., 2011; Treffinger et al., 2008), we encouraged students in this study to look back at the first stages while finding ideas. In order for these processes to be transferred to primary education, we think it is important to scaffold the CPS stages first. This might help students to develop a CPS habit that embeds the exploration of knowledge and the identification of the problem before generating ideas. Additionally, explicitly embedding the full CPS process in such a task could help teachers to not only focus on the idea finding stage but pay sufficient attention to the other stages as well (Cropley, 2006; Piffer, 2012). We encourage teachers to take a more flexible approach later on. Additionally, we encourage teachers to discuss the most creative ideas with students. This might give students even more insight in what a final, creative solution could look like.

5. Conclusions

Our results indicated that when dealing with primary school children and when aiming especially for more and original ideas, it is beneficial to apply fact finding and problem finding before engaging in idea finding. As such, teachers may explicitly pay attention to these preparatory stages. Our study also indicated students are able to identify their most creative ideas and do not undervalue specific aspects of creativity in this solution finding process. In general, findings were rather similar across the two CPS tasks we used. Overall, we think CPS is a welcome addition to the contemporary primary education curriculum, connecting knowledge and creativity in a fun and flexible way.

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CRediT authorship contribution statement

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

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