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From perceived competence to emotion regulation: assessment of the effectiveness of an intervention among upper elementary students

Vanessa Hanin[1] · Stéphane Colognesi[1] · Catherine Van Nieuwenhoven[1]

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Abstract

The aim of this article is to assess the effects on learners' emotions and emotion regulation of an intervention promoting the development of cognitive strategies for mathematical problem-solving and positive perceptions of problem-solving competence (SEP), embedded in an overall self-regulated approach, with upper elementary students ($N = 334$, mean age = 10.6 years). Using a quantitative quasi-experimental design (three measurement points), two conditions (cognition vs. cognition + SEP) were contrasted with a control group. Findings revealed that the combined condition stood out positively from the other two in terms of level of SEP, indicating that the SEP-related part of the designed intervention did effectively support the learners' SEP. With regard to effects on emotions and emotion regulation, although nurturing one dimension (cognition) produced beneficial effects, fostering two dimensions (cognition + SEP) led to more and stronger benefits in terms of both emotions and emotion regulation strategies. Participants in both experimental conditions also substantially improved their problem-solving performance. The implications in terms of pedagogical practices for teachers are also discussed.

Keywords Perceived competence · Emotion regulation · Elementary school students · Mathematical problem-solving performance · Intervention

✉ Vanessa Hanin
vanessa.hanin@uclouvain.be

Stéphane Colognesi
stephane.colognesi@uclouvain.be

Catherine Van Nieuwenhoven
catherine.vannieuwenhoven@uclouvain.be

[1] Research Institute of Psychological Sciences, Faculty of Psychology and Education, Université Catholique de Louvain, 10 Place Cardinal Mercier, 1348 Louvain-la-Neuve, Belgium

Introduction

Students' poor performance in mathematical problem-solving has preoccupied researchers for several decades now (Hanin & Van Nieuwenhoven 2018a; Blum 2011; Kramarski and Mevarech 2003; Schoenfeld 1992; Schukajlow et al. 2015; Verschaffel et al. 2000). Until recently, the focus has been on the development of cognitive (or heuristic) and metacognitive (or cognitive self-regulatory) strategies to overcome the observed difficulties. But the accumulating evidence, collected during the past decade, of the profound effects exerted by achievement emotions on students' learning and academic performance has changed the perspective of educational psychologists (Pekrun et al. 2017). Studies have shown that mathematics, and especially mathematical problem-solving tasks, are particularly affected by the issue of emotions (Ahmed et al. 2013; Hanin & Van Nieuwenhoven 2018b; Passolunghi et al. 2019). Empirical studies have reported that students experienced mostly negative emotions during mathematical problem-solving tasks (Hanin & Van Nieuwenhoven 2018b; Ramirez et al. 2016). So, just as it is highly important for students to be aware of and control their cognitive activities, it is crucial that they do the same with their emotions. However, in the same way that the acquisition of cognitive and self-regulatory skills does not necessarily occur spontaneously or automatically, the individual is also not likely to be naturally endowed with emotional knowledge and skills. These latter need to be fostered and taught at school (Kim and Hodges 2012; Schukajlow et al. 2017; Tzohar-Rozen and Kramarski 2017). The issue then is to identify the type of intervention that most effectively promotes the development of emotional competence.

An overview of the available literature on this topic highlights the existence of two kinds of such interventions: on the one hand, programs that aim at developing the general emotional competences of undergraduate students (Nelis et al. 2011; Pool and Qualter 2012) and, to a much lesser extent, of primary and secondary students (Brasseur 2013; Qualter et al. 2007; Viguer et al. 2017) and, on the other hand, social and emotional learning programs that aim to prevent risks and promote positive development among young people through the development of cognitive, affective, communication, and behavioral competences (Payton et al. 2000). However, both types of interventions offer decontextualized emotional training, although several empirical studies have shown that achievement emotions are domain-specific (Goetz et al. 2007) and task-specific (Schukajlow et al. 2012). Further, findings have emphasized that learning strategies are better integrated by students when they are rooted in a concrete subject (Dignath and Büttner 2008; Weinstein et al. 2000). So, it follows that this training must be disciplinarily situated. To our knowledge, so far, only two exploratory studies taking this perspective have been conducted in the field of mathematical learning (Hanin & Van Nieuwenhoven 2018c; Tzohar-Rozen and Kramarski 2017). According to the latter, a combined intervention offering both emotional and cognitive support embedded in an overall self-regulated approach turned out to be more effective than a purely emotion-related intervention. However, the authors reported fewer changes in emotions than expected. The question therefore remains whether there is a way to induce significant changes in learners' mathematics-related emotions.

In that respect, according to control-value theory (CVT; Pekrun 2006), a theoretical framework depicting the role played by emotions in learning processes, and based on empirical findings as well (Ahmed et al. 2010; Peixoto et al. 2017; Stephanou 2011), perceived competence appears to be decisive in shaping the learner's achievement emotions. Doubting or being confident about one's capabilities is assumed to lead the learner to experience different emotions. This close relationship has led several scholars to suggest intervening with regard to the learner's sense of competence in order to reach his/her emotions more deeply

(Kim and Hodges 2012; Pekrun et al. 2017; Schukajlow et al. 2017). This study adopts that perspective and aims to design and assess the effects on learners' emotions of an intervention that promotes the development of cognitive problem-solving strategies and positive perceptions of problem-solving competence (SEP), embedded in an overall self-regulated approach, among upper elementary mathematics students. In other words, we seek to find out if it is possible to affect the emotional dimension by intervening on the cognitive and motivational dimensions. The effectiveness of the intervention is also assessed in terms of problem-solving performance.

Theoretical foundations

This study is based on a simplified version of the control-value theory of achievement emotions (Pekrun 2006) (Fig. 1). Concretely, we have set aside the factors of the school environment (distal antecedents of emotions), values appraisal, and one of the two dimensions of control appraisal (i.e., control attribution) to focus on the two dimensions documented in the literature as having the most decisive impact on emotions in mathematics: the perception of competence and cognitive strategies (Justicia-Galiano et al. 2017; Peixoto et al. 2017; Pekrun et al. 2011).

In this section, we start by clarifying the concepts studied. Then, we examine the relationships between perceived competence and both achievement emotions and emotion regulation strategies. Finally, we look at the second part of the model, that is, at the connections between achievement emotions, emotion regulation strategies, cognitive strategies, and performance.

Conceptual clarifications

Achievement emotions refers to emotions that are directly related to achievement activities or to achievement outcomes (Pekrun et al. 2017). Within CVT, achievement emotions are classified according to the dimensions of valence (positive vs. negative) and activation (activating vs. deactivating). Based on these criteria, four groups of achievement emotions can be distinguished: positive activating emotions (e.g., enjoyment, pride), positive deactivating emotions

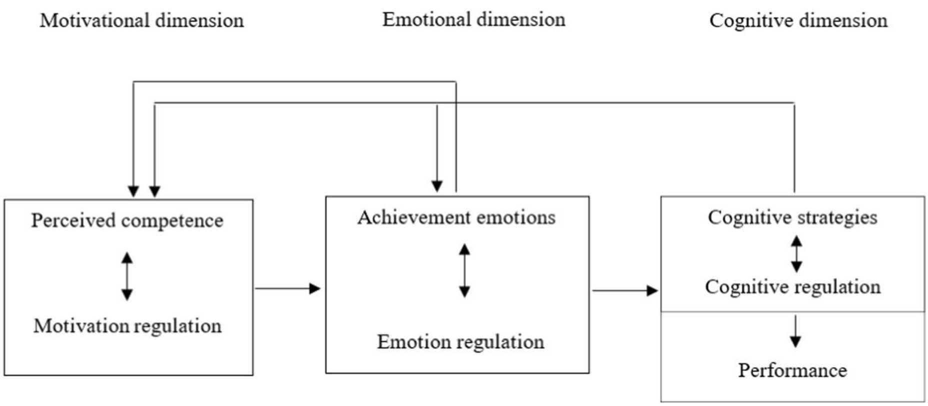

Fig. 1 A simplified version of the control-value theory of achievement emotions with the studied variables

(e.g., relief), negative activating emotions (e.g., anger, anxiety), and negative deactivating emotions (e.g., boredom, hopelessness) (Pekrun 2006).

Building on Bandura's (1997) social cognitive theory, *perceived competence* is conceptualized in CVT as an individual's judgment of his/her personal ability to organize and execute a course of action in order to attain self-set goals—in the school context, these goals are very often set by the teacher. Like many scholars, the authors consider that when assessed at the level of specificity of a task, perceived competence and self-efficacy belief reflect the same reality (Ahmed et al. 2012; Bouffard and Vezeau 2010; Valentine et al. 2004). In this document, we use the acronym SEP to refer to the task-specific perception of competence.

According to CVT, the cognitive dimension covers the learning strategies adopted, the source of regulation used, and the cognitive resource allocation (Pekrun 2006). In the present study, we focused on the *cognitive strategies* used in mathematical problem-solving tasks. They are defined as "search strategies for problem analysis and transformation which do not guarantee, but significantly increase the probability of finding the correct solution of a problem because they induce a systematic approach to the task" (De Corte et al. 2004, p. 372).

These three dimensions (emotion, motivation and cognition) can be *regulated*, that is, they can be guided, controlled, and adjusted to increase one's efficiency (Allal 2007). As a consequence of the social nature of the learning environment, regulative processes occur under the joint influence of students and other sources such as peers, teachers, and the learning materials (Hadwin et al. 2018; Malmberg et al. 2017). Three types of regulated learning are commonly distinguished: self-regulation, co-regulation, and socially shared regulation (Hadwin et al. 2018; Malmberg et al. 2017). In the first form, regulation is purely the responsibility of the learner, the product of internal efforts while, in the two others, which can be grouped under the heading of *hetero-regulation or external regulation*, regulation results from multiple classroom elements acting together. *Co-regulation* occurs when learners' regulatory activities are guided, foster, shaped, or constrained by other members in the group. *Socially shared regulation* emerges when group members work together to supplement and negotiate shared understandings and goals for the task. While the importance of external regulation should not be underestimated, since self-regulatory behaviors are not acquired spontaneously and automatically (Schunk 2001), it should also be borne in mind that it is self-regulatory behaviors alone that ensure learning (Allal 2007). So, as scholars pointed out, progress in student learning is the result of the interplay between individual and social aspects of regulation (Allal 2007; Hadwin et al. 2018; Malmberg et al. 2017). In this study, we investigate whether an intervention that promotes a shift from hetero-regulation to self-regulation of SEP and cognitive strategies impacts the emotional dimension, that is, promotes the learner's emotional self-regulation.

Relationships between perceived competence, achievement emotions, and emotion regulation strategies

Control-value theory asserts that control and value appraisals are the proximal determinants of achievement emotions. Empirical findings have shown that control appraisals, and more specifically, perceived competence, are the strongest determinants of achievement emotions, whether positive or negative, in the context of mathematics (Ahmed et al. 2010; Peixoto et al. 2017; Stephanou 2011).

With respect to the relationship between perceived competence and emotion regulation strategies, there are very few studies to date in this area. In the correlational studies conducted by Burić and her colleagues (Burić et al. 2016; Sorić et al. 2013) with high school and university students, they observed that students' self-efficacy belief correlated negatively with avoidance (i.e., avoiding academic situations that can trigger unpleasant emotions) and venting (i.e., behavioral manifestations and expressions of unpleasant emotions as a way of releasing negative energy). No significant relation was found for reappraisal (i.e., redefining a potentially emotion-eliciting situation in such a way that its emotional impact is changed), suppression (i.e., attempts to suppress subjective and behavioral manifestations of unpleasant emotions in academic situations in order to hide them from others), respiration (i.e., attempts to reduce subjective feelings of tension accompanied by unpleasant emotions through deep breathing), and seeking social support (i.e., sharing unpleasant emotions and seeking comfort from close members of the learner's social milieu). However, a study conducted with upper elementary students revealed that the emotion regulation strategies used by younger learners in school settings differ from those usually found in older age groups in everyday life situations (Hanin et al. 2017). Six strategies used by this age group were identified. Negative self-talk or rumination involves focusing on the negative aspects of the situation by dramatizing them, by constantly thinking them over or by convincing oneself that they are beyond one's control. Dysfunctional avoidance consists of avoiding dealing with the task, despite the fact that its completion is beneficial in the long run. Emotion expression refers to the social sharing of one's emotions. Task-utility self-persuasion or utility value reappraisal consists of convincing oneself of the personal utility of the task despite the fact that it generates unpleasant emotions. This strategy aligns with the conceptualization of task value by Eccles et al. (1993) and can therefore also be considered as a strategy to regulate one's motivation. Help seeking is about seeking peer and teacher assistance. While help seeking is better known as a cognitive regulation strategy, the help provided (e.g., hint, advice, encouragement) addresses the trigger of the negative emotion (e.g., difficulty in solving the task) and in this way reduces or even removes that negative feeling (Karabenick and Berger 2013; Nelis et al. 2011). Emotion expression, help seeking, and brief attentional relaxation all three correlated weakly and negatively with perceived problem-solving competence, while no significant relation was found between task utility self-persuasion and perceived problem-solving competence. In contrast, more substantial relationships were found between perceived problem-solving competence and both dysfunctional avoidance and negative self-talk (Hanin & Van Nieuwenhoven 2019).

Relationship between achievement emotions, emotion regulation strategies, cognitive mechanisms, and performance

Control-value theory postulates a direct and bidirectional link between achievement emotions and cognitive strategy use (Pekrun 2006). More precisely, empirical research conducted with secondary students highlighted positive associations between positive activating emotions and the use of elaborate, deep cognitive strategies, and negative relations between both negative activating and negative deactivating emotions and the use of those strategies (Ahmed et al. 2013). Even more, the authors observed that changes in positive emotions (enjoyment and pride) were positively associated with changes in cognitive strategies (shallow vs. deep). This finding is consistent with the broaden-and-build theory which posits that positive emotions broaden an individual's momentary thought-action repertoire (Fredrickson 2001). With respect to emotion regulation, few results are available. The few existing studies conducted with upper elementary students in the context of math problem solving showed that students who received a pure emotion regulation intervention partially transferred the ability to self-regulate their emotions to the cognitive dimension while those who were trained only in cognitive self-regulation did not also regulate their emotions (Hanin & Van Nieuwenhoven 2018c; Tzohar-Rozen and Kramarski 2017). In other words, promoting cognitive self-regulation does not seem to induce emotional self-regulation.

The effect of achievement emotions on performance is mediated in part by the kind of cognitive strategies used, according to CVT (Pekrun et al. 2017). Numerous quasi-experimental studies have demonstrated the effectiveness of the explicit teaching of cognitive or heuristic strategies for enhancing upper elementary students' problem-solving performance (e.g., Hanin & Van Nieuwenhoven 2016; Fagnant and Jaegers 2018; Mevarech et al. 2010).

Description of the intervention

The authors designed and developed an intervention that aims to develop cognitive problem-solving strategies (Hanin & Van Nieuwenhoven 2016, 2018a) and that fosters the development of positive perceptions of problem-solving competence (SEP) (Artino 2012; Bandura 1997; Bouffard and Vezeau 2010) in order to induce changes in upper elementary mathematics students' achievement emotions and emotion regulation strategies, first, and their problem-solving performance, second. While the cognitive effectiveness of a similar intervention has already been demonstrated (Hanin & Van Nieuwenhoven 2016, 2018a, 2018b), that is not the case for its motivational component. A prerequisite will therefore be to ensure that the intervention that aims to foster the learner's SEP does so effectively.

More precisely, three conditions were contrasted. The first was a *cognition* condition, in which eight cognitive or heuristic strategies of particular importance in solving non-routine mathematics problems were taught. The term "non-routine" is used to designate problems for which the solution does not appear immediately and for which the resolution is not based on applying the procedure that has just been seen in class (Elia et al. 2009; Fagnant et al. 2003). These eight strategies (i.e., building a representation of the problem, estimating the answer a priori, identifying the mathematical structure, planning, executing the necessary calculations, checking the outcome and the procedure, interpreting the outcome, and communicating the answer; for a more detailed description of these strategies, see Hanin & Van Nieuwenhoven 2016, 2018a) were taught according to the method suggested by Veenman et al. (2006). For each strategy, this method consists of specifying the *what* (what it consists of), the *why* (its usefulness), the *when* (the most relevant moment in the problem-solving process to implement it), and the *how* (the way to implement it correctly). This method aims to develop among students an overall self-regulatory approach, that is the ability to choose wisely the strategies to use given the type of problem, as well as when to stop using them, to change them, or to apply them more precisely (Berger and Büchel 2012). The second was a *cognition + SEP* condition, which embraced the cognitive strategy instruction provided in the previous condition while proposing additional activities aiming to enhance the learner's sense of competence. These activities targeted the four sources from which people acquire information to evaluate their competence, namely, enactive mastery experiences, vicarious experiences (observation of the successes and failures of significant others), forms of persuasion (recognition by others of one's skills), and physiological and affective states (interpretation of physiological signs such as sweating, rapid heartbeat, and hyperventilation) (Bandura 1997). Finally, there was a *control* condition, which received no specific intervention but solved the same problems (examples are available in Appendix Table 5 at the same rate). The problems chosen for the intervention presented a structure distinct from those of the problems addressed in the problem-solving tests so as to avoid a potential learning effect. The intervention comprised 8 sessions (one session per week lasting between 110 and 150 min), during each of which a different problem was addressed (for a more detailed description of the eight sessions for the cognition + SEP condition, see Appendix Table 6). The control condition engaged in additional mathematics activities on a weekly basis in order to spend as much time on mathematics as the two other conditions. In that way, we controlled for the "time on task" variable. As far as ecological validity, the three conditions were implemented by the regular classroom teachers, who had previously received 2-day training from the first author.

The present study

The current study sought to contribute to the growing knowledge base on the key cognitive and motivational ingredients of mathematical problem-solving interventions that promote the development of positive emotions and appropriate emotion regulation behaviors and improve performance. On the basis of the literature presented above, the following hypotheses were formulated.

Regarding the prerequisite objective identified, namely, the motivational effectiveness of the cognition + SEP intervention, it has been shown that perceived competence is improved both by working on its different sources of information and by teaching effective cognitive strategies by pointing to their usefulness (the *why*) (Artino 2012; Bouffard and Vezeau 2010). So, the expectations for improvements in perceived problem-solving competence were as follows:

- The cognition + SEP condition will surpass the two other conditions.
- The cognition condition will surpass the control condition.

With respect to the core objective of the study, namely, the effectiveness for emotions and emotion regulation of the combined intervention, based on previous interventional studies that have shown that a purely cognitive intervention has very little effect on the emotional dimension (Hanin & Van Nieuwenhoven 2018a; Tzohar-Rozen and Kramarski 2017) and on the close relationship between perceived competence and achievement emotions (Ahmed et al. 2010; Peixoto et al. 2017), we postulated that with regard to the development of positive emotions and appropriate emotion regulation strategies:

- The cognition + SEP condition will surpass the two other conditions.
- There will be no significant difference between the cognition condition and the control condition.

With regard to problem-solving performance, as previous studies have consistently reported that the more positively learners' perceive their competence, the better their math performance is (Frenzel et al. 2007; Justicia-Galiano et al. 2017; Peixoto et al. 2017), our assumptions were as follows:

- The cognition + SEP condition will surpass the two other conditions.
- The cognition condition will surpass the control condition.

Method

Participants

A total of 334 upper elementary students (fifth and sixth graders) from five French-speaking Belgian schools took part in the present study. The sample size was determined by a power analysis, assuming $\alpha = .05$, high power ($\beta = .95$), average effect size (Hanin & Van Nieuwenhoven 2018a; Pool and Qualter 2012; Viguer et al. 2017), and a high correlation between repeated measures ($r = .75$) supported by previous studies (Ahmed et al. 2013). Schools' and teachers' characteristics are summarized in Table 1. Although the authors took care to make the three conditions as comparable as possible, they were dependent on the teachers' choices. The latter joined the project on a voluntary basis and chose their condition. However, according to previous studies conducted in the field of mathematical learning (Opdenakker and Van Damme 2006; Star et al. 2015), it turns out that teachers' socio-demographic (e.g., age, gender) and socio-professional (e.g., years of teaching experience) characteristics do not directly influence their teaching practices and the quality of students' learning.

The control condition was made up of 93 students (mean age ± SD = 10.5 ± 0.50 years, 44.1% girls, 52.7% fifth graders); the cognition condition consisted of 85 students (mean age ± SD = 10.9 ± 0.2 years, 42.5% girls, 44.7% fifth graders); and the cognition + SEP condition was composed of 155 students (mean age ± SD = 10.6 ± 0.6 years, 53.5% girls, 45.2% fifth graders). While the three groups presented comparable levels of initial problem-solving performance ($F(2, 231) = 1.071, p = .344$), they differed significantly in terms of socio-economic index ($F(2, 231) = 105, 532, p < .001$). Regarding the latter, both the cognition ($MD = 4.94, p < .001$) and the control ($MD = 5.55, p < .001$) conditions had a higher socio-economic index score than the cognition + SEP condition. As mentioned below, this index score was included in the statistical model as a control variable.

There were no missing data in the self-report measures, due to the fact that students who were absent when the questionnaires were completed were invited to complete them upon their return to class.

Table 1 Schools' and teachers' characteristics

School	Class	Teacher's gender	Class size	Teacher's years teaching	Condition
1	1	M	26	8	Control
	2	F	22	22	Control
2	1	M	23	35	Control
	2	F	22	5	Control
	3	F	25	6	Cognition + SEP
	4	F	19	9	Cognition + SEP
	5	M	25	12	Cognition
	6	F	24	37	Cognition
3	1	M	19	7	Cognition
	2	F	17	18	Cognition
4	1	F	19	3	Cognition + SEP
5	1	M	23	30	Cognition + SEP
	2	M	24	13	Cognition + SEP
	3	F	23	20	Cognition + SEP
	4	F	23	5	Cognition + SEP

Measures

Participants provided data on three occasions: prior to (time 1, pretest), immediately after (time 2, posttest), and 6 weeks after the intervention (time 3, follow-up test).

Achievement emotions experienced by the students while solving a mathematical problem were evaluated through a questionnaire presenting facial expressions (one pictorial item per emotion) (Hanin & Van Nieuwenhoven 2018a, 2018c). These included three positive activating emotions (enjoyment, pride, hope), one positive deactivating emotion (relief), six negative activating emotions (shame, fear, worry, nervousness, anger, frustration), and three negative deactivating emotions (hopelessness, sadness, boredom) most frequently experienced by elementary students when dealing with problem-solving tasks (Hanin & Van Nieuwenhoven 2018b; D'Mello and Graesser 2011; Frenzel et al. 2007). Students were asked to indicate to what extent they felt each emotion when solving a math problem, using a 5-point Likert scale (1 = *never* to 5 = *always*). The distribution of the data on a histogram led us to transform them into a binary scale for the nine negative emotions assessed.

Emotion regulation strategies were appraised using the Children's Emotion Regulation Scale in Mathematics (CERS-M) (Hanin et al. 2017). This questionnaire consists of 14 items, rated on a 4-point Likert scale (ranging from 1 = *(almost) never* to 4 = *(almost) always*) and targets six strategies used by 5th and 6th graders to regulate their emotions when solving mathematical problems (Table 2). Regarding the reliability scores, many educational scholars (Field 2018; Taber 2018) define the acceptable reliability threshold at 0.65, while others (Van Griethuijsen et al. 2014) set their cut-off at 0.6.

Perceived problem-solving competence was assessed through seven items adapted from Boekaerts' (2002) Online Motivation Questionnaire (e.g., "How good do you think you are at mathematical problem-solving tasks?"). The items were rated on a 4-point scale with various

Table 2 Description of the emotion regulation strategies scale

Scale name	Number of items	Cronbach α or *Spearman-Brown statistic*[1]			Sample item
		Pretest	Posttest	Follow-up test	
Help-seeking	2	.74	.76	.83	"I ask the teacher to help me to solve the problem"
Brief attentional relaxation	3	.71	.73	.82	"I put down my pen for a few seconds and stretch my arms"
Task-utility self--persuasion	2	.66	.72	.73	"Even if I do not like solving math problems, I tell myself that it is important to do so in order to be able to understand them and thereby to succeed"
Emotion expression	2	.71	.75	.73	"I tell my neighbor that the problem makes me angry, sad, hopeless, or bored"
Negative self-talk	3	.73	.79	.78	"I tell myself that it is terrible not being able to solve the problem and that I am sure that it only happens to me"
Dysfunctional avoidance	2	.64	.66	.65	"In order not to experience an unpleasant moment, I tell myself that I will solve the problem later"

[1] Following the recommendations of Eisinga et al. (2013) we used the Spearman-Brown statistic for the two-item scales and the Cronbach's alpha for the three-item measures

anchors. The internal consistency was satisfactory to good (pretest: α = .87, posttest: α = .86, follow-up test: α = .89).

Problem-solving performance was assessed by means of a performance test made up of four non-routine problems. This test was designed based on the analysis by Bednarz and Lajoie (2018) and on Fagnant and Demonty's (2005) textbook. In selecting these problems, our main concern was to respect the three characteristics of openness, realism, and complexity that are recommended by Verschaffel et al. (2000) to develop among students an expert and reflexive approach to problem solving. Students' performance was evaluated by a global score obtained by averaging their scores for the four items on a binary scale (0 = *wrong answer*, 1 = *right answer*). Interscorer agreement, computed for the scoring of 40% of the responses by two independent blind scorers, was 0.95. The test took on average 45 min to complete. For each measurement point, the same four mathematical structures (e.g., were used to design the problems' statements, and only the presentation of the problem was modified. The internal consistency was moderate (pretest: α = .68, posttest: α = .71, follow-up test: α = .70).

Students' previous problem-solving performance, included as a control variable, was assessed 3 months before the start of the study, using a standardized test made up of four non-routine word problems similar to those used to assess students' actual performance. Accuracy of problem responses was scored using the same procedure (k = 0.90; α = .66).

The schools' socio-economic index score, included as a control variable, was collected from the Ministry of the French Community of Belgium's website. This index classifies schools on a scale from 1 (the lowest index) to 20 (the highest index). It is calculated from five factors measured for each student: the per capita income, the level of educational qualification, the unemployment status, the professional activities, and the housing conditions. The index score of each school is then defined on the basis of the average of the indices of its population.

Fidelity of implementation

As outlined by Durlak and Dupre (2008), one cannot interpret the results of the implementation of an intervention without first ensuring that it has been delivered as planned. Therefore, the fidelity of implementation of the intervention was evaluated. First, the teachers who were implementing it received a half-day's training during which the components of the intervention were outlined. A manual containing the description of the intervention components and the lesson plans as well as detailed examples of anticipated correct representations, procedures, and solutions was given to each teacher. Second, a checklist that contained step-by-step instructions was provided for each lesson. As the teacher completed a step, he or she had to check it off. Examination of the checklists showed that teachers completed 98% of the steps as prescribed. Third, teachers were asked to keep a diary with their feelings, students' responsiveness, potential adaptations, and any other piece of information considered to be relevant. On this point, while the teachers reported being convinced of the relevance of the intervention, they also pointed out that it was quite dense and intense. Finally, meetings were organized to share positive experiences and difficulties encountered, as well as to take stock of the previous lessons and to plan those to follow.

Analysis

A linear mixed model (LMM) was run with gender, grade (fifth vs. sixth), condition, school socio-economic index score, and students' previous problem-solving performance as fixed main effects. The model also included interactions between time and condition. When repeated measures are used, scores from different time points are likely to be related because they come from the same participant. As a result, it must be ensured that these intra-individual variations are taken into account, not as part of the systematic variation, but in the error term. To do so, a random factor has to be included in the model. In the present study, a random intercept was included in the model, set to be free to vary across participants (Field 2018). LMM makes it possible not only to consider the particularity of each subject, but also to use all the observations for the same subject even when they are incomplete (Field 2018).

The Bonferroni post hoc procedure was used to compare the three times (time 1 (pretest), time 2 (posttest), and time 3 (follow-up test)), two by two. A standardized measure of the magnitude of the mean difference between the three conditions at each measurement time (Cohen's *d*) was also calculated to provide a better understanding of the observed effects (Cumming 2012; Lakens 2013).

Results

The descriptive information is reported in Appendix Table 7 and baseline differences between the three groups for the variables under consideration are presented in Appendix Table 8. With regard to the latter, no significant differences were observed.

Results of the interaction between time and condition are presented in Table 3 and Cohen's *d* in Table 4. Only the significant effects are described in the text.

Table 3 Linear mixed model for time × condition

	df_1	df_2	F	p
Perceived competence	6	967	8.52	< .001
Achievement emotions				
Hope	6	963	1.95	.070
Enjoyment	6	954	8.47	< .001
Pride	6	955	5.89	< .001
Relief	6	960	4.58	< .001
Boredom	6	954	1.57	.150
Anger	6	954	2.07	.054
Frustration	6	954	1.12	.347
Hopelessness	6	954	.79	.577
Nervousness	6	954	1.23	.287
Fear	6	954	1.15	.334
Worry	6	954	1.55	.159
Sadness	6	954	.78	.586
Shame	6	954	.19	.979
Emotion regulation strategies				
Task utility self-persuasion	6	953	3.52	002
Help seeking	8	955	11.83	< .001
Brief attentional relaxation	6	955	1.36	.229
Emotion expression	8	956	3.01	.002
Negative self-talk	6	952	3.62	.001
Dysfunctional avoidance	6	959	7.56	< .001
Problem-solving performance	8	963	34.92	<.001

Table 4 Standardized magnitude of the mean differences between conditions at each measurement time (Cohen's *d*)

	Time 1			Time 2			Time 3		
Cohen's d between …	CS and CT	CS and CG	CG and CT	CS and CT	CS and CG	CG and CT	CS and CT	CS and CG	CG and CT
Perceived competence	3.19	2.28	0.71	7.70	5.90	1.43	9.02	8.18	0.71
Achievement emotions									
Hope	2.21	0.07	1.67	4.92	0.65	3.33	7.87	2.23	3.04
Enjoyment	2.07	0.45	2.59	0.07	0.07	0.00	0.91	0.30	1.02
Pride	2.51	3.84	5.51	5.30	1.27	5.21	10.04	0.91	8.43
Relief	2.31	4.20	0.55	3.58	0.64	3.31	5.01	0.08	4.00
Boredom	0.21	0.00	0.14	1.13	0.00	0.80	1.11	0.52	0.46
Anger	5.01	0.69	3.74	0.20	0.42	0.24	2.05	1.04	0.73
Frustration	3.80	1.12	3.94	1.24	0.38	0.62	3.65	1.12	3.85
Hopelessness	3.50	2.75	0.75	1.75	1.14	0.18	1.37	1.04	0.00
Nervousness	3.95	1.93	1.47	1.37	2.77	1.14	2.59	0.32	1.71
Fear	5.01	0.69	3.74	1.25	0.42	1.38	0.91	0.00	0.73
Worry	3.15	1.12	1.42	0.43	0.64	0.96	1.00	1.21	0.33
Sadness	3.01	1.37	1.23	1.75	2.45	0.56	2.73	0.00	2.45
Shame	1.33	1.87	2.45	1.33	1.39	2.14	1.67	0.52	1.72
Emotion regulation strategies									
Task utility self-persuasion	4.36	2.20	1.73	2.30	2.67	0.27	1.15	3.59	3.73
Help seeking	4.13	0.26	3.40	1.29	0.91	0.30	0.39	0.13	0.40
Brief attentional relaxation	0.34	0.12	0.18	2.07	0.35	1.36	3.56	1.62	1.55
Emotion expression	4.45	1.20	2.36	0.16	1.49	1.30	0.16	0.75	0.47
Negative self-talk	1.45	0.86	1.90	3.27	2.20	0.76	3.88	1.59	1.90
Dysfunct. avoidance	2.40	0.17	2.14	4.12	2.41	1.20	1.72	1.61	0.00
Problem-solving performance	1.00	0.42	0.40	9.08	0.42	7.67	4.95	0.42	4.33

CS cognition + SEP condition, *CG* cognition condition, *CT* control group

Perceived problem-solving competence

As expected, at time 2, the cognition + SEP condition displayed a more positive perception of competence compared to both the control condition (*MD*[1] = 0.42, $p < 0.001$) and the cognition condition (*MD* = 0.31, $p = 0.001$) (Fig. 2). These differences were maintained at time 3 (cognition + SEP vs. control: *MD* = 0.47, $p < 0.001$; cognition + SEP vs. cognition: *MD* = 0.43, $p < 0.001$). However, contrary to our assumption, there was no significant difference between the control condition and the cognition condition.

These findings indicate that the part of the intervention designed to support positive perceptions of competence does so. This prerequisite objective fulfilled, we can now look at the emotional effectiveness of the combined intervention.

[1] MD stands for mean difference.

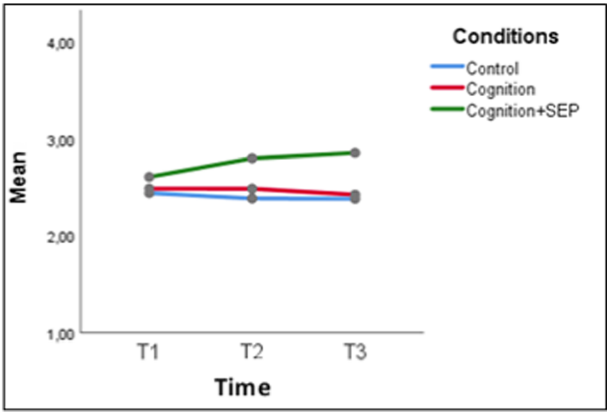

Fig. 2 Mean perceived problem-solving competence (ranging from 1 to 4) over time as a function of condition

Achievement emotions

The results regarding achievement emotions only partially corroborated our initial assumptions. Indeed, although, according to our hypothesis, the cognition + SEP condition stood out to its advantage from the control group, the findings indicated that the cognition condition did so, too.

Regarding hope, both the cognition ($MD = 0.60$, $p = 0.013$) and the cognition + SEP ($MD = 0.70$, $p = 0.004$) conditions showed higher significant values than the control condition at time 2 (Fig. 3). At time 3, this significant difference was maintained only by the cognition + SEP condition ($MD = 0.69$, $p = 0.005$).

As for enjoyment, although the sequential Bonferroni procedure did not highlight any significant differences, the graph shown in Fig. 4 displays the evolution of enjoyment across the three conditions, revealing a decline in enjoyment within each of the three conditions. Yet, while enjoyment decreased following time 1 for the control condition, for the two experimental conditions, it decreased only after time 2. The administered intervention seems to have slowed down the decline.

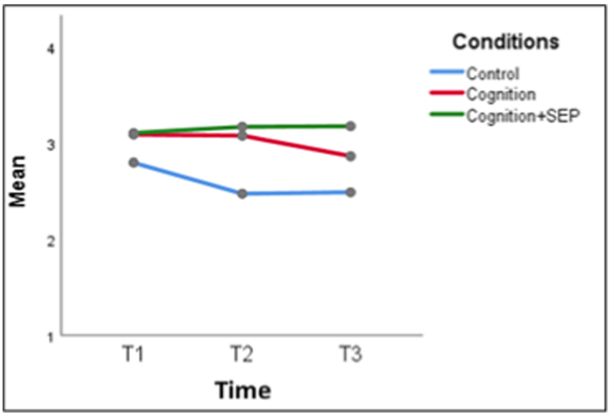

Fig. 3 Mean hope (ranging from 1 to 5) over time as a function of condition

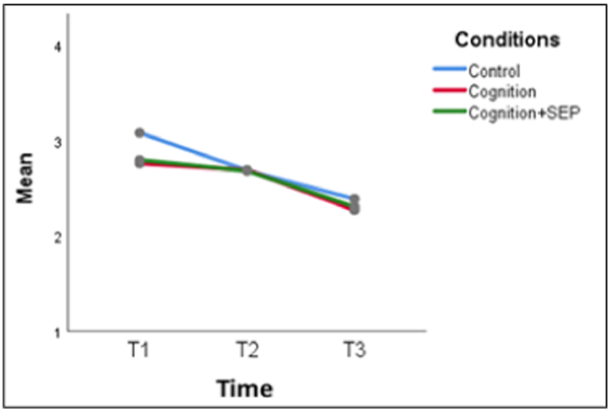

Fig. 4 Mean enjoyment (ranging from 1 to 5) over time as a function of condition

With respect to pride, a significant difference was observed at time 1 between the cognition and the control conditions (*MD* = 0.55, $p = 0.003$). At time 2, both the cognition (*MD* = 0.73, $p < .001$) and the cognition + SEP (*MD* = 0.60, $p = .001$) conditions showed greater pride than the control condition (Fig. 5). These differences were maintained at time 3 (cognition vs. control: *MD* = 0.82, $p < 0.001$; cognition + SEP vs. control: *MD* = 0.72, $p < 0.001$).

Concerning relief, findings revealed significantly higher means in both the cognition condition (*MD* = 0.49, $p = 0.045$) and the cognition + SEP condition (*MD* = 0.45, $p = 0.045$) compared to the control condition, starting at time 2 (Fig. 6). These differences persisted at time 3 (cognition vs. control: *MD* = 0.64, $p = 0.004$; cognition + SEP vs. control: *MD* = 0.63, $p = 0.004$).

Finally, significant differences regarding anger were also observed between the three conditions, but only at time 1 (Fig. 7). For a correct reading of the graph, it is good to remind that negative emotions were converted to a binary scale. More precisely, both the cognition (*MD* = 0.14, $p = 0.014$) and the cognition + SEP (*MD* = 0.16, $p < 0.001$) conditions displayed a higher level of anger than the control condition at time 1. However, these initial differences were absorbed by a change in the control condition, which recorded a substantial increase in anger over the three measurement points. The mean anger of the cognition condition increased

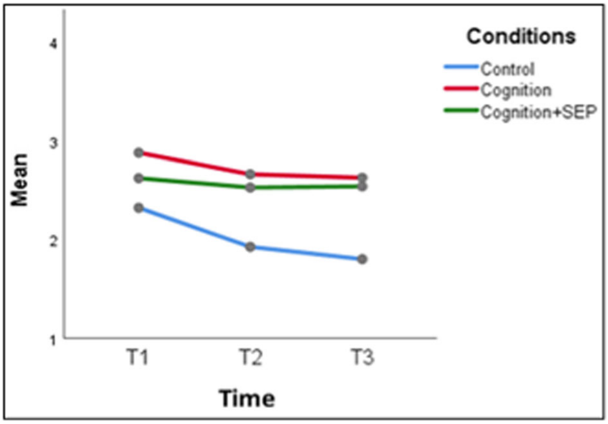

Fig. 5 Mean pride (ranging from 1 to 5) over time as a function of condition

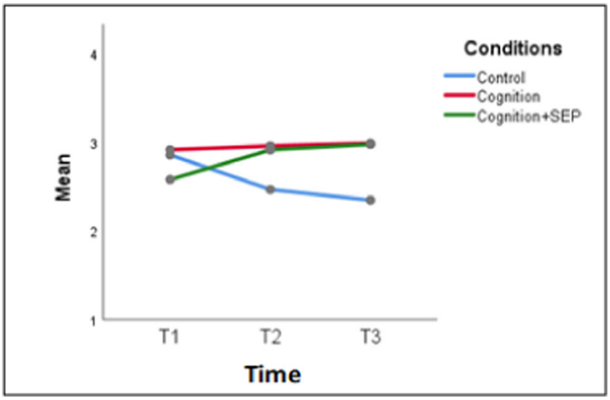

Fig. 6 Mean relief (ranging from 1 to 5) over time as a function of condition

slightly between times 1 and 2 and then tended to stabilize. The cognition + SEP condition displayed a slight decrease between time 1 and time 2, but rose back up between times 2 and 3.

Emotion regulation strategies

In line with our expectation, the cognition + SEP condition stood out advantageously from the control condition as far as emotion regulation strategies. However, as was noticed for achievement emotions, the cognition condition tended to stand out from the control condition too.

First, as regards the task-utility self-persuasion strategy, the cognition + SEP condition relied on it significantly less at time 1 ($MD = 0.39$, $p = 0.012$) than the control condition (Fig. 8). This difference faded at time 2. At time 3, the cognition condition used it significantly more than the control group ($MD = 0.38$, $p = 0.025$). As shown on the graph, while the control group made less use of the strategy over the three measurement points, the two experimental groups used it in a more or less constant way.

Second, at time 1, the cognition + SEP condition displayed higher use of the emotion expression strategy than the control condition ($MD = 0.28$, $p = 0.019$) (Fig. 9). However, this

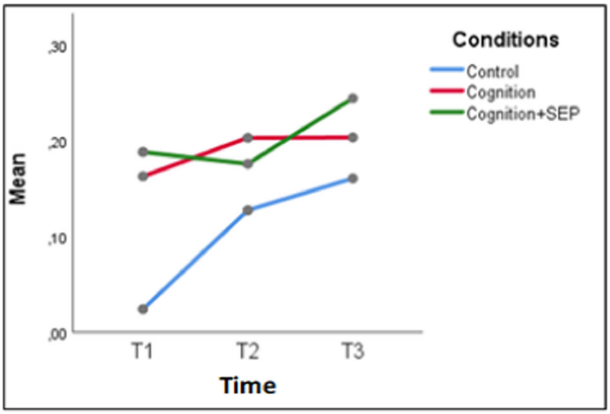

Fig. 7 Mean anger (ranging from 0 to 1) over time as a function of condition

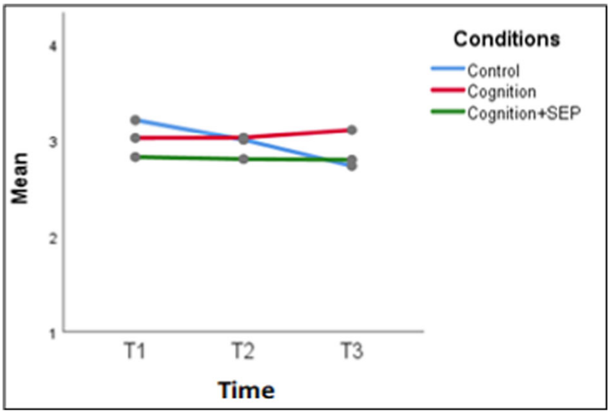

Fig. 8 Mean task utility self-persuasion (ranging from 1 to 4) over time as a function of condition

difference faded at times 2 and 3. The control group increased its use of the strategy while the cognition + SEP condition reduced its use.

Third, at time 1, both the cognition (*MD* = 0.34, *p* = 0.018) and the cognition + SEP (*MD* = 0.32, *p* = 0.018) conditions resorted to the help-seeking strategy to a greater extent than the control condition (Fig. 10). Both experimental conditions recorded a substantial drop between time 1 and time 2, making the difference no longer significant.

Fourth, at time 3, the cognition + SEP condition showed significantly less use of the negative self-talk strategy compared to the control condition (*MD* = 0.32, *p* = 0.038) (Fig. 11).

Fifth and last, the cognition + SEP condition stood out advantageously at time 2 from the control group regarding the dysfunctional avoidance strategy (*MD* = 0.24, *p* = 0.027). As can be seen from Fig. 12, at time 3, the control condition decreased its use of the strategy while the cognition + SEP condition slightly increased it, removing the significant difference.

Finally, in light of the strong societal interest, described in the introduction, in improving student performance in mathematics, we examined whether the two experimental conditions differed from the control condition in terms of problem-solving performance.

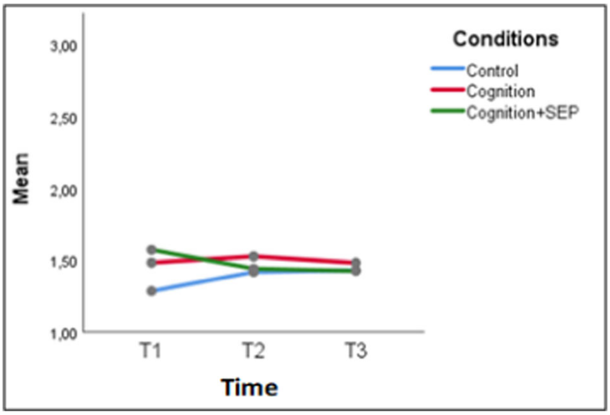

Fig. 9 Mean emotion expression (ranging from 1 to 4) over time as a function of condition

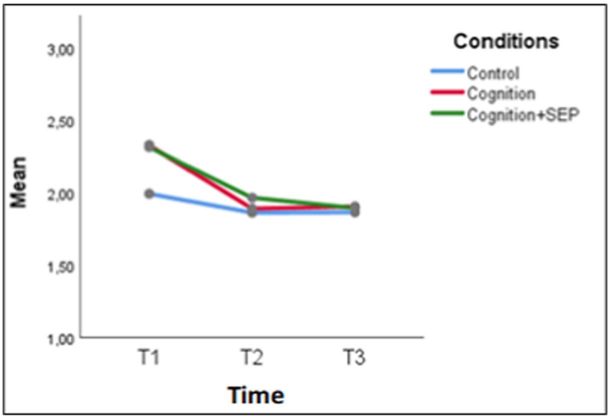

Fig. 10 Mean help seeking (ranging from 1 to 4) over time as a function of condition

Problem-solving performance

Both the cognition and the cognition + SEP conditions displayed better problem-solving performance than the control group, both at time 2 (cognition: *MD* = 0.23, $p<0.001$; cognition + SEP: *MD* = 0.23, $p<0.001$) and at time 3 (cognition: *MD* = 0.13, $p<0.001$; cognition + SEP: *MD* = 0.13, $p<0.001$), which partially confirmed our hypothesis (Fig. 13).

Discussion

The present study examined the effectiveness for emotions and emotion regulation of a problem-solving intervention that aims both to develop cognitive problem-solving strategies and to foster positive perceptions of problem-solving competence (SEP) among upper elementary mathematics students. Concretely, two quasi-experimental conditions (cognition vs. cognition + SEP) were contrasted with a control group. The three groups were compared on three levels: (1) in terms of SEP, to ensure that the intervention aiming to address that

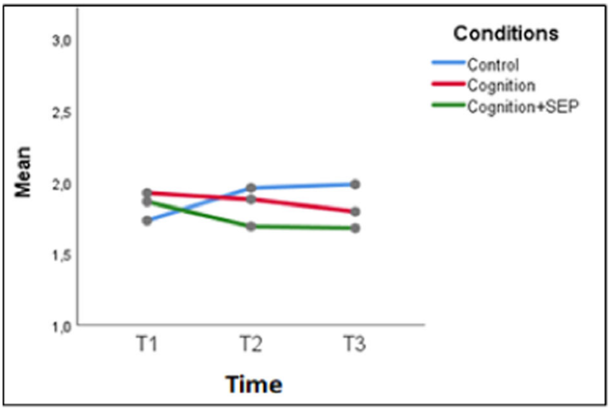

Fig. 11 Mean negative self-talk (ranging from 1 to 4) over time as a function of condition

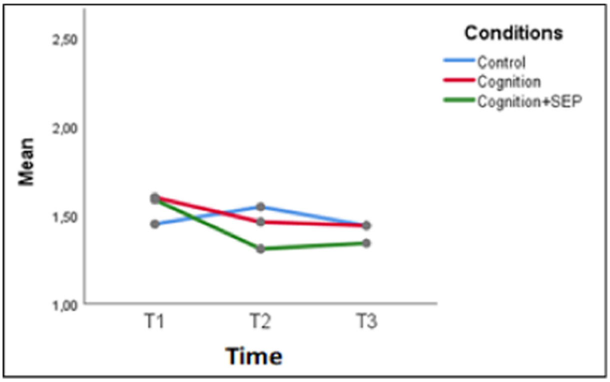

Fig. 12 Mean dysfunctional avoidance (ranging from 1 to 4) over time as a function of condition

component does so effectively, (2) in terms of achievement emotions and emotion regulation strategies, and (3) in terms of performance.

Regarding the emotional dimension, while, as expected, the combined condition stood out positively from the control group, what is more surprising is that the cognitive condition did the same. More precisely, if we look at change over time in the achievement emotions, while the control group recorded significant drops in positive emotions (hope, enjoyment, pride, relief) and a substantive increase in anger, both experimental conditions held or even increased their initial levels of positive emotions, while showing only a slight increase of anger. However, albeit both experimental conditions followed a similar evolution, the combined condition presented a steeper slope and maintained the observed changes over the longer term, indicative of more substantial effects. With respect to emotion regulation strategies, similar observations can be drawn. As they constitute the core of this study, it seemed important to us to develop them further. A first observation is that, unlike the control group, both the cognition and the cognition + SEP conditions helped the students to maintain, both short and long term, their initial perception of the utility of solving math problems. Second, both experimental conditions fostered, throughout the intervention and even after it, the adoption by the learners of a more responsible and autonomous approach to problem-solving, in other words, a self-

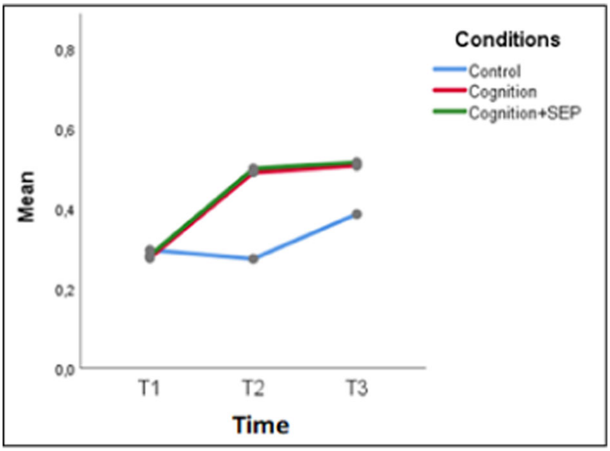

Fig. 13 Mean problem-solving performance (ranging from 0 to 1) over time as a function of condition

regulated approach (Allal 2007). This observation, based on a decline in the use of the help-seeking strategy, is consistent with previous studies (Hanin & Van Nieuwenhoven 2018a, 2018c). Third, while the control group focused substantially more on the negative aspects of the situation, in both the short and long term, both experimental conditions reduced their use of that strategy. Fourth and in the same vein, the control group more often avoided dealing with problem-solving tasks while both experimental conditions relied markedly less on that strategy. Finally, while the two intervention groups showed similar curves for the emotion-related variables discussed thus far—although more marked for the combined condition—they behaved differently concerning the emotion expression strategy. In that respect, the work on SEP seems to have induced a reliable decrease in the expression of negative emotions, while the pure cognitive scaffolding appeared to have stabilized the baseline frequency of use of this strategy.

These findings strengthen and broaden the current knowledge in two ways. First, the question of whether exposure to a cognitive intervention with a self-regulated approach impacts the other dimensions of the learning process, that is, motivation and emotions, is attracting the attention of many researchers today. Although several empirical studies have shown that promoting cognitive and self-regulatory support for problem solving leads to greater general motivation (Hoffman 2010; Kramarski and Gutman 2006; Kramarski and Mizrachi 2006), whether this also concerns the emotional dimension has, to date, received little attention. While the two existing exploratory studies concluded that there was little effect of a purely cognitive intervention on the emotional dimension (Hanin & Van Nieuwenhoven 2018a; Tzohar-Rozen and Kramarski 2017), the present work indicates that nurturing the cognitive aspect of self-regulation also affects the emotional aspect. As emotional changes take time (Viguer et al. 2017), the longer duration of the intervention proposed here could be one of the explanations for the difference observed. Further, in addition to corroborating CVT's assumption that there is a direct and close relationship between achievement emotions and cognitive processes, this study refines our current knowledge on the subject by indicating that this relationship held only for certain emotion-related variables, those that are the most impacted by effective cognitive support (positive emotions, task-utility self-persuasion, and help seeking). Effectively, such support promotes the generation of emotions associated with positive outcomes (expectancies) (Pekrun 2006), increases the desire and motivation of the learner to tackle the task (Tzohar-Rozen and Kramarski 2014), and promotes the transition from external regulation to self-regulation (Hanin & Van Nieuwenhoven 2018b; Mevarech et al. 2010). Second, this study reinforces the close relationship between the emotional dimension and perceived competence posited by CVT (Pekrun 2006), confirmed by numerous correlational studies (Ahmed et al. 2010; Peixoto et al. 2017) and the relevance of addressing the learner's SEP to reach his/her achievement emotions. More precisely, it turns out that an intervention that simultaneously targets the cognitive and the motivational dimensions through a global self-regulated approach results in more numerous, stronger, and more sustainable emotional effects. In other words, it appears that the emotional effects induced by the mastery of specific problem-solving strategies are complemented by those associated with the reinforcement of SEP. The close and negative relationships between perceived competence and both the negative self-talk and the dysfunctional avoidance strategies (Hanin & Van Nieuwenhoven 2019; Johnston-Wilder et al. 2015) are visible in the steeper downward slopes for the combined condition.

With respect to problem-solving performance, both experimental conditions outperformed the control condition, in both the short and the long run. The lack of difference between the two experimental conditions is all the more surprising as SEP is acknowledged to be a powerful predictor of mathematical performance (Frenzel et al. 2007; Justicia-Galiano et al.

2017; Peixoto et al. 2017). One explanation may be that more positive SEP does not *de facto* imply better engagement (Walker and Greene 2009). In other words, even if the SEP intervention made the learners more confident about their ability to attain their own goals, this does not necessarily mean that they would strive their utmost to perform well on this particular task. Future research is needed to shed light on this observation.

In sum, the present study offers a theoretical as well as a practical contribution. Theoretically, it expands our knowledge of the interrelationships between the cognitive, emotional, and motivational dimensions of learning. Consistent with previous studies, it appears that supporting one dimension has a selective impact on the other two. Our findings suggest that acting indirectly on the emotional dimension, through a cognitive and motivational intervention, especially affects the positive emotions. A previous study showed that a direct intervention targeting emotions predominantly impacted the negative emotions (Hanin & Van Nieuwenhoven 2018c). Together, these findings deepen our understanding of the crucial and unique role played by each learning dimension and thereby the necessity of examining them together to have a more complete picture of the learning process. In practical terms, the study highlights the necessity of including helping students to develop a more positive perception of competence in mathematics teachers' specified objectives. This is all the more important as SEP is a strong predictor of students' effort expenditure, interest, persistence in the face of difficulties, self-regulated behaviors (Bouffard and Vezeau 2010; Peixoto et al. 2017) and of achievement and choice of math careers in adolescence and beyond (Ceci et al. 2014; Musu-Gillette et al. 2015). This work on SEP is critical not only for SEP itself, but also for its positive impact on emotions. The latter also have a prevalent effect on students' strategy choices, persistence, effort expenditure, self-regulatory behaviors and motivation (Pekrun 2006). In addition, emotions provoke feelings of alienation from learning and school, starting in the fifth grade (Artino 2009; Kramarski et al. 2010); according to Artino (2009), the 9- to 12-year-old period is the most important for developing attitudes about and emotional reactions to mathematics. The present study suggests an effective intervention for that age group, and in this way responds to the lack of interventions noted in the introduction.

Constraints on generalizability and directions for future research

Our findings provide evidence of the emotional and motivational efficacy of an intervention that promotes the development of specific problem-solving cognitive strategies and positive perceptions of competence among a large sample of upper elementary mathematics students from all over French-speaking Belgium. Empirical studies conducted worldwide have all come to the same conclusion: there is a strong link between cognition, emotions, and motivation in mathematics (e.g., Ahmed et al. 2013; Hanin & Van Nieuwenhoven 2016; Dettmers et al. 2011; Peixoto et al. 2017; Tzohar-Rozen and Kramarski 2017). This leads us to expect our findings to generalize to upper elementary students who participate in the eight sessions with the same content as described in this research. The length of the intervention matters, as evidenced by the close link between the duration of an intervention and its effectiveness (Dignath and Büttner 2008; Viguer et al. 2017). Previous empirical studies have shown that teachers' socio-demographic and socio-professional characteristics (Opdenakker and Van Damme 2006; Star et al. 2015), as well as students' level in mathematics (Hanin & Van Nieuwenhoven 2018a), do not influence the implementation of the intervention. Consequently, we do not expect these variations in the context to matter. However, the presence of an emotional and motivational decline during schooling (Jacobs et al. 2002; Metsämuuronen and Tuohilampi 2014; Roeser et al. 2000), the automatization of inappropriate strategies with age, and developmental issues do not allow us to predict similar outcomes with a younger or older sample. In the same vein, as we know that motivational and emotional constructs predict learning outcomes more strongly when measured at the level of specificity of a school subject (Schukajlow et al. 2017) or task (Ahmed et al. 2010; Bandura 1997), additional studies are needed to determine whether the same conclusions can be drawn about the replication of the study with other mathematical content and other school subjects.

Moreover, although the intervention is among the longest of those presented in the literature, 8 sessions remain rather brief, as possibly evidenced by the non-maintenance over time of certain changes (i.e., enjoyment, anger) observed at time 2 and by the absence of significant difference in performance between the two experimental groups. Thus, longer-term studies would be useful for determining all of the effects of the interventions, both immediate and delayed. Further, the present study relied solely on quantitative tools. However, scholars increasingly recommend adopting a mixed method approach, that is, combining qualitative and quantitative tools, to portray more fully and in greater detail the complexity of the phenomenon under study (Amaratunga et al. 2002; Creswell 2014). So, for instance, interviews and diaries could be used to complement self-report questionnaires. A mixed method approach could strengthen the measurement of emotion regulation strategies which, although it is based on solid psychometric properties (Hanin et al. 2017), operationalizes each strategy through a limited number of items. Finally, since the combined intervention in this study and the emotion intervention tested in a previous study (Hanin & Van Nieuwenhoven 2018c) act on different emotional variables, it would be interesting to examine the added value for mathematics achievement of an intervention combining activities addressing cognition, perceived competence, and emotions.

Appendix 1

Table 5 Examples of problem statements

Example 1	Mrs. Pissenlit's 5th grade class is going on an excursion. Several activities are planned for the 24 participants (Mrs. Pissenlit and the 23 students). Visit to the "Sea Life" aquarium: 6 admissions for 10 €. Rail journey: 120 € for the group. Each participant contributes €5. The rest of the excursion is paid for by the school. How much does the school have to pay?
Example 2	To celebrate his 60th birthday, my grandfather organized a picnic afternoon in his garden. He had ordered 260 balloons to inflate to decorate the garden. After the party, he suggested that all the grandchildren share the balloons. There are 8 grandchildren in total. How many balloons will each of the grandchildren receive?

Appendix 2

Table 6 Description of the eight sessions for the cognition + SEP condition

	Time Alloted	Description	Dimension targeted
Session 1	10 min	(1) Students listen to the reported opinions of other students in the 5th/6th grade on the utility of asking myself cognitive-motivational-emotional questions at different moments in solving a mathematical problem in order to convince myself of the importance of thinking and reflecting on my problem-solving process.	SEP (vicarious experiences)
	15 min	(2) Students define a clear, measurable and achievable goal for the entire sequence (the set of 8 problems that are going to be solved), by: - defining what I intend to do concretely to achieve my goal - specifying how I will check that my goal has been achieved.	SEP (enactive mastery experiences)
	8 min	(3) Students reflect before embarking on the problem about: - their capacity to solve the problem, - their strengths, - what they already learned that they could use, - the difficulties that they could encounter and what they could put in place to overcome them, - the emotions they feel.	SEP (self-evaluation; enactive mastery experiences; physiological and affective states)
	15 min	(4) Students solve the problem individually.	Cognitive dimension
	8 min	(5) Once the problem is solved, students reflect about what they just did and about the emotions they are feeling.	SEP (self-evaluation; physiological and affective states)
	30 min	(6) Students pool their individual approaches in small groups and develop a joint solution approach and solution.	Cognitive dimension
Session 1 and session 2	3–4 h	(7) -Group products are exploited in the form of teacher-student interactions to highlight the key cognitive strategies for solving a problem. - A summary sheet is co-constructed for each strategy specifying what it consists of, when it is appropriate to use it, its usefulness and how to proceed to implement it.	Cognitive dimension
Session 2	8 min	(8) Students try to understand their result (success vs. failure).	SEP (enactive mastery experiences)
	10 min	(9) Students take stock of their progress towards their goal (with the teacher's help) by asking themselves: - where am I in relation to my goal? - what should I change to get closer to my goal/what brought me closer? - what do I commit to for the next problem?	SEP (verbal and written persuasion through the teacher's individual feedback)
	Timing	Description	Dimension targeted
	10 min		- SEP (enactive mastery experiences)

Table 6 (continued)

	Time Alloted	Description	Dimension targeted
Sessions 3, 4, 6, and 7		(1) - Each student reads the objective (s)he has set for the sequence and the means (s)he has listed to achieve it. - Students engage in recall of cognitive strategies.	- Cognitive strategies
	8 min	(2) Students reflect before embarking on the problem about: - their capacity to solve the problem, - their strengths, - what they already learned that they could use, - the difficulties that they could encounter and what they could put in place to overcome them, - the emotions they feel.	SEP (self-evaluation; enactive mastery experiences; physiological and affective states)
	15 min	(3) Students solve the problem individually.	Cognitive dimension
	15 min	(4) In pairs, students explain their solution approach (verbalization and justification of the cognitive strategies used).	Global metacognitive strategy
	8 min	(5) Once the problem is solved, students reflect about what they just did and about the emotions they are feeling.	SEP (self-evaluation; physiological and affective states)
	45 min	(6) The teacher and students correct the answers to the problem together by reviewing each cognitive strategy.	Cognitive dimension
	8 min	(7) Once the answers have been corrected, students try to understand their result (success vs. failure).	SEP (enactive mastery experiences)
	10 min	(8) Students take stock of their progress towards their goal (with the teacher's help) by asking themselves: - where am I in relation to my goal? - what should I change to get closer to my goal/what brought me closer?- what do I commit to for the next problem?	SEP (verbal and written persuasion through the teacher's individual feedback)
	Timing	Description	Dimension targeted
	20 min	(1) Midway through the problem-solving sequence, students hear about the opinion of other students in the 5th/6th grade who have gone through the same sequence.	SEP (vicarious experience)
Session 5	10 min	(2) - Each student reads the objective (s)he has set for the sequence and the means (s)he has listed to achieve it. - Students engage in recall of cognitive strategies.	- SEP (enactive mastery experiences) - Cognitive strategies
	8 min	(3) Students reflect before embarking on the problem about: - their capacity to solve the problem, - their strengths, - what they already learned that they could use, - the difficulties that they could encounter and what they could put in place to overcome them, - the emotions they feel.	SEP (self-evaluation; enactive mastery experiences; physiological and affective states)
	15 min	(4) Students solve the problem individually.	Cognitive dimension
	8 min	(5) Once the problem is solved, students reflect about what they just did and about the emotions they are feeling.	SEP (self-evaluation; physiological and affective states)
	15 min		Cognitive dimension

Table 6 (continued)

	Time Alloted	Description	Dimension targeted
		(6) In pairs, students explain their solution approach (verbalization and justification of the cognitive strategies used).	
	45 min	(7) The teacher and students correct the answers to the problem together by reviewing each cognitive strategy.	Cognitive dimension
	8 min	(8) Once the answers have been corrected, students try to understand their result (success vs. failure).	SEP (enactive mastery experiences)
	10 min	(9) Students take stock of their progress towards their goal (with the teacher's help) by asking themselves: - where am I in relation to my goal? - what should I change to get closer to my goal/what brought me closer? - what do I commit to for the next problem?	SEP (verbal and written persuasion through the teacher's individual feedback)
	Timing	Description	Dimension targeted
Session 8	10 min	(1) - Each student reads the objective (s)he has set for the sequence and the means (s)he has listed to achieve it.- Students engage in recall of cognitive strategies.	- SEP (enactive mastery experiences)- Cognitive strategies
	8 min	(2) Students reflect before embarking on the problem about: - their capacity to solve the problem,- their strengths,- what they already learned that they could use,- the difficulties that they could encounter and what they could put in place to overcome them,- the emotions they feel.	SEP (self-evaluation; enactive mastery experiences; physiological and affective states)
	15 min	(3) Students solve the problem individually.	Cognitive dimension
	15 min	(4) In pairs, students explain their solution approach (verbalization and justification of the cognitive strategies used).	Cognitive dimension
	8 min	(5) Once the problem is solved, students reflect about what they just did and about the emotions they are feeling.	SEP (self-evaluation; physiological and affective states)
	45 min	(6) The teacher and students correct the answers to the problem together by reviewing each cognitive strategy.	Cognitive dimension
	8 min	(7) Once the answers have been corrected, students try to understand their result (success vs. failure).	SEP (enactive mastery experiences)
	15 min	(8) - Students take stock of their progress towards their goal regarding this last problem.- Students review each session to assess their goal attainment with the help of the teacher.	SEP (enactive mastery experiences; persuasion through the teacher's individual feedback)

Appendix 3

Table 7 Descriptive statistics

	Time 1			Time 2			Time 3		
	CT	CG	CS	CT	CG	CS	CT	CG	CS
Variable	*M* (*SD*)	*M* (SD)	*M* (SD)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Perceived competence	2.44 (.07)	2.49 (.07)	2.61 (.04)	2.39 (.07)	2.49 (.07)	2.80 (.04)	2.38 (.07)	2.43 (.07)	2.86 (.04)
Hope	2.80 (.18)	3.10 (.18)	3.11 (.11)	2.48 (.18)	3.08 (.18)	3.17 (.11)	2.49 (.18)	2.87 (.18)	3.18 (.11)
Enjoyment	3.08 (.17)	2.76 (.17)	2.80 (.11)	2.69 (.17)	2.69 (.18)	2.68 (.11)	2.39 (.17)	2.27 (.17)	2.31 (.11)
Pride	2.33 (.14)	2.89 (.14)	2.61 (.09)	1.94 (.14)	2.67 (.14)	2.53 (.09)	1.81 (.14)	2.63 (.14)	2.53 (.09)
Relief	2.86 (.15)	2.92 (.16)	2.58 (.10)	2.47 (.16)	3.00 (.16)	2.92 (.10)	2.35 (.16)	2.99 (.16)	2.98 (.10)
Boredom	.28 (.06)	.27 (.08)	.27 (.04)	.35(.07)	.29(.08)	.29 (.04)	.31 (.06)	.28 (.07)	.25 (.05)
Anger	.02 (.02)	.16 (.05)	.19 (.04)	.13 (.04)	.20 (.06)	.18 (.04)	.16 (.05)	.20 (.06)	.25 (.04)
Frustration	.15 (.05)	.41 (.08)	.34 (.05)	.22 (.06)	.26 (.07)	.28 (.04)	.14 (.04)	.38 (.08)	.31 (.05)
Hopelessness	.09 (.04)	.12 (.04)	.23 (.04)	.12 (.04)	.13 (.07)	.19 (.04)	.14 (.03)	.14 (.06)	.19 (.04)
Nervousness	.29 (.07)	.40 (.08)	.52 (.05)	.35 (.07)	.27 (.07)	.43 (.05)	.26 (.06)	.38 (.08)	.40 (.05)
Fear	.02 (.02)	.16 (.05)	.19 (.04)	.13 (.04)	.20 (.06)	.18 (.04)	.16 (.05)	.20 (.06)	.20 (.04)
Worry	.26 (.06)	.36 (.08)	.43 (.05)	.30 (.07)	.36 (.08)	.32 (.05)	.30 (.05)	.28 (.07)	.35 (.05)
Sadness	.07 (.03)	.12 (.05)	.18 (.04)	.09 (.04)	.07 (.03)	.16 (.04)	.06 (.03)	.16 (.05)	.16 (.04)
Shame	.06 (.03)	.19 (.07)	.10 (.03)	.07 (.03)	.17 (.06)	.11 (.03)	.06 (.03)	.13 (.05)	.11 (.03)
Task utility self-persuasion	3.21 (.11)	3.02 (.11)	2.83 (.07)	3.00 (.11)	3.03 (.11)	2.80 (.07)	2.70 (.11)	3.11 (.11)	2.80 (.07)
Help seeking	1.99 (.10)	2.33 (.10)	2.31 (.06)	1.86 (.10)	1.89 (.10)	1.96 (.06)	1.86 (.10)	1.90 (.10)	1.89 (.06)
Brief attentional relaxation	2.31 (.11)	2.33 (.11)	2.34 (.07)	2.18 (.11)	2.33 (.11)	2.36 (.07)	2.16 (.11)	2.33 (.11)	2.47 (.07)
Emotion expression	1.29 (.08)	1.49 (.09)	1.57 (.05)	1.42 (.08)	1.53 (.09)	1.43 (.05)	1.44 (.08)	1.48 (.09)	1.43(.05)
Negative self-talk	1.74 (.10)	1.93 (.10)	1.86 (.07)	1.96 (.10)	1.88 (.11)	1.69 (.07)	1.99 (.10)	1.80 (.10)	1.67 (.07)
Dysfunctional avoidance	1.45 (.07)	1.60 (.07)	1.59 (.05)	1.55 (.07)	1.46 (.08)	1.31 (.05)	1.44 (.07)	1.44 (.08)	1.34 (.05)
Performance	.30 (.02)	.29 (.03)	.28 (.02)	.28 (.03)	.51 (.03)	.50 (.02)	.39 (.03)	.52 (.03)	.51 (.2)

Note: M = mean; SD = standard deviation. Perceived competence ranges from 1 (low) to 4 (high); achievement emotions range from 1 (low) to 5 (high); emotion regulation strategies range from 1 (low) to 4 (high) and performance is from 0 (low) to 1 (high). CT = control group, CG = cognition condition, CS = cognition + SEP condition

Appendix 4

Table 8 Baseline differences between the three groups

Variable	$F(2, 331)$	p
Perceived competence	.054	.948
Achievement emotions		
Hope	.494	.611
Enjoyment	1.617	.200
Pride	1.092	.352
Relief	1.211	.305
Boredom	1.275	.281
Anger	1.718	.183
Frustration	1.702	.185
Hopelessness	.904	.409
Nervousness	1.620	.198
Fear	.902	.412
Worry	1.645	.191
Sadness	1.090	.354
Shame	2.281	.104
Emotion regulation strategies		
Task utility self-persuasion	1.171	.302
Help seeking	1.075	.340
Brief attentional relaxation	.219	.804
Emotion expression	.997	.409
Negative self-talk	.885	.414
Dysfunctional avoidance	.783	.458

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Vanessa Hanin. Prof. Université Catholique de Louvain, Research Institute of Psychological Sciences, Faculty of Psychology and Education, 10 Place Cardinal Mercier, B-1348 Louvain-la-Neuve, Belgium. email address: vanessa.hanin@uclouvain.be

Current research themes:

Vanessa Hanin obtained a Ph.D degree in psychological and educational sciences from the Université catholique de Louvain (UCLouvain) in 2018. She is now a professor in the Department of Sciences of Education at UCLouvain. Her research interests focus on how to promote the integrated mastery of both cognitive, metacognitive, emotional and motivational processes in upper elementary students in the context of mathematical problem-solving. She lectures in educational sciences, psychology and didactics of mathematics to graduate and undergraduate students.

Stéphane Colognesi. Prof. Université Catholique de Louvain, Research Institute of Psychological Sciences, Faculty of Psychology and Education, 10 Place Cardinal Mercier, B-1348 Louvain-la-Neuve, Belgium. Email address: stéphane.colognesi@uclouvain.be

Stéphane Colognesi obtained a Ph.D degree in psychological and educational sciences from the Université catholique de Louvain (UCLouvain) in 2015. Currently, he is a professor at UCLouvain in the Department of Sciences of Education. He lectures in Bachelor's and Master's programs in Psychology and Education. He is an active researcher in the field of teaching and learning – especially cognitive, metacognitive and motivational engagement – in both primary and secondary education and in the field of preservice teacher training.

Catherine Van Nieuwenhoven. Prof. Université Catholique de Louvain, Research Institute of Psychological Sciences, Faculty of Psychology and Education, 10 Place Cardinal Mercier, B-1348 Louvain-la-Neuve, Belgium. Email address: catherine.vannieuwenhoven@uclouvain.be

Current research themes:

Catherine Van Nieuwenhoven obtained a Ph.D. degree in Psychology from the Université Catholique de Louvain (UCLouvain). She is now a professor in the Department of Psychology at UCLouvain. She lectures in educational psychology, pedagogy, and research methodology to undergraduate and master students. Her research interests focus on how to promote the self-efficacy belief, emotional competencies, and heuristic and self-regulation strategies in upper elementary students in the context of mathematical problem-solving. She also undertakes research in the field of teacher training.

Most relevant publications in the field of Psychology of Education:

Hanin, V. & Van Nieuwenhoven, C. (2019). Emotional and motivational relationship of elementary students to mathematical problem-solving: a person-centered approach. *European Journal of Psychology of Education.* https://doi.org/10.1007/s10212-018-00411-7.

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