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Metacognitive Knowledge and Skills in Students with Deep Approach to Learning. Evidence from Mathematical Problem Solving

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Abstract

Student approaches to learning and metacognitive strategies are two important conditioning factors in solving mathematical problems. The evidence suggests that it is the deep approach to learning which leads to student success in such tasks. The present study focused on analyzing the differences in metacognitive knowledge and skills in a sample of 524 fifth and sixth grade students divided into three groups based on their different levels of use of a deep approach (241 = low; 152 = medium; and 131 = high). Metacognitive knowledge was assessed using the Learning Strategies Knowledge Questionnaire, while evidence about metacognitive skills was gathered by means of process measures (Triple Tasks Procedure) during students' solving of two mathematical word problems. Statistically significant differences in metacognitive knowledge were found among groups while differences in metacognitive skills were only found in the second task, with a low effect size.

Keywords: Deep approach to learning, Elementary school, metacognitive knowledge, metacognitive skills, Mathematics problem solving.

Resumen

El enfoque de aprendizaje y las estrategias metacognitivas son importantes condicionantes en la resolución de problemas matemáticos. La investigación ha puesto de relevancia que el enfoque profundo de aprendizaje dirige al estudiante al éxito en la ejecución de estas tareas. Este trabajo ha pretendido analizar las diferencias en el conocimiento y habilidades metacognitivas de 524 estudiantes de quinto y sexto de primaria clasificados en tres grupos en función del nivel de uso del enfoque profundo (241 = bajo; 152 = medio; 131 = alto). El conocimiento metacognitivo fue evaluado con el cuestionario de conocimiento de estrategias de aprendizaje, y las habilidades metacognitivas con medidas del proceso (Triple Tarea) durante la resolución de dos problemas matemáticos. Los resultados mostraron diferencias estadísticamente significativas en el conocimiento metacognitivo y, en las habilidades metacognitivas en la segunda tarea con un bajo tamaño del efecto.

Palabras clave: Enfoque profundo, educación primaria, conocimiento metacognitivo, habilidades metacognitivas, resolución de problemas matemáticos.

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Introduction

Solving mathematical problems is known to be an important issue in the formal educational setting. However, students often have difficulties in this area. This activity, which is first introduced in the early elementary years, may suppose the basis to develop further problem-solving skills. Much of the research has focused on the cognitive and metacognitive processes involved in solving mathematical word problems, highlighting the importance of self-regulated learning (SRL) as a determining factor of problem-solving proficiency (Krawec, Huang, Montague, Kressler, & Melia, 2012; Montague, Enders, & Dietz, 2011). In this way, recent studies have highlighted the relationship between SRL and the learning approaches adopted by the student as a key aspect of his or her achievement, specifically in problems that require deep processing (García, Betts, González-Castro, González-Pienda, & Rodríguez, in press; Ranellucci et al., 2013).

Approaches to learning

According to Baeten, Kyndt, Struyven and Dochy (2010), an approach to learning embeds both the intention of the student when starting a task and the learning processes and strategies they use to carry out this task. Biggs (1987) distinguished three approaches to learning (deep, surface and achieving), which have been substantiated in a wide range of studies (Kizilgunes, Tekkaya, & Sungur, 2009). A *deep approach* involves an attempt to integrate new information with prior knowledge and enables students to organize new information, relate ideas, and monitor their understanding of the information, which would be translated into a better performance (McInerney, Cheng, Mok, & Lam, 2012). A deep approach to learning is intimately linked to academic success (Murayama, Pekrun, Lichtenfeld, & vom Hofe, 2013). A s*urface approach* to learning involves rote memorization without deep elaboration. It commonly leads to acquire knowledge that fades quickly (McInerney et al., 2012; Murayama et al., 2013). Finally, an *achieving approach* refers to students making an effective use of space and time in order to maximize outcomes.

The students' choice of an approach to learning and its effectiveness relies on many different factors. However, authors such as Biggs (1993) noted that only the deep approach is "task focused"; that is, students using a deep approach pursue meaning and integration of knowledge, which leads to better results (Cano, García, Justicia, & García-Berbén, 2014). As such, studies in different educational levels have focused on encouraging students to develop a deep approach to learning (Murayama et al., 2013).

In this sense, the use of a deep approach to learning involves strategies such as reading deeply, thinking about what one has read or done, and making connections with prior knowledge or courses of action. All these processes require time and mental effort, and are related to students' ability to monitor their own learning progress in order to be successful (Biggs, 1987). This has led many authors to study to what extent a deep approach is linked to metacognitive and self-regulatory mechanisms (Ranellucci et al., 2013).

Metacognitive knowledge and skills

Metacognition is characterized by Pintrich as a superordinate ability to direct and regulate cognitive, motivational, and problem-solving processes in order to achieve a specific goal (Ifenthaler, 2012). It involves two main components: Knowledge and skills (Lucangeli & Cabriele, 2006). *Metacognitive knowledge* refers to declarative knowledge about learning strategies, procedural knowledge about how to use these strategies, and conditional knowledge about when and why to use them. *Metacognitive skills* (or application of this knowledge) involve those aspects that facilitate the control and regulation of one's cognitive system and learning process. These skills refer to abilities such as planning, self-monitoring, and self-evaluation and would represent the authentic procedures and strategies used during task performance to monitor and control one's cognition (Pennequin et al., 2010). Traditionally, both metacognitive components have been assessed through self-report techniques, mainly by means of questionnaires and interviews. However, many authors argue that, given its strategic and complex nature, evidence from metacognitive skills should be gathered by using methods based on real-time, or concurrent measures (Veenman, 2011). This approach, commonly referred to as *on-line* methods, includes procedures such as the Think-aloud (Montague et al., 2011) or the Triple Task protocols (Kellog, 1987; Piolat, Kellogg, & Farioli, 2001).

The distinction between these two components lies in the fact that, even when students know the different strategies, they do not necessarily are able to use them purposefully (Bransford, Brown, & Cocking, 2000). It has been argued in this sense that metacognitive knowledge might precede metacognitive skills (Pennequin et al., 2010). In this way, these authors pointed out that while metacognitive knowledge seems to start developing at the age of 6, the proper application of this knowledge (i.e., metacognitive skills) seems not to reach maturity until early adolescence, at the age of 11-12. As such, the present study focused on this particular age range, using a wide sample of 5th and 6th grade students from Northern Spain.

The present study

In this context, the present study was aimed at analyzing the relationship between a deep approach to learning and metacognition in its two dimensions (metacognitive knowledge and skills), focused the latter on mathematical problem-solving situations. To accomplish that, the sample of students was divided into three groups based on their use of a deep approach to learning (UDAL), determined by means of the Processes Study Inventory-PSI (Núñez et al., 2011; Rosário et al., 2013). Metacognitive knowledge was assessed through the Learning Strategies Knowledge Questionnaire (LSKQ: Núñez et al., 2011), while the application of this knowledge (or metacognitive skills) were assessed through on-line methods. Specifically, the Triple Task Procedure in Mathematics (TPTM; García et al., in press) was used to obtain an evidence of the metacognitive processes involved in solving two mathematical word problems.

Given the main aim of the present study, two specific goals were established: (1) to determine if students with different levels of use of a deep approach to learning exhibited different degrees of metacognitive knowledge, evaluated by means of self-report; and (2) to examine if those students showed different metacognitive skills, assessed through on-line measures. Given students' age range (10-12 years), it is presumable that they have acquired a basic metacognitive knowledge, but they are not necessarily able to properly use this knowledge in mathematics problem-solving situations.

Method

Participants

Participants were 524 students from 12 primary schools in northern Spain. Their ages ranged from 10 to 13 years (M = 10.99, SD = 0.716). Of them, 49.6% were female (n = 260). The sample comprised 220 students from 5th grade (42%; male = 108, female = 112) and 304 from 6th grade (58%; male = 156, female = 148). Sample selection was made through convenience procedures. Students volunteered for the study and presented informed consent from their parents. Children with a diagnosis of severe learning disabilities were excluded from the analyses. Students were divided into three groups based on the deepness of their approach to learning:

Group 1 (low use of a deep approach to learning UDAL) was composed of 241 students with a score below the 50th percentile on the Processes Study Inventory-PSI (Núñez et al., 2011; Rosário et al., 2013). Of them, 116 were female (48.1%) and 125 male (51.9%). Ages ranged from 10 to 13 years (M = 10.99; SD = 0.671). 95 students (39%) attended 5th grade and 147 (61%) attended 6th grade.

Group 2 (medium UDAL) was composed of 152 students with a score between the 50th and the 75th percentile on PSI. Of them, 79 (52%) were female and 73 (48%) male. Age ranged between 10 and 13 years (M = 11.05; SD = 0.783). 62 students (40.8%) attended 5th grade and 90 (59.2%) attended 6th grade.

Group 3 (high UDAL) was composed of 131 students with a score over the 75th percentile on the aforementioned questionnaire: 65 (49.6%) female and 66 (50.4%) male. Age ranged between 10 and 12 years (M = 10.92; SD = 0.713). 64 students (48.9%) attended 5th grade and 67 (51.1%) 6th grade.

There were no differences among UDAL groups in age $F(2, 523) = 1.166, p = .314$.

Measures

Deep approach to learning was assessed by means of the Processes Study Inventory-PSI (Núñez et al., 2011; Rosário et al., 2013). This variable was used to establish the different groups of comparison in the present study. The PSI scale measures both deep and surface approaches and is made up of 12 items (6 per component). Given the aim of the present study, only the first dimension of the scale, related to the deep approach to learning, was considered. Items are positively expressed and are scored on a 5-point Likert-type format, ranging from 1 (never) to 5 (always). The internal consistency of the dimension used, established through Cronbach's alpha, was .72 in this sample. Although not excellent, this coefficient is higher than those found with similar tools, such as the Learning Process Questionnaire (LPQ; Biggs, Kember, & Leung, 2001).

Metacognitive knowledge was assessed by means of the Learning Strategies Knowledge Questionnaire (LSKQ: Núñez et al., 2011). This test consists of 10 questions with 3 response options, 2 false and 1 true. Maximum score in this scale is 10. The items refer to important general strategies students use in learning situations. This scale does not differentiate among different phases in the learning process, in contrast to the measure of metacognitive skills presented below. Thus, it only evaluates a dimension, based on general metacognitive knowledge. Cronbach's alpha of the total scale was .89 in the present sample. The ten strategies evaluated, as well as the items of the deep approach to learning dimension can be shown on https://www.dropbox.com/s/z5088t7uf5jest0/Cuestionarios%20Psicodid%C3%A1ctica.pdf?dl=0

Metacognitive skills were assessed through process measures, taken during problem-solving performance. The *Triple Task Procedure in Mathematics-TTPM* (García et al., in press) was used for this purpose. It is based on the Triple Task technique (Piolat, Kellogg, & Farioli, 2001), initially used in written composition. In Triple Task procedures, students perform three tasks simultaneously: (a) a primary task under investigation (mathematics problem solving in this study), (b) a secondary probe task (based on Response Time —RT—), and (c) a third task of categorization, in which participants are asked to label the process that was interrupted by the probe. RT's are collected as a control measure, which guaranties that students are engaged enough in the task and report the process they are concurrently performing.

Triple Task protocols are based on directed introspection, (i.e., students are provided with a system of categories or sub-processes according to which they categorize their cognitive activity). In this sense, the main characteristic of TTPM is related to the designed category system, based on the Self-Regulated Learning (SRL) phases of planning, execution and evaluation (Núñez et al., 2011, Zimmerman, 2000) and Bransford and Stein's (1993) IDEAL model of problem solving. This model defines five steps to be taken in order to solve a problem successfully. A total of eight categories or sub-processes were proposed. Chart 1 shows these subprocesses in relation to the phases and steps of the two models. In accordance with previous studies (Piolat et al., 2001; Rodríguez et al., 2012), an additional category "other" was incorporated to gather thoughts and activities unrelated

Chart 1

Category System. Based on Self-Regulation Model (Rosário et al., 2008; Zimmerman, 2000) and the IDEAL Problem-Solving Model (Bransford & Stein, 1993)

SRL Model	IDEAL Model	Process categories (I am ...)
Planning	Identification of the problem	Reading
	Definition and representation	Drawing or summarizing Recalling similar problems
	Exploration of possible strategies	Thinking about a solution
Execution	Action based on the strategy	Calculating Writing a response
Evaluation	Look at effects of solutions	Reviewing Correcting mistakes
"Other"		Doing something unrelated

to the mathematical task (i.e., day-dreaming). The categories "reading" and "writing", which may result ambiguous at first glance, refer to reading the statement of the problem and writing a response to the problem, respectively. Prior to the administering the TTPM protocol, students were trained in recognizing each category.

The TTPM was administered during the performance of two mathematical word problems, taken from the book *"Problem solving and comprehension"* (Whimbey & Lochhead, 1993):

— Problem 1*: "Beatriz lends €700 to Susana. But Susana borrows €1500 from Ester and €300 from Juana. In addition, Juana owes Ester €300 and Beatriz €700. One day they meet at Beatriz's home to settle their debts. Who went back home with €1800 more than she brought?"* Correct Response: Esther.
— Problem 2: *"Paula, Mari and Juana have a total of 16 dogs, 3 of which are poodles, 6 are hounds, and the rest of them are German shepherds and Pekinese dogs. Juana does not like poodles and Pekinese dogs, but she has 4 hounds and 2 German shepherds, giving a total of 6 dogs. Paula has a poodle and 2 more dogs, which are German shepherds. Mari has 3 Pekinese dogs and several dogs of other breeds. Which breeds, and how many dogs of each breed, does Mari have?"* Correct Response: Mari has two poodles and two Pekinese dogs.

These kinds of problems are stated in everyday language and deal with fairly realistic situations. They are characterized as *context problems* (Harskamp & Suhre, 2006), and do not contain algebraic expressions. As they do not involve specific mathematical contents, students' failure is assumed to be due to other, more strategic, processes.

Procedure

The study was conducted in accordance with The Helsinki Declaration of the World Medical Association (Williams, 2008). The evaluation was collectively administered during two regular classes. The deep approach to learning and metacognitive knowledge (using self-report) were assessed in the first session. Metacognitive skills, evaluated by means of process measures (TTPM), were taken in the second session, concurrent to the performance of the two mathematical problems.

The first phase in TTPM administration consisted of training students to become familiar with the category system and the evaluation procedure. The hypothetical case of a boy of their age (Alex), who tried to solve a mathematical problem, was used. After training, students performed a category-recognition test consisting of 18 multiple-choice items (2 per category), with four response alternatives. Students had to indicate the category that best fitted each proposed activity (e.g., for the statement "Alex made a mistake, so he is erasing", the alternatives were Alex is: "thinking about a solution", "writing a response", "doing something unrelated to the task" or "correcting mistakes").

Before starting TTPM administration, students performed a preliminary RT task, based on responding to an image accompanied with a tone, and presented at different time intervals (10-15 seconds). They had to mouse click on the stimuli appearing on the screen as quick as possible. This task was aimed at making students familiar with the response method. Thus, students were told that the same stimuli would appear while solving the tasks, after which a box with the category system would appear on the computer screen, asking them to report the sub-process they were engaged in at each moment. During TTPM performance, the visual-auditory stimulus were presented in intervals of 40-45 seconds, and RT's were measured (i.e., probe task). As data were collected from individual students simultaneously, headphones were provided in order that other students were not disturbed. Data collection was implemented through Moodle platform. In order to accomplish that, a multidisciplinary team, including psychologists, teachers, and a computer engineer collaborated during the study. Once data were obtained and stored, they were automatically transferred to an Excel file for subsequent processing. Students were given the mathematical problems on paper, which were also displayed on the computer screen.

Students who showed difficulties understanding the category system (those with less than 90% correct responses in the categorization test) were excluded from the analyses. Process variables were based on frequency counts. Frequency of each sub-process or category was established by dividing the frequency of election of each category by the total number of elections across categories. These frequency counts were then transformed into percentages by multiplying the quotient by 100.

Data analysis

First, in order to analyze differences among groups with different use of a deep approach to learning (UDAL) in metacognitive knowledge, Univariate Analysis of the Variance (ANOVA) was conducted. Considering the criterion of Finney and Di Stefano (2006), for whom intervals of ±2 and ±7 are the allowable values of skewness and kurtosis respectively to conduct parametric analyses, this variable met normality conditions. For the interpretation of effect sizes, Cohen's (1988) criterion was used, which establishes that the effect is small when $\eta p^2 = .01$ ($d = 0.20$), medium when

ηp^2 = .059 (*d* = 0.50), and high if ηp^2 = .138 (*d* = 0.80). Schefee's post-hoc analyses were carried out to determine differences between pairs of groups. Second, and given that process variables (TTPM) did not meet normality conditions (Tables 2 and 3), nonparametric analyses were conducted. Kruskal-Wallis statistic was used to analyze differences among groups. As the nonparametric nature of these statistics did not allow to conduct post-hoc analyses, differences between pairs of groups were analyzed using Mann-Whitney U-statistic for each comparison. Cliff's delta was taken as a measure of effect size (Macbeth, Razumiejczyk, & Ledesma, 2011). The value of this statistic ranges from –1 (if scores in Group 2 are larger than scores in Group 1) to +1 (if scores in Group 2 are smaller than scores in Group 1), and takes the value of zero if the two distributions are similar (i.e., absence of significant differences).

SPSS v.19 was used to conduct statistical analyses, except for calculating effect size for process variables. Cliff's Delta Calculator (CDC; Macbeth et al., 2011) was used for this purpose. To interpret effect size, Cohen (1988) established a correspondence between Cohen's *d* and this statistic. An δ value of ±.147 will have an effect size of *d* = 0.20, an δ value of ±.33 will correspond to an effect size of *d* = 0.50, and an δ of ±.474 will have an effect size of *d* = 0.80. Separate analyses were conducted for each task. A *p*-value ≤ .05 was established as criterion of statistical significance.

Results

Metacognitive knowledge

The mean of the general group in the LSKQ scale (Núñez et al., 2011) indicated a moderate but not high metacognitive knowledge among the students (*M* = 5.527; *SD* = 1.870). Descriptive analyses also indicated that this variable met normality conditions (*Kurtosis* = –.234, *Skewness* = –.017).

ANOVA indicated the existence of statistically significant differences in metacognitive knowledge among groups with different use of a deep approach to learning (UDAL) [$F(2, 523)$= 17.463, $p \le .001$] with a medium effect size (ηp^2 = .063). In this sense, increasing levels of UDAL related to an increase in metacognitive knowledge (low UDAL: *M* = 5.037, *SD* = 1.919; medium UDAL: *M* = 5.793, *SD* = 1.714; high UDAL: *M* = 6.122, *SD* = 1.723). Scheffé's post-hoc analyses indicated that differences were significant between the groups with low and medium UDAL ($p \le .001$), and the groups with low and high UDAL ($p \le .001$).

Metacognitive skills

Descriptive statistics for process variables in each task are shown

Table 1

Descriptive Statistics for Process Variables and Group Differences. Task 1

Process categories	Group 1 (*n* = 241)	Group 2 (*n* = 152)	Group 3 (*n* = 131)	General group		
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*	Kurtosis	Skewness
Reading	15.937 (14.460)	17.092 (15.555)	16.603 (15.823)	16.438 (15.109)	5.871	1.952
Drawing or summarizing	10.885 (17.408)	12.210 (17.996)	12.438 (16.556)	11.984 (17.352)	2.507	1.663
Recalling similar problems	2.829 (6.794)	3.065 (6.381)	3.328 (6.913)	3.022 (6.697)	8.160	2.693
Thinking about a solution	20.564 (18.424)	18.322 (16.619)	17.610 (15.273)	19.175 (17.181)	1.250	1.111
Calculations	27.240 (22.523)	28.848 (24.009)	26.877 (22.102)	27.616 (22.832)	–0.314	0.646
Writing	11.340 (11.999)	10.842 (11.204)	13.542 (13.023)	11.746 (12.066)	1.942	1.280
Reviewing	6.070 (9.412)	5.710 (8.695)	7.404 (9.466)	6.299 (9.230)	2.319	1.566
Correcting mistakes	3.688 (7.731)	3.875 (7.935)	3.771 (8.433)	3.763 (7.955)	8.431	2.658

Note. Group 1 = low use of a deep approach to learning (UDAL), Group 2 = medium UDAL; Group 3 = high UDAL. Means refer to the mean frequency percentage reported by students in each category.

$^*p \leq .05$. $^{**}p \leq .01$. $^{***}p \leq .001$.

in Tables 1 and 2. As these variables did not meet normality criterion, non parametric analyses were conducted.

Regarding the metacognitive process showed by students in the general group, means indicate the presence of quite similar profiles in both tasks. Specifically, students reported spending most time doing calculations in comparison to the rest of sub-processes. Students in the two tasks also reported spending a large amount of time thinking about solutions, and less time using strategies such as recalling similar problems or drawing/summarizing. Regarding evaluation processes, the use of reviewing and correcting mechanisms were the least frequently reported by students.

With relation to differences among groups, Kruskal-Wallis statistic indicated a lack of significant differences in Task 1. Results in this sense are explained as tendencies. Specifically, means in Table 1 indicated the following pat-

Table 2

Descriptive Statistics for Process Variables and Group Differences. Task 2

Process categories	Group 1 (*n* = 241)	Group 2 (*n* = 152)	Group 3 (*n* = 131)	General group		
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*	Kurtosis	Skewness
Reading	14.771 (13.928)	11.914 (15.976)	12.816 (13.931)	13.454* (14.579)	8.040	2.232
Drawing or summarizing	13.215 (21.254)	12.782 (20.286)	14.389 (22.005)	13.383 (21.138)	3.043	1.868
Recalling similar problems	2.352 (6.143)	3.118 (8.081)	1.938 (4.918)	2.471 (6.510)	16.305	3.553
Thinking about a solution	18.527 (20.208)	19.322 (19.100)	17.954 (18.599)	18.614 (19.467)	2.110	1.439
Calculations	31.107 (25.056)	33.335 (26.090)	27.984 (24.668)	30.973 (25.298)	-0.847	0.438
Writing	13.933 (14.238)	11.776 (13.646)	15.771 (14.831)	13.767* (14.270)	2.435	1.375
Reviewing	3.062 (6.084)	3.703 (6.967)	6.984 (10.113)	4.229*** (7.683)	4.877	2.052
Correcting mistakes	3.203 (7.550)	4.203 (9.681)	2.236 (5.843)	3.251 (7.888)	17.255	3.498

Note. Group 1 = low use of a deep approach to learning (UDAL), Group 2 = medium UDAL; Group 3 = high UDAL. Means refer to the mean frequency percentage reported by students in each category.

*$p \le .05$. **$p \le .01$. ***$p \le .001$.

tern: Groups with medium and high UDAL tended to read, use information representation strategies, and recall similar problems more frequently than the group with low UDAL, while this last group spent more time thinking about solutions. he group with high UDAL tended to do calculations less, but to write a response and use revision mechanisms more frequently than the other groups; finally, no differences seemed to be observed in correcting mistakes.

With regard to Task 2, Kruskal-Wallis statistic showed statistically significant differences in reading [$\chi^2(2)= 8.215$, $p = .016$], writing [$\chi^2(2) = 7.170$, $p = .028$], and reviewing [$\chi^2(2) = 17.951$, $p \le .001$]. Student with low UDAL spent more time reading than the rest of the groups, while the high UDAL group wrote and reviewed more frequently than those with low and medium UDAL (Table 2). Mann-Whitney U-test conducted for pairs of groups indicated that there were signifi-

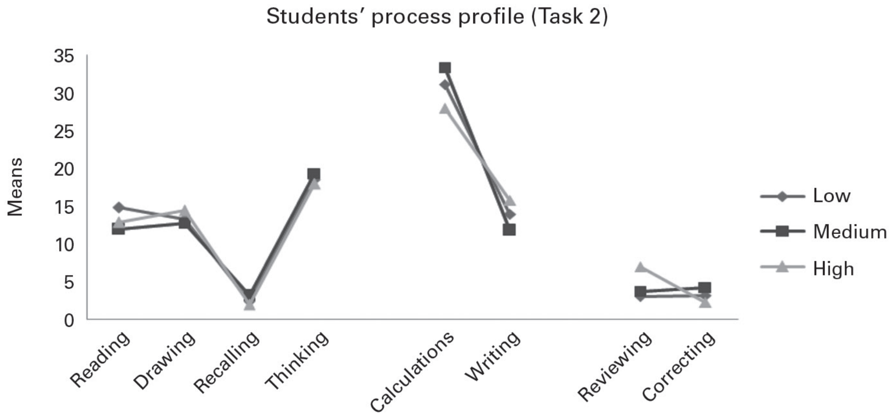

Figure 1. Process reported by students in the three groups in Task 2. Statistically significant differences among groups with different use of a deep approach to learning (UDAL) were found in the sub-processes of "reading", "doing calculations" and "reviewing".

cant differences in reading between the groups with low and medium UDAL (U = 12533.500, p = .005, Cliff's δ = .118), while differences in writing were found between the groups with medium and high UDAL (U = 8160.500, p = .008, Cliff's δ = –.132). Finally, significant differences in reviewing were found between the groups with low and high UDAL (U = 12522.500, $p \leq .001$, Cliff's δ = –.138) and between the groups with medium and high UDAL (U = 8236.000, p = .003, Cliff's δ = –.132). The negative sign of Cliff's δ statistic indicated that means were higher in the second group of comparison. Taking Cohen's (1988) correspondence criterion into consideration, effect sizes were low.

Figure 1 shows the metacognitive process exhibited by the different groups in Task 2.

Discussion

The main purpose of the present study was to analyze the differences in metacognitive knowledge and skills among groups with different use of a deep approach to learning (low, medium, and high UDAL). A sample of 524 fifth and sixth grade students took part in the study. Regarding metacognitive knowledge, students in the general group had a moderate but not high knowledge of the metacognitive strategies, evaluated by means of a strategy recognition test. However, statistically significant differences among groups with different UDAL were found. Specifically, a higher UDAL was related to increasing levels of metacognitive knowledge. These findings reflect those of previous studies that highlighted an association between metacognition and a deep approach to learning (Malmberg, Jarvenoja, & Jarvela, 2013; Rosário et al., 2013).

With regard to self-regulation skills, assessed though the TTPM in two mathematical problem-solving tasks, the results did not show the existence of a clear pattern of differences. Although some significant differences among groups were found in Task 2, mainly concerning revision, it can be concluded that student seem to undertake the problems in the same way, regardless of the deepness of their approach to learning. The finding that only significant differences were present in Task 2 could be related to the fact that this second problem involves more relationships to establish, which could have made it more complex, enhancing the use of metacognitive skills, mainly those related to revision mechanisms. However, the use of only two problems impedes to reach a clear conclusion in this sense.

A feasible explanation for these results is related to the fact that, generally speaking, students in the present study showed moderate but not high levels of metacognitive knowledge. This result could be related to a lack of experience with or explicit use of metacognitive strategies in common learning situations, as authors such as Sengodan and Zanaton (2012) suggested. This lack of experience could then explain why students were not particularly successful identifying those strategies in the LSKQ. Considering metacognitive knowledge as the basis for the development of metacognitive skills (Pennequin et al., 2010), it is not surprising that the absence of high levels of knowledge of metacognitive strategies predicts a low application of them in real situations. Previous studies showed that students commonly demonstrate poor metacognitive skills while solving mathematical problems. They forge ahead without considering alternative decisions, jumping immediately into calculations, giving impulsive responses, trying the same strategies even when they are wrong, or using trial and error as solving mechanisms (Montague et al., 2011). In fact, students in the general group showed a lack of revision mechanisms, and a clear preference for using familiar processes such as doing calculations as a method to solve the problems, instead of using other kind of strategies (i.e., information representation), which have demonstrated their usefulness in problem solving (García et al., in press). Among other factors, this could be related to a lack of familiarity with these sorts of tasks. Previous studies focused on the process suggest that novice students tend to spend more time on familiar procedures (e.g., calculations) without making sure they follow a correct solution plan. On the other hand, experts are more capable of representing problem situations in many forms (e.g., a graph, a sketch or a table), they are more flexible in the strategies they use, and are more able to monitor their resolution process (Harskamp & Suhre, 2006).

Another explanation for these results could be related to the distinction between on-line and off-line measures, and the low degree of correspondence they show (Özcan, 2014; Veenman, 2011). It is necessary to point out that the use of deep approach to learning and metacognitive knowledge were assessed by means of questionnaires (i.e., off-line measures) in the present study, while metacognitive skills were evaluated though the administration of a measure of the process, concurrent to problem-solving performance (i.e., on-line measures). Thus, an absence of significant differences in metacognitive skills could be partially explained by the use of different types of measures.

Implications

Beyond the relationship between a deep approach to learning and the components of metacognition, is important to note that while students in the present study had a moderate metacognitive knowledge, they showed poor metacognitive skills during problem-solving situations. This suggests that students might have not developed adequate metacognitive skills yet, at least for the sort of tasks they tackled in this study. As Valle et al. (2009) pointed out, for students to be successful, they need to understand and know these strategies, but also put them into practice accurately. This aspect has an important educational implication that is the need to provide students with learning situations and tasks that help them to develop these skills.

Limitations

First, the low effect size found in process measures calls for a certain degree of caution concerning the scope of our findings. As this low effect size seems to be related to the high variability observed in student problem-solving processes, obtaining more homogeneous groups may be imperative in future research. Second, students were classified according to their learning approach by administering a unique self-report scale. Third, only the deep approach to learning was taken into account to classify students. Different approaches and their possible interactions should be considered in further research (Chen & McNamee, 2011; Malmberg et al., 2013). Finally, the possibility that TTPM results reactive for students, leading to changes in both process and performance, must be considered. In this line, Kellog (1987) found that although the use of this sort of measure may increase the time to complete the task, simply instructing participants to verbalize of categorize their thoughts during a task does not alter the sequence of the cognitive processes or performance. The use of low- to medium-rate time intervals between probes (e.g., 40-45 seconds) has also demonstrated to help reduce this effect (García & Rodríguez, 2007).

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