When metacognitive prompts help information search in collaborative setting

Effets d'incitations métacognitives sur la recherche d'information en situation collaborative

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Abstract

Introduction

It is not surprising that information problem solving (hereafter IPS) as “metacognitively complex situations” (Veenman, Wilhelm and Beishuizen, 2004) become an interesting area to study ways to foster the metacognitive processing they required, but that are not spontaneously activated.

Objective

The goal of the present study was to investigate the positive effect of metacognitive incentives, provided as question prompts, on the metacognitive processing required to collaboratively solve the information problem, and on the IPS scores.

Method

On the basis of the literature, the prompts were embedded in the IPS process and aimed to support three steps of IPS: information search, information classification and information presentation. Such question prompts were expected to positively impact IPS scores related to each step, compared to a condition without prompt. Moreover, we assumed that the positive effects of question prompts would be mediated by the level of metacognitive processing they activated. An experimental study involving IPS partially conducted in dyads was conducted with two conditions (with prompts, n =12 and without prompts, n = 14).

Results

Results partially confirmed the direct and mediated effects of question prompts, but only when oriented on the first step of information search. There were no effects of the question prompts orienting on the next steps of information classification and information presentation.

Conclusion

Results of this study shed light on the role of metacognition in IPS and allowed to suggest some instructional implications of question prompts to support the IPS process.

Keywords: metacognition, information-problem solving, questions prompts, peer interactions.

Cette recherche a pour but d'étudier l'effet d'incitations métacognitive sous forme de question sur la résolution de problème d'information (ci-après IPS) en situation collaborative. Ces prompts métacognitifs étant spécifiques au domaine, ils se sont basés sur une segmentation du processus de résolution du problème telle que définie dans les modèles théoriques du domaine. Ainsi, trois étapes ont été distinguées, de recherche d'information proprement dite, de classification des informations et de présentation de ces informations. Il était attendu que les prompts métacognitifs aient un effet positif sur les scores relatifs à chaque étape. Cet effet positif devait être un effet indirect des prompts métacognitifs, médiatisé par le traitement métacognitif du problème qu'ils devaient préalablement provoquer. Une étude expérimentale a été réalisée, partiellement conduite en binômes, impliquant deux conditions (avec prompts métacognitifs, n=12 et sans prompts, n=14). Les résultats ont partiellement confirmé les effets directs et médiatisés des prompts métacognitifs, puisqu'ils ne se sont réalisés que dans la première étape de recherche d'informations. Aucun effet des prompts métacognitifs n'a été vérifié dans les deux autres étapes de classification et de présentation des informations. Une discussion de ces résultats est proposée, ainsi qu'une mise en perspective de leurs limites et de leur potentielle contribution à la problématique du rôle de la métacognition dans les résolutions de problèmes d'information.

Mots-clés: métacognition, resolution de problème d'information, questions incitatives, interactions

1. Introduction

It is commonly observed that metacognition is a "hallmark of effective learning" (Kauffman, 2004). This is particularly true in information problem solving (IPS), which are "metacognitively complex situations" (Veenman, Wilhelm and Beishuizen, 2004), in the sense that they require executing metacognitive strategies such as orientation, monitoring and evaluation (Brand-Gruwel, Wopereis and Vermetten, 2005; Walraven, Brand-Gruwel, and Boshuizen, 2008; Wopereis, Brand-Gruwel, and Vermetten, 2008). Indeed, searching and processing information is a complex cognitive process (Stadler, Bromme, and Stahl, 2008), that can be considered as an ill-structured problem consisting to "*find the most relevant information in the least amount of time*" (Wopereis *et al*., 2008). It is so not surprising that IPS become an interesting area to study ways to foster metacognition, especially since IPS has started to emerge as a learning task embedded in curricula (Lazonder and Rouet, 2008). However, according to these authors, research in this field of interest has until now hardly investigated the adequate instructional methods to develop IPS skills, and particularly the possible role of metacognitive mediation in learning IPS.

Following this direction, we first propose to clarify what we mean by metacognition and then characterize information problem solving on the basis of the information-problem solving processes and steps as decomposed in the literature (Walraven *et al*., 2008; Wopereis *et al*., 2008; Stadler *et al*., 2008). On the basis of this framework, we propose a method of metacognitive prompting that takes the form of driving questions (Bannert, 2006; Berardi-Coletta, Dominowski and, Rellinger, 1995; Berthold, Nückles and, Renkl, 2007); Thillmann, Künsting, Wirth and, Leutner, 2009). Such driving questions are expected to positively impact performance on information problem solving, but indirectly, according to a mediation hypothesis. This hypothesis states that the effect of metacognitive prompts is mediated by the amount of metacognitive processes actually activated. We then propose to examine the role of this intermediate variable that lies in the causal paths between the driving questions and outcome variables. Finally, we discuss the findings regarding their theoretical and practical limits and implications.

1.1. What do we mean by metacognition?

Since Flavell (1979) introduced the concept of metacognition in the seventies, and despite the extensive body of research that has been carried out on the area, metacognition still remains a fuzzy concept (Veenman, Van Hout-Wolters, and Afflerbach, 2006). This may explain why most researchers neglect to establish their conceptual definition of metacognition, although their investigation deals with this concept (Lazonder and Rouet, 2008; Kaplan, 2008; Alexander, 2008). However, according to Lazonder and Rouet (2008), the primary condition to study positive effects of metacognitive interventions on information problem solving is to clarify what we mean by metacognition.

According to Nelson and Narens (1994), metacognition is defined as a system that functions at a meta-level. This meta-level represents and governs an object-level, that is, cognition (Efklides, 2008). The meta-level is informed by the object-level through monitoring processes and modifies the object-level through control processes. Distinct metacognitive subcomponents are manifestations of these two processes. Metacognitive knowledge and experiences are related to the monitoring function, whereas metacognitive strategies are manifestations of the control function (Efklides, 2006). What distinguishes metacognitive knowledge from metacognitive experiences is the kind of monitoring they involve. Metacognitive knowledge are related to an offline monitoring of cognition whereas metacognitive experiences represent an online monitoring of cognition (Efklides, 2008).

The focus is here on metacognitive experiences, occurring during a cognitive activity (Flavell, 1979), such as a learning task. They are “the interface between the person and the task, the awareness the person has of task features, of the fluency of cognitive processing, of the progress toward the goal set, of the effort exerted on cognitive processing, and of the outcome of processing" (Efklides, 2008, p. 279). When they result from conscious and analytic metacognitive judgment, these metacognitive experiences, through the monitoring of cognitive processing features, call for control decisions that are then consciously triggered. As described earlier, these control decisions are related to metacognitive strategies, such as planning strategies, strategies of regulation of cognitive processing, strategies for monitoring the execution of planned action and strategies for the evaluation of the outcome of task processing (Veenman *et al*., 2006). Thus, metacognitive experiences and metacognitive strategies are closely connected, since metacognitive experiences provide the input that trigger control decisions (Efklides, 2008). They form a self-regulation process, oriented towards the regulation of cognitive operations when solving a problem.

As noticed by Veenman *et al.* (2004), information problems are typically the kind of problems that require to carry out and regulate complex cognitive processes. On the basis of our conceptualization of metacognition, we propose to portray the IPS process as described in various theoretical models in this field.

1.2. What do we mean by IPS?

Information seeking behavior has been extensively studied in the last decades. This is not surprising, given that information search became, in particular with the development of Internet, one of the basic daily tasks that people perform for professional, educational or personal objectives. In a broad perspective, various theoretical models have clarified the cognitive processes underlying information search (Lazonder and Rouet, 2008). In a more restricted learning-oriented perspective, the research has focused on what has been called information problem solving (Brand-Gruwel and Gerjets, 2008). When embedded in curricula, information problem appears as challenging problem-based learning task (Nadolski, Kirschner and van Merriënboer, 2006; Walraven et al., 2008; Wopereis et al., 2008). Despite its apparent triviality, information problem matches the definition of an ill-defined problem, with ill-defined goal, open solutions, infinite search space, and in most cases, no general strategy readily available (Guthrie, 1988; Rouet and Tricot, 1996). The model of Wopereis *et al.*, (2008), in decomposing the substantial number of constituent skills and sub skills included in information problem, reveals the complexity of IPS. Five constituent skills are mentioned, that are "*defining the information problem*", "*searching for information*", "*scanning information*", "*processing information*" and "*organizing and presenting information*". Lazonder and Rouet, (2008) pointed out that their status is ambiguous. According to these authors, these components should refer to steps rather than skills, in order to reveal the time-ordered sequence of IPS.

In addition to propose a detailed decomposition of steps and sub skills involved in an IPS process, the model of Wopereis et al. (2008) integrates three other important dimensions of IPS. Firstly, sub skills involved in the information-searching phase reveal the complex cognitive processes required in IPS that rely on general cognitive abilities like text comprehension and working memory capacity (e.g., Rouet and Tricot, 1996), as well as on students' knowledge, both for domain-specific concepts and for information search expertise (e.g., Vibert, Rouet, Ros *et al.*, 2007).

Secondly, a regulation component is included in the model, which iteratively involved different regulatory activities over the whole IPS process. These activities, referred as orientation, monitoring, steering and testing, are continuously required during the execution of all the constituent steps of the IPS process. Beyond the particular terms used by the authors, the different regulation activities they define do not differ from the self-regulation process described earlier. As for any ill-defined problem solving activity, this self-regulation process is involved in all stages of the process and dramatically affects performance (Boekhorst, 2003; Brand-Gruwel *et al.*, 2005; Hill, 1999; Lazonder, 2003). In the field of IPS, research demonstrated that an effective IPS requires constant monitoring, evaluation and regulation processes, particularly regarding the assessment of relevance of sources and information within sources (Strømsø, Bräten and Britt, 2009).

Thirdly, the model of Wopereis *et al*., (2008) brings together the first four steps of the IPS process into an analysis phase, whereas the last step is related to a synthesis phase. These phases are oriented towards two distinct sub goals, namely generating and transforming information (Lazonder and Rouet, 2008; Thillman *et al*., 2009). Indeed, in an information problem, information required to solve the problem are not present at the beginning of the process; they must be generated before being transformed. In other words, the goal of the synthesis phase is to organize and present the product of the analysis phase, according to the form required in the task requirements, such as reports, articles or presentations (Brand Gruwel *et al*., 2005). Thereby, successfully solve an information problem involves to allocate as much attention and cognitive resources to the two sub goals.

The model of Wopereis *et al*., (2008) gives rise to the substantial set of cognitive and metacognitive requirements required to succeed in solving an information problem. The research has provided evidences that, when proposed as a learning task, information problem can cause difficulties (Brand-Gruwel and Gerjets, 2008; Walraven *et al*., 2008). More particularly, the metacognitive processing required in IPS seems particularly problematic because not spontaneously activated (Stadler and Bromme, 2008). Consequently, this problematic dimension needs to be “carefully framed and supported” (Lazonder and Rouet, 2008). Designing effective metacognitive support constitutes an important issue in the fields of metacognition and IPS. Question prompts are a promising way to support metacognition in IPS, when the literature and the research on the matter guide their design.

1.3. Metacognitive prompts as a way to improve IPS

There is a wide variety of question prompts, regarding the different purposes they serve, the different processes they guide, the different domains they are related to. When question prompts aimed to support knowledge acquisition, they are domain-specific, because they act at the problem level, in asking questions such as: "what field of low dose this case belong to?" (Nadolksi *et al*., 2006). On the contrary, when question prompts aimed to systematize general metacognitive skills (Schraw and Moshman, 1995), they could be applied in multiple domains, because they are content-free and take the form of regulatory checklists such as "What is my goal?", "Do I have a clear understanding of what I am doing?". When these two kinds of question prompts are combined, they become metacognitive domain-specific question prompts, in integrating the domain-specific characteristic of the first question prompts and the focus on a metacognitive level of the second. Berardi-Coletta *et al*., (1995), in asking questions such as "how are you deciding which disk to move next?", have demonstrated the potential of these metacognitive domain-specific question prompts to induce a metacognitive processing, by explicitly focusing the participants on what they were doing, how and why, and on checking the value of their strategies and actions.

In the more specific field of IPS, when information problems are proposed as realistic whole learning tasks, question prompts have to support the substantial number of phases, steps and sub skills involved in the IPS process. However, regarding the complex segmentation of IPS, the difficulty is to find a relevant integration of question prompts. Indeed, Nadolski *et al*., (2008) assumed a detrimental interaction between the number of phases and the availability of question prompts in the sense that giving question prompts when the whole task is divided in a high number of phases might provide too much support, and then become detrimental to learning.

The design of metacognitive IPS question prompts is also based on what we mean by metacognition, previously clarified. To induce a metacognitive processing, as defined in metacognitive theories, question prompts have to act as “strategy activators” (Thillmann *et al*., 2009) in the way they activate self-regulation processes not spontaneously carried out. In order to avoid this production deficit (Bannert, 2006), question prompts explicitly focus the participants on what they were doing, how and why, by means of questioning words (Berardi-Coletta *et al*., 1995). Self-regulation process is then triggered in response to this verbalization demand, as learners consciously monitor and control their cognitive strategies and actions. According to their point of presentation time (Thillmann *et al*., 2009), question prompts are oriented towards distinct phases of the cyclical self-regulation process (Zimmerman, 2002). When presented before action, the orientation of question prompts is on the forethought phase. When presented during action, question prompts are related to the performance phase, whereas a presentation after action guides the self-reflection phase.

Metacognitive domain-specific question prompts have been shown to be successful in distinct specific domains, such as well-structured problems (Berardi-Coletta *et al*., 1995), problem related to the domain of law (Nadolski *et al*., 2006), but also information problems (Stadler and Bromme, 2008; Saito and Miwa, 2007).

1.4. Collaboration and information search

Collaborative learning, through peer interactions, appears to be an effective strategy to scaffold the learning process (Baker and Lund, 1997; Hadwin, Oshige, Gress and Winne, 2008; King, 1991). Ge and Land (2004), in proposing peer interactions as a scaffold of ill-structured problem solving process, pointed out its potential to improve different phases of this process. In the problem representation phase, peer interactions may direct each other’s attention to particular features of the problem they do not understand, leading to a more complete problem representation. In addition, it seems that peer interactions are useful for developing solutions, in exposing students to different perspectives. In the argument construction phase, peer interactions provide a context for constructing arguments and making justifications (King, 1998). Lastly, in making the thinking process visible and available for examination, peer interactions have a potential to improve the monitoring and evaluation phase (Ge and Land, 2003). However, as students do not realize metacognitive activities spontaneously, they do not always engage in high-level discourse unless they are prompted to do so (King, 1998). Hence an interesting question for research is whether providing question prompts is sufficient for guiding learners' interactions toward a better metacognitive awareness of their progress in the task and learning processes.

2. Hypotheses

This research addresses the effect of question prompts aiming to foster the metacognitive processing required, but not spontaneously activated, in an information problem-solving task. These question prompts are called metacognitive prompts hereafter. On the basis of the metacognitive conceptualization and the IPS characterization proposed earlier, we formulated three hypotheses:

- We assumed that answering metacognitive prompts would allow learners to shift towards a metacognitive level of processing, which was expressed in the dyads interactions. In other words, we expected that dyads benefiting from metacognitive prompts would produce more utterances classified as metacognitive than dyads without metacognitive prompts (H1).

- We hypothesized a positive effect of metacognitive prompts on information-problem solving performance, meaning that the scores on the three IPS steps of information searching, classifying and presenting would be higher for the dyads benefiting from metacognitive prompts (H2).

- We assumed that the positive effect of metacognitive prompts on information-problem performance was mediated by level of metacognitive processing actually activated and appearing in the interactions (H3).

2. Method

Participants and design 26 undergraduate students (20 men and 6 women, aged from 20 to 24 years old) in Social Sciences at University of Savoy participated voluntarily in this experiment carried out as a regular activity of a class in communication. They were randomly set in dyads and assigned to one of the two between-subjects conditions (with or without question prompts). There were 6 dyads (12 participants) in the condition with question prompts and 7 dyads (14 participants) in the condition without prompts. A majority of these pairs (11 out of 13) were same-gender couples.

Material

Learning environment The web-based system used was the Electronic Schoolbag Workspace (Martel *et al.*, 2004), which provided individual applications as well as collaborative ones with educational and basic group work functionalities. Participants, as students of the university, had a regular practice of this environment. It offered two particular areas: a personal "schoolbag" and group workspaces. Specific workspaces have been created to allow the collaborative information problem solving of this study. Each dyad was provided with a workspace, which functioned as a folder, allowing members to add and structure all the resources and documents founded on the Web. The communication tool used was a textual chat. At that time, no collaborative application was available to allow online collaborative content authoring and history tracking. Instead, the forum has been used to keep track of all the versions of the final document made by each of the two partners in a dyad.

Information problem task The participants were asked to solve an information search problem that required selecting the three most relevant resources they could find on the web on how to perform an online press analysis. These resources had to define, explain and review what is online press. The instruction segmented the task into smaller task assignments, according to the difficulty raised by Nadolski *et al*., (2006) of achieving a realistic whole learning task without a process support. Thus, the instruction provided three successive steps to solve the information problem, including some of the five steps defined in the model of Wopereis *et al.*, (2008).

- In a first information searching step, the instruction proposed to select relevant sources of information on the Web in defining keywords and using search engines.

- In a second classifying step, dyads had to define a system for categorizing the information selected in their workspace.

- Finally, in a third presenting step, participants had to organize and present information generated in the previous steps in a final document (one per student) according to the criteria defined by the teacher, such as the nature of the document, the status of information, the kind of resources referred and a comment on the global quality of the source.

Metacognitive prompts To ensure avoiding the detrimental effect of metacognitive prompts when a whole task is divided in a high number of phases, we used the broader distinction between an analysis and a synthesis phase proposed in the model of Wopereis *et al*., (2008) to define two points of presentation time of metacognitive prompts. The first prompting was presented before the first analysis phase and aimed to orient attention on cognitive strategies participants intended to develop in order to achieve the two steps of the analysis phase (information search and classification). The second prompting aimed to orient participants towards the cognitive strategies required for the synthesis phase (presentation step).

Figure 1 displays the steps that have been scored and the points in time when metacognitive prompts were presented, in relation to the segmentation of the IPS process proposed by Wopereis *et al*., (2008).

INSERT FIGURE 1 ABOUT HERE

Different questioning words were used to progressively focus participants on a metacognitive processing (Berardi-Coletta *et al.*, 1995). According to these authors, answering *what*, *how* and *why* questions lead to respectively focus on the problem itself, on the strategies required to solve the problem, and on the regulation of those strategies. As they were presented before action, question prompts were related to the forethought phase of the self-regulation process (Zimmerman, 2002). Table 1 characterizes the question prompts used, according to the level of processing they aim to focus on, the constituent IPS steps they aim to support, in each of the two phases of the IPS process they are related to.

INSERT TABLE 1 ABOUT HERE

Procedure

At the beginning of the experiment, participants were informed by the teacher about purpose and procedure of the session. They were informed that they would have to work collaboratively, at a distance, on an information-search task with the partner of their choice. In order to have authentic conditions of online collaboration, dyads were separated in two different classrooms and randomly assigned to one of the two conditions. As the students were acquainted to the learning environment used in this experiment, no introduction phase was needed.

After the students were installed in front of the computer, they received instructions for solving the information problem as described in the Material section. Participants of the condition with metacognitive prompting were asked to individually fill in the first prompting questionnaire (See Table 1 for a description of the items used in the prompting questionnaires). After completing the first two steps of the task, participants were instructed to move to the third step. Participants in the metacognitive prompting condition were asked to fill in the second questionnaire before starting the third step. In the third step, participants could send their responses to their partner in using the forum, but had to individually complete the final document. At the end of the task, all the participants reported the searching and classifying strategies used in the first two steps of the task in a written report. They had also to record the data of their *chat* dialogue in a file and stored it in their workspace for subsequent analyses. The time allocated to the different phases of the task has been fixed in order to avoid time on task difference across the two conditions. The teacher defined the time required to achieve the IPS task. All the participants had 30 minutes for the first two phases (information search and classification), and 20 minutes for the final document completion. An additional time was given to complete the questionnaires in the metacognitive prompting condition.

Data analyses

Coding of the verbal interactions

As mentioned before, the chat was the only tool available for synchronous interactions between members of the dyads. Its content over the three phases was recorded and coded. To determine the reliability of the coding procedure, both the teacher and the experimenter rated 10% of the corpus independently from each other. The level of agreement reached a Cohen's Kappa of 0.94.

First, the chat content was segmented into utterances on the basis of communicative acts conveying separable semantic contents (Baker and Lund, 1997) and turn taking. A coding schema was defined, consisting of scoring each utterance in order to identify and characterize the occurrence of metacognitive dimension in the chat interactions between partners of all the dyads (see Table 2):

- Firstly, utterances were contextualized according to the IPS steps they were related to, as described in the model of Brand-Gruwel *et al.,* (2005). Then, utterances were coded according to their orientation on the steps of (a) definition of the information problem, (b) searching information, (c) classifying information and (d) presenting information in a final document.

- In a second category, the metacognitive level of each utterance was evaluated. An utterance was coded as metacognitive when focused on the *regulation* of cognitive strategies planned to solve the information problem. Utterances focused on problem-solving strategies or on the solution of the problem were coded as not metacognitive.

INSERT TABLE 2 ABOUT HERE

Scoring of information problem task performance

The different steps involved in the information problem-solving task (searching information, classifying information and presenting information) were scored on the basis of criteria defined by the teacher for each of the three phases:

- The information-searching phase was scored in 5 points, on the basis of the search engines, the keywords and the sources used and reported by the participants at the end of the study. Search engines used and keywords specified were evaluated on 2 points, according to their diversity and their relevance. Sources selected were scored in 1 point, according to their relevance, since the diversity of sources selected was evaluated in the final document.

- The classification phase was scored in 5 points, on the basis of the degree of relevance of the sources classification observed in the dyads' workspaces: (0) no sources were stocked in the workspace, (1) sources were stocked but not classified, (2) sources were classified but inconsistently, (3) sources were consistent with their categories (4) classification was relevant, (5) classification was consistent, relevant and hierarchical.

- The final document completion phase was scored in 10 points, according to the degree of completeness and relevance of the sources selected (from 1 = totally incomplete and irrelevant to 10 = totally complete and relevant).

Resulting dependant variables

On the basis of the aforementioned analyses, several dependant variables were constructed and analyzed in the results section.

- As the number of utterances per dyads was irregular, we used the ratio of metacognitive utterances related to the different IPS steps of searching, classifying and presenting information as the measure of a metacognitive level of processing. According to our conceptualization of metacognition, this metacognitive level of processing refers to a monitoring and control of cognition that are exercised in a conscious analytic mode, and then explicitly formulated in dyads' interactions.

- The participants' information problem solving performance resulted in three scores: a) the score in a 5 point-scale on the information searching step, b) the score in a 5 point-scale on the information classifying step, c) the score in a 10 point-scale on the final product writing step.

Results

Effect of metacognitive prompts on the level of processing

Our first hypothesis predicted that question prompts should orient interactions on a metacognitive processing level. The mean ratios of metacognitive utterances related to the three phases of the IPS process were summarized in table 3.

INSERT TABLE 3 ABOUT HERE

In the information searching step, according to the normal distribution of the data (Z=.894, *ns*) and the homogeneity of variance (F(1,25)=.265, *ns*), conditions for the applicability of an analysis of variance have been verified. This analysis indicated that the mean ratio of metacognitive utterances was significantly higher in the metacognitive prompts condition, compared to the other condition, ($F(1,25)=9.47$, $p<.005$, $\eta^2 = 0.34$).

When occurring in the second step of information classification, the mean ratio of metacognitive utterances was not significantly higher in the prompted condition ($U = 46.5$, $Z = -.29$, *ns*).

In the same way, metacognitive utterances in the information-presenting step did not occur more frequently in the prompted condition ($U = 49$, $Z = -.108$, ns). Besides, contrary to our hypothesis, metacognitive utterances have been more important in the non-prompted condition, even if this result is not significant.

These results partially confirm our first hypothesis. They are summarized in table 4.

INSERT TABLE 4 ABOUT HERE

Effect of metacognitive prompts on IPS performance

The second hypothesis assumed higher scores on the three IPS steps of the prompted condition in comparison to the non-prompted condition. The average IPS scores were summarized in table 5.

INSERT TABLE 5 ABOUT HERE

In the first information-searching step, according to the normal distribution of the data (Z=.806, ns) and the homogeneity of variance (F(1,25)=.309, *ns*), an ANOVA has been conducted. As expected, dyads prompted with metacognitive questions performed better than dyads without such question prompts ($F(1,25)=6.44$, $p < .05$, $\eta^2 = 0.26$). Because assumptions regarding the normal shape of the distribution and the homogeneity of variance are not satisfied, we conducted non-parametrical tests to verify the positive effect of metacognitive prompts on the two latter IPS scores.

Concerning the average scores related to the second information-classifying step, no difference was observed between prompted and non-prompted conditions (U = 36, $Z = -1.13$, *ns*). Similarly, scores on the last synthesis phase were not significantly higher in the prompted condition compared to the condition without prompt ($F(1,25) = .08$, *ns*).

As showed in table 6, the effects of metacognitive prompts on IPS scores were partially verified.

INSERT TABLE 6 ABOUT HERE

Mediation effect of the metacognitive processing

Finally, our last hypothesis H3 stated that the effect of metacognitive prompts on IPS performances is an indirect effect, mediated by the effect of metacognitive prompts on the level of processing. This mediation hypothesis has only been tested on the first phase of information searching, since there was a positive effect of metacognitive prompts in this phase.

To assess this mediation, four steps have been completed following the procedure suggested by Baron and Kenny (1996):

- Firstly, the independent variable (metacognitive prompting factor) must affect the mediator (metacognitive level of processing). A simple linear regression confirmed this relation ($\beta = .59$, $p<.005$, $r^2 = .30$). A more important mean ratio of metacognitive utterances have been found in the prompted condition, in comparison to the non-prompted condition ($F(1,25) = 9.47$, $p<.05$, $\eta^2 = 0.34$).

- Secondly, the independent variable (metacognitive prompting factor) must affect the dependent variable (performance on the information-searching phase). A simple linear regression verified this relation ($\beta = .513$, $p < .05$, $r^2 = .22$) and confirmed the positive effect of metacognitive prompts on average scores ($F(1,25) = 6.44$, $p < .05$, $\eta^2 = 0.26$).

- Thirdly, the mediator (metacognitive level of processing) must affect the dependent factor (performance on the information-searching phase). A simple linear regression confirmed this relation ($\beta = .52$, $p < .05$, $r^2 = .23$). Mean ratio of metacognitive utterances actually appear as significant predictors of mean scores on the information-searching phase ($F(1,25) = 6.69$, $p < .05$, $\eta^2 = 0.27$).

- In the last step, a stepwise regression has been conducted, in order to predict performances on the information-searching phase from the independent variable “metacognitive prompting factor” and the mediational variable “metacognitive level of processing”. This analysis reveals that metacognitive prompting factor is not any more a significant predictor ($\beta = .31$, *ns*) whereas metacognitive level of processing is still a significant one ($\beta = .52$, $p < .05$).

To summarize, results confirmed that, according to our mediation hypothesis, the metacognitive level of processing has mediated the positive effect of metacognitive prompts on information-searching performances. The figure 2 below depicts the four steps of this mediation analysis.

INSERT FIGURE 2 ABOUT HERE

Discussion and conclusion

The goal of the present study was to investigate the effect of metacognitive prompts on the monitoring and control of planned IPS strategies and, consequently, on IPS performance. Furthermore, a central mediation hypothesis has been proposed, assuming that the positive effect of metacognitive prompts on IPS performance was mediated by the level metacognitive processing they previously activated. It was expected that these direct and indirect effects occurred in the information-searching, information-classifying and information-presenting steps of the IPS process, defined on the basis of the model of Wopereis *et al.*, (2008).

The results only partially confirmed these assumptions, since direct and indirect effects of metacognitive prompts have only been confirmed in the information-searching step of the IPS process. Indeed, a direct effect of metacognitive prompts on the level metacognitive processing has been verified, as participants in the prompted condition expressed significantly more metacognitive utterances than participants in the unprompted condition. Another potential direct effect of metacognitive prompts could be on the level of collaboration between partners. According to a social level of metacognition (Efklides, 2008), the metacognitive judgments and decisions about oneself on which question prompts focused could possibly activate an awareness about the other, leading to formulate metacognitive judgments and decisions oriented towards the regulation of the interaction with this other. This assumption would be in line with the work made by Sangin (2009), related to mutual knowledge modeling process that allow a mutual understanding and an effective collaboration. This focus on collaboration is also consistent with actual research conducted in the field of IPS (Brand-Gruwel and Gerjets, 2008). Here, collaboration has not here been manipulated as a factor but was used as an "enhancer" of metacognitive instruction. Moreover, collaboration served as a methods for the on-line assessment of metacognition, providing access, through verbal interactions, to metacognitive processes otherwise covert (Bannert, 2008). Suggestions for further investigation regarding the effect of metacognitive prompts on collaboration are proposed later.

Concerning the indirect effect of metacognitive prompts on information-searching scores, it can be interpreted as an activation of "metanavigation" strategies (Puntembekar and Stylianou, 2005). Such strategies would lead to better monitoring and controlling of the processes involved while searching information on the web, and avoid two recurrent problems encountered by users (Walraven *et al.*, 2008). The first difficulty is to succeed in specifying relevant keywords for those who lack of domain expertise, such as learners involved in this study. Their searches were then too broad, resulting in an overload of results. The second difficulty is to “judge search results” (Walraven *et al*., 2008). Inspection of search results are often made in the order they were presented, instead of looking at relevant information, such as the origin of the source, the title, the description. We assume that metacognitive prompts, in activating metanavigation strategies, have allowed participants in the prompted condition to overcome these two recurrent problems.

In the information-classifying step, no significant positive effects of metacognitive prompts were found (direct or indirect). The explanation proposed by Kauffman *et al.*, (2008) match quite well with our results. Indeed, according to these authors, metacognitive prompts are effective to foster metacognition in problem solving tasks, but only when there is a clear understanding of the problem-solving process. As Brand-Gruwel *et al*., (2005) underlined, classification task seems to be sensitive to expertise, and usually superficially and illogically carried out by novices (Stadler *et al*., 2008). As our students were quite novice in the domain of on-line press, the metacognitive prompts were not effective in the classification phase.

Metacognitive prompts, when aimed to support the information-presenting step of the IPS process, had no positive effects (direct or indirect). Yet, supporting the productive process of writing an information-searching product has been pointed out as an important issue (Ge *et al*., 2005). This disappointed result could be interpreted as follows. Two distinct point of presentation time of metacognitive prompts have been defined, at the beginning of two interrelated phases of analysis and synthesis, the analysis phase converging on the synthesis phase. As the first prompting was provided before the analysis phase and oriented towards its two constituent steps, it could be suggest that it has extinguished the positive effect of the other prompting in the subsequent synthesis phase, in decreasing the solution space (Nadolski *et al*., 2006). Based on these findings, we can draw some conclusions and suggestions for future research on metacognitive IPS prompting.

With respect to the generalization of our findings, it should be noted a limitation related to the relatively small sample size. As the present study was conducted in an ecologically setting, the number of participants was restrained to students involved in the course. Thus, the suggestions we propose for further investigations must take place with larger sample sizes.

Firstly, we propose a suggestion to avoid the potential extinction effect that could have hampered the effects of metacognitive prompts when presented before the last information-presenting step. It seems that other types of metacognitive prompts could be more relevant at this point of presentation time. As these metacognitive prompts aimed to orient attention on the planning of cognitive strategies participants intend to develop, their first point of presentation time, at the beginning of the IPS process, was optimal (Thillman et al., 2009). On the contrary, when proposed before the later step of the IPS process, the same prompts might have been contrary to this optimal point. At this time of the IPS process, self-reflection or post-action prompts would be more effective to regulate the organization and the presentation, in the synthesis phase, of previously selected resources. Such self-reflection prompts would induce retrospective metacognitive strategies. Besides, literature reported that such retrospective strategies are more easily activated than prospective strategies, because they refer on actions and strategies already undertaken (Saito et Miwa, 2007; Zimmerman, 2002). The combination of these two kinds of metacognitive prompts, aiming to induce prospective and retrospective metacognitive strategies, seems to be a promising way to support realistic whole task such as information problems, in extending the scope of process supports in the entire IPS process. Furthermore, self-reflection prompts appear to be particularly relevant process-prompts when they propose a feedback of the process (Saito et Miwa, 2007). These authors demonstrated that in providing learners, after they solved an information-seeking task, a feedback system composed of a visual schema representing their search-process and question prompts oriented towards their search strategies, reflection on strategies used and performances were improved on a post-test, compared to learners who did not receive the feedback system.

Another point that needs further investigation is the potential effect of metacognitive prompts on the level of collaboration. Some studies have demonstrated this effect in online communication using structured (Baker et Lund, 1997) or guided (Hadwin *et al*., 2008) chat interfaces. According to these authors, in orienting interaction with starter statements more or less similar to those used in traditional question prompts, individual and collaborative processes are enhanced in a way that shared activity becomes collectively regulate.

To sump up, a combination of these different suggestions seems to be a promising path for the future to provide the best possible support for supporting the metacognitive processing required when solving information problems, individually or collaboratively.

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Figure Captions

Figure 1. Segmentation of the IPS process based on the model of Wopereis *et al*., (2008) and integration of the metacognitive prompts in the present study

Figure 2. The four steps of the mediation analysis

Table 1. Characterization of the metacognitive prompts used in this study

Table 2. Coding scheme

Table 3. Mean ratios and standard deviations of the prompted and unprompted conditions' of metacognitive utterances per phase.

Table 4. Summary of the effects of metacognitive prompts on the mean ratio of metacognitive utterances.

Table 5. Mean scores and standard deviations of the prompted and unprompted conditions related to the three steps of the IPS process.

Table 6. Summary of the effects of metacognitive prompts on the IPS mean scores