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Virtual Tutoring: An Online Environment for Scaffolding Students' Metacognitive Problem Solving Expertise

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ABSTRACT

Online learning technologies and virtual learning environments in particular are attracting considerable attention, and are likely to form key strategic aspects of teaching and learning science subjects at the post secondary level. Learners at various levels seem to enjoy the autonomy of gaining access to expertise through online communications and web-based resources. However, simply having access to knowledge without experience does not seem to be sufficient for the development of problem solving expertise and metacognitive control. This study investigated the effects of embedded metacognitive prompts on students' metacognitive awareness, and the effects of virtual tutoring on the development of students' metacognitive problem solving expertise in physics. Virtual tutoring environment in this study can be described as an online environment that consists of different metacognitive scaffolds: expert modelling on digital online video, access to procedural, and self-assessment prompts, and collaborative interaction among teachers and students on a WebCT platform. The results suggest that embedded metacognitive prompts can be used as scaffolds to enhance learners' awareness of their ongoing thinking processes, and the need to plan their course of action and check their accuracy as they progress through any problem solving task. It also appears that externalizing the expert's mental activities to the students can be an effective scaffolding strategy in guiding students' attention to specific aspects of their learning processes, and engaging them in self-assessment of their own learning and understanding.

Key Words: Virtual Tutoring; Online Environment; Scaffolding; Metacognitive Problem Solving; Expertise.

INTRODUCTION

The potential benefits of online virtual learning environments in facilitating quality learning experiences are expanding exponentially, and significantly affecting the practice of

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learning and teaching. Online learning technologies and virtual learning environments in particular are attracting considerable attention, and are likely to form the key strategic dimension of teaching and learning science subjects at the post secondary levels. Apparently, students at various levels seem to enjoy the autonomy of gaining access to expertise through online communications and web-based resources. However, simply having access to knowledge without experience does not seem to be sufficient for the development of problem solving expertise and metacognitive control (McLoughlin & Hollingworth, 2002; Volet, 1991). What matters, thus, is not so much what problem solving strategies students possess or have access to, but rather, their knowledge of when to use these strategies, and their abilities to coordinate between various strategies. Research has shown that developing students' problem solving expertise requires not only worked-out examples and practice, but also intensive instructional support such as expert modelling, and metacognitive scaffolds and guidance (Chalk, 2001; DeCorte, Verschaffel & OpTeynde, 2000; Halttunen, 2003; Whie, 1999). Obviously, metacognition converges with other attributes that have been linked to the abilities necessary for school success in a construct of developing problem solving expertise. It is also essential that learners be tutored and provided with online opportunities to assess the outcomes of their efforts, and reflect on their own approaches to problem solving.

Online learning environments require that tutoring should be an integral part of the instructional process. The online tutor, whether co-present or virtual, must take on a large part of the responsibilities normally assumed by the classroom teacher (De Lievre, Depover & Dillengbourg, 2006). Online tutoring, thus, should provide students with not only "process displays" and "process models", but also with the metacognitive prompts that may, in turn, help them realize the need to carefully plan and organize their learning, and develop their expertise. Weedon (1997) points out that the role of the tutor is that of a facilitator who allows the students to progress towards mastering a higher level of knowledge and expertise. According to Goodyear (2002), online tutoring is more than just marking students' work. It is, instead, an active role in accompanying learners on the path towards knowledge acquisition, application and construction.

Expert modelling in online learning environments has been used as both a tutoring mode and a scaffolding strategy to promote student engagement with ill-structured problem solving situations, and as tool that helps them organize their knowledge in ways that reflect expertise in their subject matter. Scaffolds are tools, strategies, and guides that can be used to support students in regulating their understanding of complex topics when using technology-based learning environments (Azevedo, Cromley & Seibert, 2004). The roles of these scaffolds may include, but not limited to: helping students with self-regulating the underlying processes associated with managing learning, assisting students with learning how to use resources or how to perform certain tasks, and making students aware of different techniques for solving problems and exposing them to the solution paths followed by experts (White, Shimoda & Frederiksen, 2000; Azevedo, Verona & Cromley, 2001; Lajoie, Guerrera, Munsie & Lavigne, 2001).

Problem solving usually involves a kind of scaffolding process that enables a novice learner to solve a problem, or carry out a task which would be beyond his/her unassisted efforts (Chalk, 2001). Koedinger, (2001) argues that if learners are to be modelled as experts and be able to use the domains' information as expert might do, then detailed account of what experts know and do is extremely necessary, and will have to be made available. Research has also shown that expert modelling has a significant impact on the quality of students' reasoning skills, and their ability to organize knowledge in ways that reflect a reasonable level of expertise in their subject matter (Jonassen, 1999; Pedersen & Liu, 2002). However, simply watching the expert model is not as effective as practicing in the cycle of acquiring, assessing, and reflecting on the modelled processes. Lin, Hmelo and Kinzer (1999) argue that it is the learners' explanation of how and why they performed certain procedures that allow them to refine and enhance future problem solving expertise. It is imperative, therefore, that the expert model solution should involve an idealization and explication of the act to be performed, and an opportunity for the learner to imitate it, and reflect on his /her own performance accordingly.

Expert modelling in this study is strongly related to metacognitive apprenticeship pedagogy, where the expert models his uses of problem solving strategies, and reflects on the thought processes underlying his declarative and procedural knowledge. Accordingly, problem solving expertise refers to how close the students would be to the expert model in terms of their self-assessment of the procedural and conditional knowledge about general physics problem strategies. Embedded metacognitive prompts are proven effective in helping learners to deepen their thinking, and monitor their learning processes (Lin, 2001; Lin et al., 1999; Winne, 2001). However, despite the research evidence on the role of metacognitive strategies in student expertise, the literature attests that a large number of students have difficulties in metacognitive behaviours (Artino, 2007; Kramarski & Gutman, 2006). Kauffman, (2004) points out that students usually do not deploy effective metacognitive strategies in online learning environments unless they are induced, or prompted to do so. Moreover, previous research has also shown that though few students are fully self-regulated, those with better self-regulation skills typically learn more with less effort, and report higher levels of academic satisfaction (Pintrich, 2000; Schraw, Crippen & Hartly, 2006; Zimmerman, 2000). It is important, therefore, that learning environments provide the students with the element and scaffolds that are likely to enhance and foster their metacognitive problem solving expertise.

The purpose of this study is two folds: to investigate the effects of embedded metacognitive prompts on students' metacognitive awareness, and the effects of virtual tutoring on the development of students' metacognitive problem solving expertise in physics.

METHODOLOGY

a) Research Design

A pre-post experimental group design was used in the study, whereby all students were given a pre-post diagnostic metacognitive awareness inventory at the beginning of the study, and then 4 weeks later at the end of the study. All the students took their physics tutorials online in a virtual learning environment. Virtual tutoring environment in this study can be described as an online environment that consists of different metacongnitive scaffolds: expert modeling on digital online video, access to procedural, and self-assessment prompts, and collaborative interaction among teachers and students on a WebCT platform.

b) Sample

The sample for this study included all students enrolled in an introductory general physics course (60 students) from the college of science at Sultan Qaboos University.

c) Instruments

The instruments used in this study included:

i) A metacognitive awareness inventory adopted from Miholic (1994) was adapted and revalidated at the SQU context for the purpose of the study. The inventory consisted of 20 statements for the students to describe themselves and their thought processes on five-point scale (from "not all" to "very much so"). The reliability coefficient of the questionnaire is 0.84.

ii) Built-in self assessment questions. These questions were used as metacognitive prompts for the students to reflect on their problem solving strategies in comparison with the expert model's answer and thought processes.

d) Procedures

Based on the theoretical framework design explained above, a metacognitive apprenticeship pedagogy was used to design a virtual tutoring environment to scaffold students' understanding to solve physics problems as experts might do, and at the same time become aware of their cognitive strategies, and be able to monitor their problem solving processes. The students were provided with two tutorials consisted of eighteen physics problems (see figure 1).

The students were required to solve each problem, submit their answers electronically, and then view the expert model answer on the provided online videos (see figures 2,3, & 4). The expert's model answer included not only the procedures and strategies for solving the presented problems, but also the underlying thoughts and reasoning for strategy selection. The release of the videos was conditional based on submission of students' answers. After viewing the expert model answer, the system provides the students with metacognitive scaffolds in a form of prompts that were removed gradually (e.g., "How do you compare yourself and the steps you followed to the expert's model answer?"). The purpose of these prompts was to enable the students to develop their expertise, and be consciously aware of their propositional, procedural and conditional knowledge (the "what", "how", and "why"). The students respond to the embedded prompt by selecting one of the four choices provided: (A) I followed the same steps as the expert; (B) almost the same as the expert; (C) somewhat different; (D) totally different (see figure 5). The students were also encouraged to share their experience and self-reflections with their classmates on the discussion board.

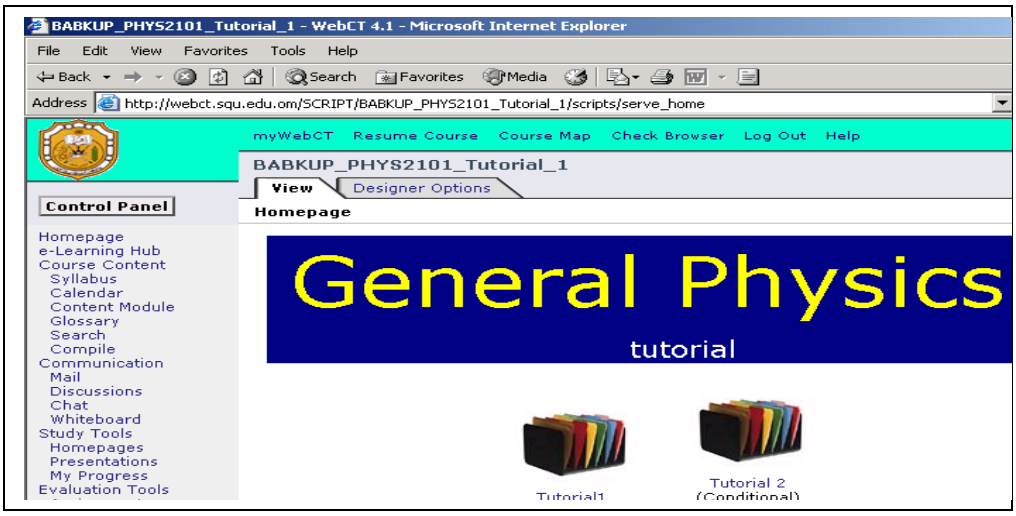


Figure 1. *WebCT tutorial home page*

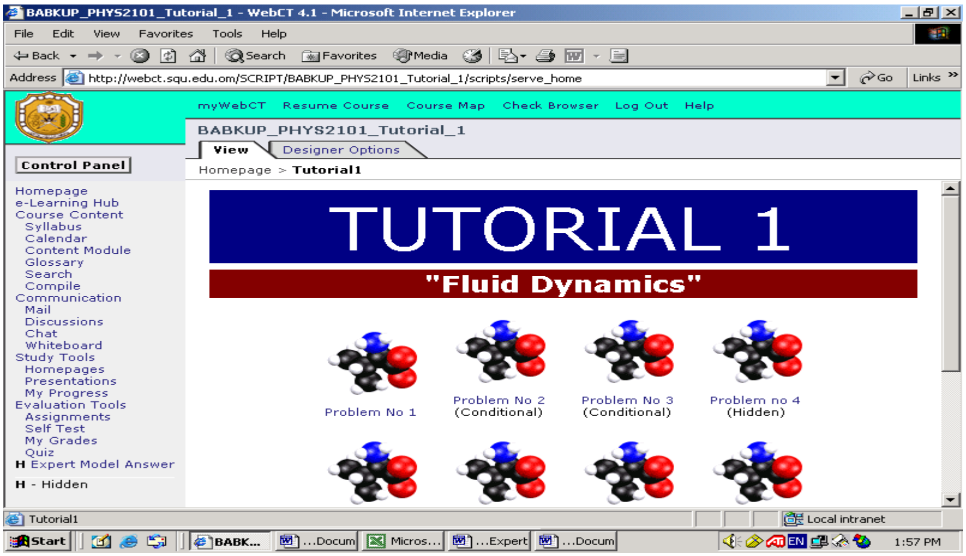


Figure 2. *Conditional release of tutorial problems*

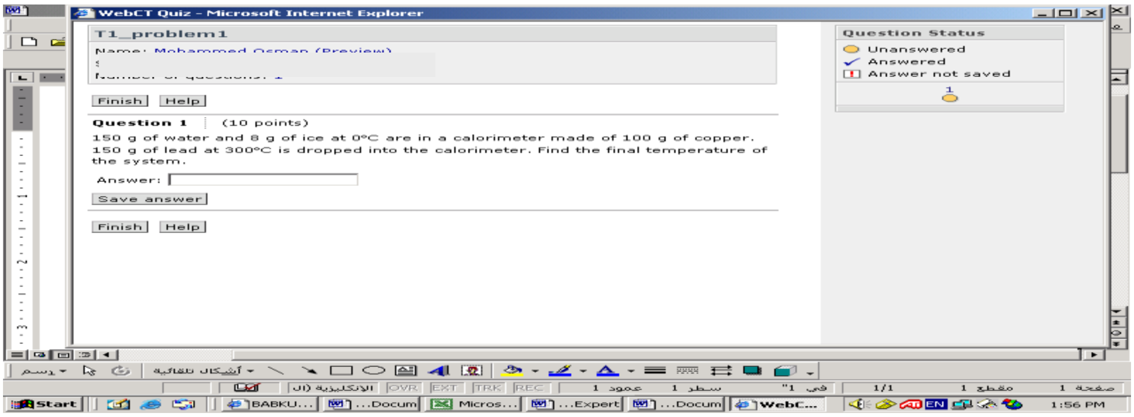


Figure 3. *An example of a tutorial problem*

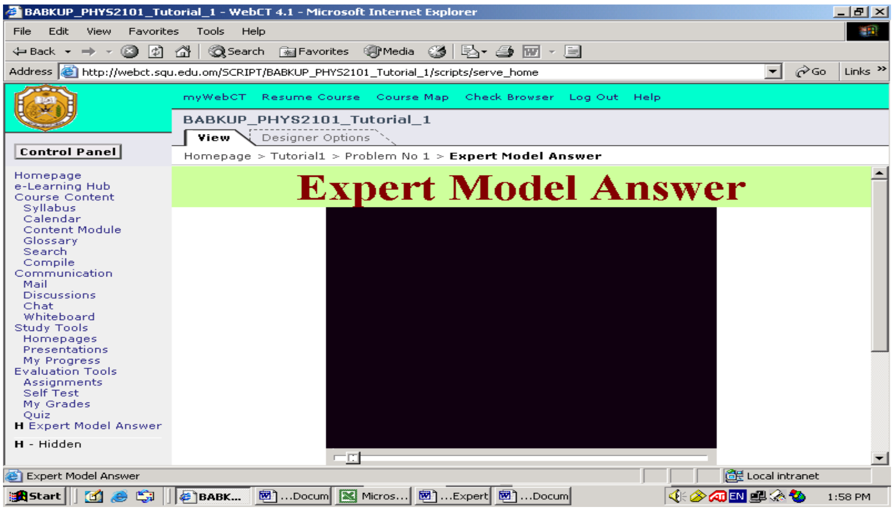


Figure 4. *Digital video of the expert model answer*

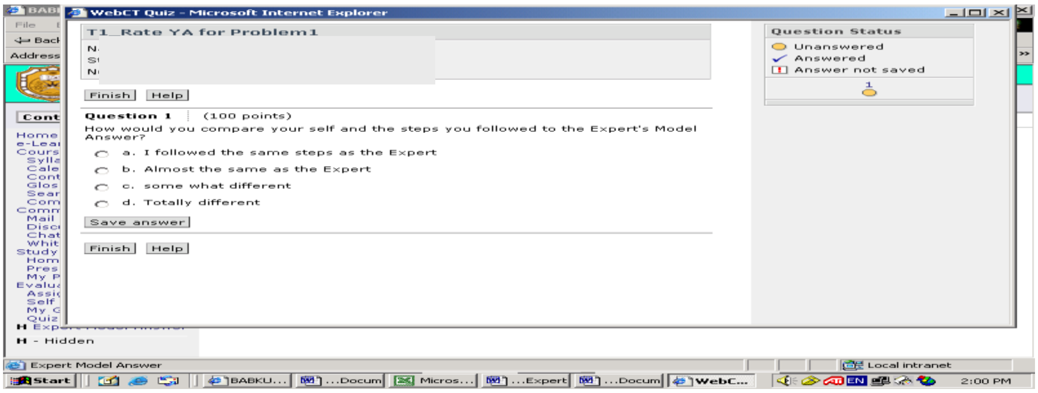


Figure 5. *Metacognitive prompts*

RESULTS

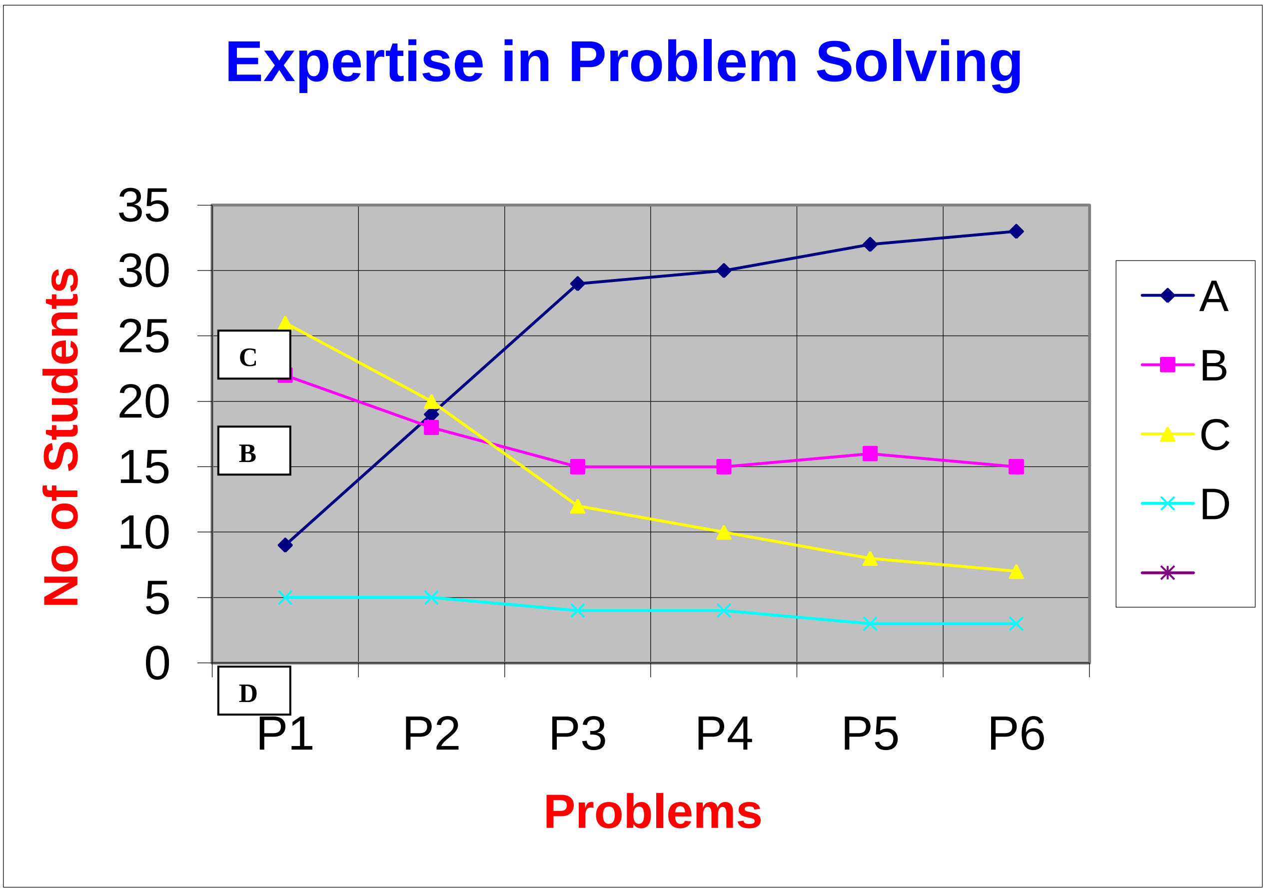
The results revealed that students' metacognitive awareness has improved significantly overtime. Table (1) shows a significant difference in students' metacognitive awareness between the pre and post self-assessment test.

Table 1. *Paired sample T-Test for Pre-Post Metacognitive Awareness*

Test	N	df	Mean	SD	t	Sig.
Pre Test	58	57	2.07	.23	66.08	.000
Post Test	58		3.00	.28		

As shown in table 1, there is a significant difference between the mean scores of the metacognitive awareness test before and after the treatment (T=66.08, significant at the 0.01 level). Having gone through a number of self reflection activities, the students indicated that they became more conscious about their ongoing thinking processes and the need to plan their course of action, and check their accuracy as they progress through a problem solving task. This finding is consistent with previous research (Davis, 2003; Dufresne et al., 2002;

Kramarski & Hirsch, 2003) that reported positive effects of embedded reflective and self assessment on students metacognitive development. Kramerski and Guman (2006) also concluded that students would be able to attain mathematical problem solving competency, and improve their metacognitive ability if they implement self-regulatory questioning, and reflect on mathematical reasoning in e-learning environment. Congruently, Lin, Kizner & Secules (1999) point out that students who possess adaptive expertise usually construct and enrich not only their declarative and procedural knowledge, but also their conditional knowledge. The findings of this study suggest that the embedded self-assessment prompts may have helped the students to be aware of their cognitive processes, and problem solving strategies. It is important, therefore, to provide the students with a learning environment that enable them to analyze the learning situation, assess their emerging understanding of the topic, and determine the effectiveness of the learning strategy on a given learning goal.



*A= followed the same steps as the expert, B= almost the same as the expert
C= somewhat different, D= totally different.

Figure 6. *Students' self-rating*

Moreover, the results shows progressive improvement in students problem solving expertise overtime after viewing the expert's tacit knowledge and thoughts, and reflecting on their own learning processes and problem solving strategies. Figure (6) shows how the students rate themselves and the steps they followed in solving the problems compared to the expert's model answer. As indicated by "line A" in the figure 6 above, only 13% of the students rated themselves as similar to the expert in solving problem one in the tutorial. However, by problem six in the tutorial, this percentage has increased dramatically to 58% of the students following the same steps as the expert did. Similarly, the percentage of students who rated themselves "somewhat different from the expert" has decreased from 47% to 10%. This outcome is also consistent with previous research that deals with embedded adaptive scaffolds that were used in variety of domains to regulate students learning (e.g., Aleven & Koedinger, 2002; Brush & Saye, 2001; Kao & Lehman, 1997). Azevedo, Cromley and Seibert (2004), for example, concluded that providing students with adaptive scaffolds during learning can facilitate their ability to regulate their learning with hypermedia by engaging several key processes and mechanisms related to self regulation such as planning, monitoring, and enactment of effective strategies. It appears that the process modelling and the embedded self-reflection prompts have significant impact on developing students' problem solving expertise. Perhaps the explanations provided by the digital tutor on request, and the possibility to access additional information related to the subject matter, made it an interesting and different way of expertise transfer.

CONCLUSION

Apparently, the acquisition of the conceptual and procedural knowledge in physics is, to some extent, interwoven. Nevertheless, students can correctly solve a problem, but often lack a deep understanding of the underlying principles, and the propositional knowledge of "how" and "why" to solve a problem. The results suggest that embedded metacognitive prompts can be used as scaffolds to enhance learners' awareness of their ongoing thinking processes, and the need to plan their course of action and check their accuracy as they progress through any problem solving task. Perhaps it is the metacognition about the strategies, rather than the problem solving strategies themselves that appears to be essential in developing students' problem solving expertise. It also appears that externalizing the expert’s mental activities to the students can be an effective scaffolding strategy in guiding students’ attention to specific aspects of their learning processes, and engaging them in self-assessment of their own learning and understanding. For students, the self-assessment prompts provide the possibility to apply the knowledge and problem solving expertise acquired in combination with indirect assessment. Furthermore, the web-based online learning environment gives support to the students in various ways, such as tools for both asynchronous and synchronous knowledge and experience sharing opportunities which may, in turn, deepen their understanding and promote their metacognitive problem solving expertise.

Online learning technologies have great potentials to make the expert’s tacit knowledge and thought processes explicit to the learners. The expert model solution, however, should involve not only an idealization and explication of the act to be performed, but also the underlying thoughts and reasoning for strategy selection, and an opportunity for the learners to replicate it, and reflect on their own performance accordingly. The learners’ ability to engage key processes such as planning, monitoring, enactment of effective strategies can facilitate the development of their metacognitive problem solving expertise. It is important, therefore, to provide students with scaffolds for reflection and embedded self-assessment prompts that can help them drive a renewed state of understanding about their performance and their own learning processes. However, further research would be needed to investigate the effects of various attributes of structured online learning environments that support not only the specific skills relevant to problem solving in science, but also the metacognitive skills that can be expandable and transferable.

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