ARTICLE IN PRESS

Computers in Human Behavior xxx (2016) 1–12

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Full length article

Supporting technology-enhanced inquiry through metacognitive and cognitive prompts: Sequential analysis of metacognitive actions in response to mixed prompts

Ying-Shao Hsu [a, *], Chia-Yu Wang [b], Wen-Xin Zhang [a]

[a] Graduate Institute of Science Education, National Taiwan Normal University, 88, Sect. 4 Ting-Chou Rd., Taipei 116, Taiwan
[b] Institute of Education, National Chiao Tung University, 1001, University Road, Hsinchu 300, Taiwan

ARTICLE INFO

Article history:
Received 27 April 2016
Received in revised form
22 September 2016
Accepted 3 October 2016
Available online xxx

Keywords:
Metacognition
Inquiry
Prompts
Technology-enhanced learning
Sequential analysis

ABSTRACT

The aim of this study was to develop and examine supports for inquiry practices in computer-based learning environments (CBLEs). Two kinds of supports for inquiry practices were developed, namely cognitive and metacognitive prompts. We employed a multiple case study design to analyze students' metacognitive reactions to these two kinds of prompts and the fading effect on the regulation process using a sequential analysis technique. The results of this study indicate that the high level inquiry group performed not only more metacognitive actions of monitoring and evaluating, but also performed them in different sequences than the less successful students (the middle and low level inquiry groups) during the prompted inquiry tasks. The sequential analysis in this study identified the students' crucial learning patterns of successful inquiry practices in both the structured and guided inquiry stages. The findings can be used to explore the possible alignment between scaffolding and learning behaviors, and the mechanism of fading for inquiry-based learning in CBLEs.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The Next Generation Science Standards (NRC, 2011) and the 2015 science framework for the Programme for International Student Assessment (PISA) (OECD, 2013) have both stressed the importance of learners possessing adequate knowledge of practices associated with scientific inquiry. An important aim of science education is to foster scientifically literate persons who possess competencies of explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence scientifically. Many curricula and instructional approaches have been developed to promote students' inquiry abilities, such as the Inquiry Training Model (Suchman, 1962), Predict–Observe–Explain (White & Gunstone, 1992), the Inquiry Cycle (White & Frederiksen, 1998), and the Investigation Web (Krajcik et al., 1998). Many of these inquiry instructions are built upon computer-based learning environments (CBLEs) to make unattainable or observed phenomena, such as topics of environmental science, accessible to learners. In addition, the characteristics of CBLEs such as open-endedness, incorporating multiple representational formats (e.g., text, graphics, animations, and pictures or video tools) can be used to provide learners with rich inquiry experiences.

Achieving successful inquiry in a CBLE requires learners to employ effective regulatory strategies to process information and solve problems (Azevedo, 2005, 2007; Crowley et al., 2010) as well as to cope with the systematic characteristics of CBLEs (Devolder, van Braak, Tondeur, & J, 2012). Students may experience cognitive overload or a feeling of being lost if they lack certain skills to help them work efficiently with an inquiry task and the CBLE. Various scaffolds have thus been developed to assist students to manage the complexity of inquiry learning situations in CBLEs (e.g., Hsu, 2008; Hsu, Lai, & Hsu, 2015; Krajcik, Blumenfeld, Marx, & Soloway, 2000; Reiser et al., 2001).

The literature shows that embedding metacognitive supports in inquiry curricula can promote the learning of conceptual understanding and inquiry abilities (e.g., Quintana, Zhang, &

* Corresponding author.
E-mail addresses: yshsu@ntnu.edu.tw (Y.-S. Hsu), cwg25@mail.nctu.edu.tw (C.-Y. Wang), haha1788@gmail.com (W.-X. Zhang).

http://dx.doi.org/10.1016/j.chb.2016.10.004
0747-5632/© 2016 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Hsu, Y.-S., et al., Supporting technology-enhanced inquiry through metacognitive and cognitive prompts: Sequential analysis of metacognitive actions in response to mixed prompts, Computers in Human Behavior (2016), http://dx.doi.org/10.1016/j.chb.2016.10.004

Krajcik, 2005; White & Frederiksen, 1998, 2005). In addition, combining conceptual and metacognitive prompts has been found to be more effective than using merely conceptual prompts in facilitating the development of inquiry ability (e.g., Zhang, Hsu, Wang, & Ho, 2015). Despite the fact that numerous studies have designed scaffolds for fostering learning regulation (see Devolder, van Braak, & Tondeur, 2012 for a systematic review), little attention has been paid to understanding how learner characteristics, other than prior knowledge, may be associated with the effect of scaffolds; in addition, little is known regarding whether learners respond to the scaffolds differently, and therefore yield different learning outcomes. While knowing that the combination of cognitive and metacognitive supports is potentially more effective, more needs to be known regarding how each type of scaffold affects the subsequent learning processes and outcomes. In addition, the effect of fading on the process of regulation is worth exploring.

The present study investigated ninth-graders' actions in response to a set of integrated cognitive (CPs) and metacognitive prompts (MPs) that were designed to support learning inquiry in a CBLE. Patterns of learners' metacognitive actions in response to CPs and MPs as well as their performance on inquiry practice were examined with two aims. The first was to understand whether and how learners respond to a set of integrated CPs and MPs, and whether the differences in their behavioral patterns lead to differences in their learning inquiry practice. Second, the effect of fading on the process of regulation was examined. We addressed these two aims using the lag sequential analysis technique.

2. Scaffolding inquiry and metacognition in a CBLE

Larkin (2009) distinguished cognition and metacognition as two levels of thinking, explaining that cognition is at the ordinary level while metacognition plays a superior role in controlling the cognitive process. Nelson's (1996) model shares this hierarchical structure of cognition and metacognition. According to Nelson, a learning task was processed at the object-level (cognition), and information about the state of the object-level is sent to the meta-level (metacognition) as monitoring. When errors or anomalies occur during the task, the meta-level may decide to change or terminate the task and send a controlling message to the object-level for execution. Metaphorically speaking, metacognition is a higher-order agent that oversees and governs a person's cognitive system (Veenman, Hout-Wolters, & Afflerbach, 2006) and is usually triggered by questions about "why do" or "how to do" something (Larkin, 2009). The current models (Winne, 1996; Zimmerman, 2002) depict self-regulated learning as a self-directive process in which learners selectively use cognitive and metacognitive processes that adapt to each learning task. Theoretically, the process of self-regulated learning is recursive, whereby metacognitive processes are linked to cognitive activities (Winne & Hadwin, 1998).

The important role of metacognition in inquiry has drawn researchers' attention. A recent review of studies of metacognition in science education indicated that, of the 178 reviewed studies, approximately 22% addressed the goal of developing inquiry learning skills (Zohar & Barzilai, 2013). Learning inquiry is complex because it involves multiple stages including questioning, designing a procedure of data collection, analyzing data, and explaining the results. It is also a recursive process in which information recognized or generalized from one stage will affect the design and/or process of other stages (Krajcik et al., 1998). For example, a scientific question synthesized for investigation will in turn influence the design of the experiment and data-collection procedure. Students also need to monitor and evaluate their task practice to regulate subsequent actions and to justify when and why to move on to another inquiry stage. When encountering a problem or limitation in their data collection and/or analysis, the students might also need to consider and decide to refine their research question or experimental design. However, many students do not automatically monitor their learning process (de Jong & Van Joolingen, 1998) and use fewer effective strategies to regulate their learning if external guidance or supports are absent (Azevedo et al., 2005). When this inquiry process is embedded in a CBLE, its systematic characteristics, such as the incorporation of multidimensional representations and resources, as well as the non-linear working procedure, may add another layer of complexity to the students' learning experience. Thus, metacognition is essential for the students to cope with learning in the CBLEs.

Although educational researchers have recognized the importance of metacognition, we noticed a lack of studies on incorporating metacognitive supports in CBLEs to facilitate science learning. Only very few studies (11 out of the 178 reviewed studies) have attempted to incorporate metacognitive supports or instructions with information communication technology (see Zohar & Barzilai, 2013 for a more thorough discussion of studies on metacognition in science education). More recently, scaffolding in CBLEs has been used to refer to the design of tools, strategies, or guides that support student learning, rather than merely being limited to interactions between learners and an expert (Devolder et al., 2012). In addition, recent studies on scaffolding inquiry in CBLEs have indicated that not only metacognitive scaffolds but also conceptual and strategic supports can influence students' metacognitive activities and domain knowledge. It was found that learners' inquiry performance was improved when metacognitive supports were provided. For instance, White and Frederiksen (1998) incorporated a set of criteria for inquiry to help students reflect upon the quality of their own and each other's inquiry processes. Their findings revealed that students who received the criteria for evaluating inquiry outperformed their cohorts on an inquiry test. This metacognitive support was also effective in closing the gap in the inquiry performance of low-achieving and high-achieving students in comparison with the case of the control group. Wang's (2015) study also showed that providing standards for peer evaluation of scientific explanation would reduce students' overconfidence and improve the quality of their scientific explanations. In addition to the facilitative effect of metacognitive supports, cognitive and strategic scaffolds may also influence students' metacognitive actions through the self-regulatory process. For example, Moos and Azevedo's (2008) study indicated that learners who received conceptual scaffolds used a significantly more thorough planning process than those who did not.

Despite the potential learning benefits of using scaffolds to enhance students' learning of inquiry in CBLEs, scaffolds to plan, monitor, and evaluate learning within technology-enhanced inquiry and modeling environments are often little used by students (Järvelä & Hadwin, 2013). Task characteristics, such as learners working as a group or individually (Järvelä & Hadwin, 2013), or learner characteristics, such as prior knowledge, cognitive and metacognitive skills, or inquiry skills (e.g., Moos & Azevedo, 2008) may influence the extent to which students use the embedded scaffolds in a computer-based learning task and their behavior patterns. In addition, the mode of delivery of the scaffolds, such as fixed versus adaptive scaffolds, was also found to be influential. Azevedo et al. (2005) pointed out that even though adequate scaffolds were sequenced in a CBLE to support learning, a student would have to actively monitor his/her learning process for a fixed scaffold to be effective. In their study, settings of adaptive, fixed,

Download English Version:

https://daneshyari.com/en/article/4937138

Download Persian Version:

https://daneshyari.com/article/4937138

Daneshyari.com