Promoting Metacognition Within a Game-Based Environment

Erica L. Snow(✉), Matthew E. Jacovina, and Danielle S. McNamara

Department of Psychology, Arizona State University, Tempe, AZ 85287, USA
{Erica.L.Snow,Matthew.Jacovina,Danielle.McNamara}@asu.edu

Abstract. Metacognition refers to students' ability to reflect upon what they know and what they do not know. However, many students often struggle to master this regulatory skill. We have designed and implemented two features to promote metacognition within the game-based system iSTART-2. These two features have been tested and shown to have positive impacts on students' ability to reflect upon their performance. Future work is being planned to further explore the most effective way to implement these features and the ultimate impact they have on learning outcomes. We are seeking advice and feedback on the methodology and metacognitive feature design that will be included in a series of follow-up studies. The implications of this work for both iSTART-2 and the AIED field are discussed.

Keywords: Metacognition · Game-based learning · Self-assessment · Design

1 Introduction

Students' ability to reflect upon what they know and what they do not know is often referred to as metacognition [1]. Metacognition is a regulatory skill that has been shown to be critical for academic and professional success [2]. However, many students struggle to effectively (and accurately) assess and reflect upon their learning and cognitive processes. Consequently, researchers have begun to develop various interventions and techniques designed to stimulate metacognition during learning tasks. These interventions often enable students to gain experience in reflecting upon what they know and how to behave while engaged in a learning task [3]. For instance, a common technique used to promote metacognition is prompted self-assessments. These instructional tools are designed to prompt students to reflect upon the assignment while objectively critiquing the quality of their own work [3]. Another technique includes the use of prompts designed to alert students to sub-optimal performance during a learning task [4]. Similar to self-assessments, the goal of performance prompts is to provide students with the opportunity to reflect upon their own performance and the learning task.

Recently, researchers have argued that metacognitive support techniques should be embedded within adaptive environments to enhance metacognition skills, which may ultimately lead to long-term learning outcomes [5]. Hence, the goal of the proposed work is to develop and test metacognitive interventions embedded within the game-based reading comprehension system, iSTART-2 (Interactive Strategy Training for

C. Conati et al. (Eds.): AIED 2015, LNAI 9112, pp. 864–867, 2015.
DOI: 10.1007/978-3-319-19773-9_134

Active Reading and Thinking; [6]). Previously, we have conducted two experiments designed to test two features embedded within iSTART-2 that indirectly promote self-reflection during learning tasks [4]. However, these experiments have been conducted separately and in isolation of each other. We propose to test these features in conjunction with each other to examine how they might interact to enhance metacognition and motivation within a more complete version of the iSTART-2 system. In this paper, we propose (and seek advice about) a series of experiments that will assess the effectiveness of these metacognitive features in prompting self-reflection, and in turn, their effects on motivation and learning outcomes.

1.1 iSTART-2

The Interactive Strategy Training for Active Reading and Thinking-2 (iSTART-2) is a game-based intelligent tutoring system (ITS) designed to improve students' reading comprehension abilities by instructing them on five self-explanation strategies (comprehension monitoring, paraphrasing, prediction, elaboration, and bridging; [6]). iSTART-2 is divided into two sections: lesson videos and game-based practice. The lesson videos provide students with information about self-explanation and comprehension strategies to improve their explanations. In the game-based practice interface, students can interact with a series of games designed to provide the opportunity to practice writing self-explanations or identifying the stratgies that they had just learned (for more info see [6]).

2 Previous Research

We have developed and independently tested two features designed to promote metacognition within iSTART-2. Both of these features (described below) are designed to prompt students to reflect upon their own performance and learning processes.

The first feature that we developed and embedded within iSTART-2 is *a performance- threshold feature*. The performance-threshold feature is incorporated within the practice games of iSTART-2. That is, after students complete each game play, their average score within the game is compared to an experimenter-set threshold. If this threshold is not met, students are presented with a message that explicitly informs them that their performance is low (promoting self-reflection) and that they will be transitioned to a remedial activity where they can receive more nuanced and direct strategy instruction. This feature is thus designed to indirectly support metacognition by presenting students with performance information. Previous work has shown that the performance-threshold feature has had a positive impact on students' self-explanation quality [4]. Specifically, after students are told of their low performance, they showed significant improvements in self-explanation quality during the following game-play, regardless of whether they received the additional instruction.

In addition to the performance-threshold feature, we also separately designed and implemented a *self-assessment feature* within the game-based practice in iSTART-2. This feature is designed to provide students with an opportunity to reflect upon and assess their performance. The embedded self-assessments prompt students to assess

the quality of their self-explanations before receiving any feedback from the system. Across two texts, students using the self-assessment feature consistently overestimated their performance within iSTART-2. Thus, the self-assessment feature does not appear to enhance students' understanding of the task or their performance. Interestingly though, the degree to which students overestimated their performance varies as a function of prior domain knowledge. Thus, high ability students tended to be more closely aligned with the system than low ability students.

3 Future Research Plans

The two studies conducted thus far have provided insights on promising future directions as well as limitations that need to be addressed. We propose, and seek advice about, three experiments designed to enhance our understanding of how these metacognitive features may be improved and ultimately impact students' learning outcomes.

In *Study 1*, we will explore how the effects of the experimenter-set threshold on motivation and learning depend on individual differences. In a sense, we will be asking if *different students need different performance thresholds*. Currently, the performance-threshold feature uses a set performance threshold. The goal of Study 1 will be to determine the extent to which the effects of the threshold depend on prior ability levels. For instance, it is our hypothesis that different thresholds are likely necessary to avoid disengagement and frustration; indeed, lower ability students may benefit from thresholds that are relatively easier to achieve, as they may be perceived as a more manageable goal. To test this hypothesis, we will conduct a between-subjects experiment where students are randomly assigned to one of three conditions, each of which includes a different performance threshold. With this design, we will examine how various thresholds interact with individual differences to influence learning and motivational outcomes.

In *Study 2*, we will examine the frequency that students should be asked to self-assess within the iSTART-2 interface. In our previous work with self-assessments within iSTART-2, students were asked to self-assess their performance after each self-explanation. However, this may appear redundant to students and subsequently promote "gaming behavior" in which students click through this task thoughtlessly. Therefore, in Study 2, we will conduct a between-subjects experiment that manipulates the frequency that students are asked to self-assess (i.e., after every two target sentences or after every completed text). This will afford the opportunity to examine and identify how *varying the frequency of self-assessments influences learning outcomes and metacognitive awareness* within iSTART-2.

Finally, in *Study 3*, information gleaned from Studies 1 and 2 (optimal thresholds and self-assessment frequencies) will be used to guide a 2 (threshold vs. no threshold) x 2 (self-assessment vs. no self-assessment) between-subjects experiment. The goal of Study 3 will be to examine *if and how these two metacognitive features interact to influence learning outcomes and self-reflection ability*. It is our hypothesis that the two features promote metacognition at different levels. For instance, self-assessments

may prompt students to reflect upon their performance at a more local level (e.g., each self-explanation they generate). By contrast, the performance-threshold feature may promote more global metacognitive reflections regarding their approach to the task (e.g., what strategy they used) rather than localized activity embedded within the task. Thus, the combination of these two features may prompt students to reflect on the task as well as how it fits into their overall learning goals.

4 Contributions

The proposed work has both local and global implications. Locally, the development and implementation of features designed to promote metacognition will improve the effectiveness and pedagogy of the iSTART-2. Currently, iSTART-2 does not explicitly promote metacognition within the game-based practice. Thus, the inclusion and testing of these features may improve the system feedback and guide the content to which students are exposed.

Globally, this project will contribute to the AIED community by enhancing our understanding of how metacognition can be supported and ultimately influence learning outcomes. Metacognition is of growing interest within the community, and researchers are beginning to develop and test interventions that promote this regulatory skill. However, more work is needed to decipher what intervention or combination of interventions is most effective at promoting self-reflection during learning. The features studied in this project are not tied to the specific context of iSTART-2 and thus can be implemented in a variety of educational systems. Although the current work is designed to test features that promote metacognition for the iSTART-2 system, this work is driven by the overarching goal of gaining a better understanding of students' learning processes.

References

1. Flavell, J.H.: Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. American Psychologist **34**(10), 906 (1979)
2. Pintrich, P.R.: The role of metacognitive knowledge in learning, teaching, and ASSESSING. Theory into Practice **41**(4), 219–225 (2002)
3. Falchikov, N., Boud, D.: Student self-assessment in higher education: A meta-analysis. Review of Educational Research **59**, 395–430 (1989)
4. Snow, E.L., et al.: Promoting metacognitive awareness within a game-based environment. Paper submitted to the 2015 Artificial Intelligence in Education Conference (in press)
5. Roll, I., Aleven, V., McLaren, B.M., Koedinger, K.R.: Improving students' help-seeking skills using metacognitive feedback in an Intelligent Tutoring System. Learning and Instruction **21**(2), 267–280 (2011)
6. Snow, E.L., Allen, L.K., Jacovina, M.E., McNamara, D.S.: Does agency matter?: Exploring the impact of controlled behaviors within a game-based environment. Computers & Education **26**, 378–392 (2014)