The instructor reads what you write: Encouraging introductory programming students to engage in self-explanation online

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ABSTRACT

There is evidence from cognitive psychology and education about the benefits of prompting people to explain the meaning of what they are learning in their own words (Williams & Lombrozo, 2013; 2010), such as why an answer they chose is correct. These findings have promising applications in learning environments, but surprisingly little research explores how to effectively motivate people to engage in reflection to enhance their learning in a real-world online educational setting. In this paper, we investigate how to motivate novice programming students to engage in prompts to explain in an online homework platform. To encourage writing explanations, we tell some students that their instructor will read their explanation submissions. We find that these students perform better on subsequent problems. Interestingly, this happens despite evidence that being told their instructor would read their explanations seemed to have no effect on how many people wrote explanations, or may even have reduced how many students actually wrote explanations (qualitative data suggests some students may not have felt confident enough to submit an explanation for their instructor to read). Our work highlights the complexities of implementing reflective exercises in a digital learning environment.

INTRODUCTION

To help students learn, it can be beneficial to prompt them to *self*-explain: explain the meaning of what they are learning in their own words (Williams & Lombrozo, 2013; 2010), such as asking students to explain why they chose an answer to an online programming question. There is evidence from cognitive psychology and education, particularly in controlled laboratory studies, that prompts to explain provide learning gains (Chi, De Leeuw, Chiu, & LaVancher, 1994; Fonseca, & Chi, 2010). Some applications of self-explanation have been in real-world physical educational settings, such as in classrooms (Chiu & Chi, 2014; McNamara, O'Riley, & Taylor, 2006). However, online educational environments are becoming ubiquitous, both as supplements to in-person or hybrid courses and on their own (e.g. an online degree program or MOOC). While findings from real-world deployments in classrooms show promise, there remains much to explore when it comes to implementing and understanding self-reflective and metacognitive prompts in real-world online learning environments, as well as how to motivate students to engage in these activities. We are particularly interested in how prompting students to write explanations in an online environment can help them learn how to program.

Some past work has shown that prompting people to explain in the context of learning to program can be helpful in an introductory programming setting (Vihainen, Miller, & Settle, 2015; Margulieux & Catrambone, 2017; Vieira, Magana, Falk, & Garcia, 2017). Despite these past studies, much of the design space and constraints of effectively delivering and especially motivating engagement in reflective prompts remain uninvestigated, particularly in an online setting–we largely lack empirical insight into how students in these environments will react to or engage in reflective prompts, or how these prompts may be implemented to enhance learning in a digital medium.

We focus on encouraging students to engage in self-explanation prompts. We ask: will telling students that their instructor will read their explanations contribute to more engagement in reflective prompts? To answer this question, we use in vivo randomized experimentation in the online homework platform of an introductory computer science course at a large Canadian research university.

EXPERIMENT

Experimental design. In two multiple-choice homework questions in separate weeks (Week A and Week B), we showed students a prompt to explain why they chose their answer, which we refer to as a "self-explanation" prompt. The multiple-choice questions presented a problem (e.g. a method and an input) and asked students to choose the right answer(s) (e.g. the correct output). Sometimes there are multiple correct options, in which students have to select all viable solutions to get the question correct. Our embedded self-explanation prompt appeared below the multiple-choice question after the student submitted their answer, regardless of correctness. All students were shown a prompt to explain why they chose their answer along with a textbox to type in and submit a response.

We randomized whether or not students would see a message stating that their instructor would read and possibly post their explanation submissions. In previous feedback on self-explanation prompts, some students mentioned that it would be motivating if they knew someone was going to read their submissions. Also supported by findings in psychology, generating an explanation for someone else may contribute to better learning gains and knowledge transfer compared to just generating an explanation for no one in particular (Rittle-Johnson, Saylor, & Swygert, 2008). For some students, we included the message *"Your instructor will read what you've written, and informative explanations might be posted on [a discussion forum used in the course] by the instructor."* along with the open-ended prompt to explain their solution after they clicked "Submit" for their answer. While the instructor did not read through all submissions, three researchers read through the students' explanations and prepared a forum post.

We hypothesized that students who received the message about the instructor would be more likely to write a response to the explanation prompt because they would know that their submission would be viewed. We also hypothesized that students would have greater learning gains if they thought their explanation would be read since they're prompted to write for an audience other than themselves and specifically for their instructor, which may motivate students to put more effort into writing a thoughtful explanation. Previous findings have suggested that a higher quality explanation results in better learning (Vihavinen, Miller, & Settle 2015).

To gain additional insight into our prompts and the instructor message, we distributed a survey at the end of the course. Students gave qualitative feedback on how they perceived the explanation prompts and instructor message while they were doing online homework. We also conducted short semi-structured interviews with students in the course to better understand what students thought of the prompts and how they engaged in them.

Course setting & participants. In the introductory computer science course we worked with, students completed online homework sections. Completing these online exercises was not only meant to help supplement students' learning throughout the course but also amounted to 14% of their entire grade.

We collected data from 141 students in Week A and 92 students in Week B enrolled in a summer section of the first introductory programming course at a large Canadian research university. Some of the students participated in both studies, but others did not. Students consented to let their data from survey responses and activities in online homework be used for this study. Students ranged from having finished their first year to having finished their fourth year of undergraduate study. There were also some nontraditional students in the course, e.g. returning to university after multiple years or taking the course as a non-degree seeking student.

RESULTS

We analyzed the effect of randomizing students to receive a message that their instructor would read their explanation submissions on how likely they were to write an explanation and on their accuracy in a subsequent related problem.

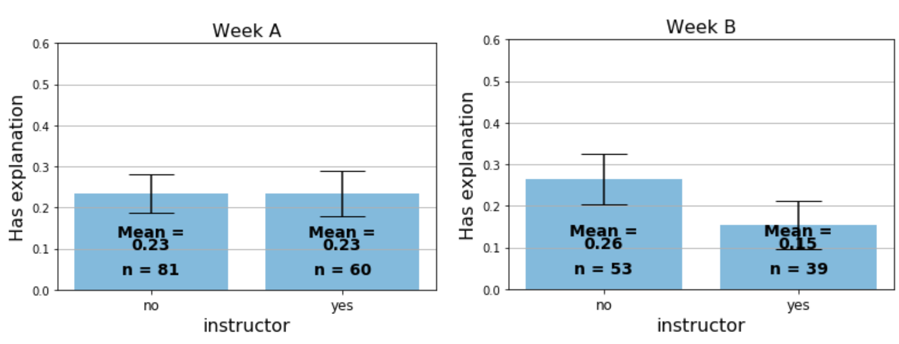

Figure 1: The proportion of students who wrote explanations. "yes" on the x-axis means students received the message that

their instructor would read their explanations.

Note. We dropped some of the students from our analysis because 1) they did not consent to their data being used for research or 2) they moved onto the next problem in less than one second after completing it and were unlikely to have seen the prompts. We randomized whether students saw the message about their instructor based on their id code in the homework system, which resulted in an unequal number of participants per condition–this was not due to differential dropout. There were 150 (64 given instructor message) and 109 (50 given instructor message) students who answered the problem in weeks A and B respectively.

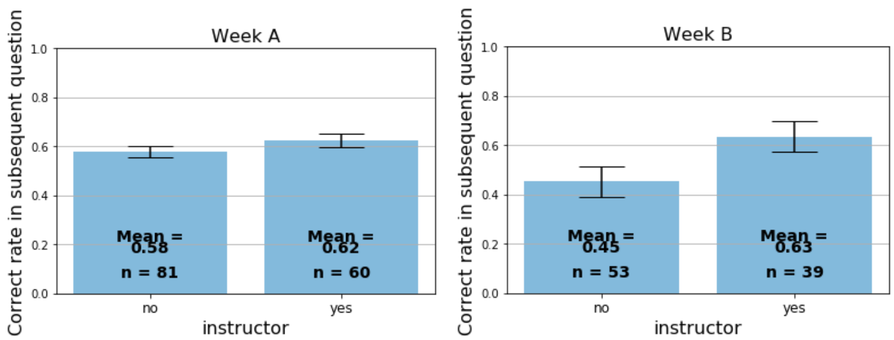

Figure 2: The performance in the subsequent problems for each week. The scores in the problems are represented as a rate of the correctness of students' answers.

We found no significant effect for the instructor message on the proportion of students who submitted explanations, and if anything, there was a trend for this to decrease the proportion of students who engaged in the prompt. As shown in Figure 1, 23% of students wrote explanations in Week A regardless of seeing the instructor message. In Week B, 15% of students who were given the instructor message wrote explanations, while 26% of students who did not receive the instructor message wrote explanations (two proportion *z*-test, $z = -1.27$, $p = 0.20$). Despite this, there was a significant effect on learning, as measured by better performance on a conceptually related subsequent problem (Mann-Whitney U-test, $U = 1267.0$, $p < 0.05$) (Figure 2). Additionally, data from an end-of-course survey and semi-structured interviews with students suggest that many learners took time to stop and think about the prompts to explain, even when they did not write any text. However, many students reported that they found it too effortful to fully articulate and type out an explanation in the textbox, and some students felt that they were not ready to write an explanation that they would feel comfortable sharing with the instructor.

DISCUSSION AND CONCLUSION

We aimed to understand if telling students that their instructor would read their explanations would encourage more students to engage in self-explanation prompts. We also investigated if students in this condition would receive greater learning gains as measured in subsequent questions compared to students who were not given a message about the instructor.

Our results show that students who received an instructor message performed better on the following related problem. This finding suggests that constructing an explanation for someone else may promote better knowledge transfer than constructing an explanation just for oneself (Rittle-Johnson, Saylor, & Swygert, 2008). However, our results also suggest that knowing an instructor reads submissions does not necessarily motivate students to participate in reflective activities. From qualitative data, we believe that some students may have been intimidated to write an explanation for their instructor or that the prompt did not affect students who would have not submitted a reflection anyway. A limitation of this study is that this effect may depend on the instructor–in our study, the same instructor taught all sections we collected data from.

In conclusion, with a focus on implementing findings from cognitive science and education in a real-world environment through in vivo experimentation, we were able to show that introductory programming students benefit from self-explanation prompts. Further, our work informs the design space of motivating students to reflect in an online educational environment and utilizes randomized controlled trials to understand the manifold nature of implementing reflective activities on a digital platform.

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