Drinking Our Own Champagne: Analyzing the Impact of Learning-by-doing Resources in an E-learning Course

Xinying Hou, Paulo F. Carvalho, Kenneth R. Koedinger
Carnegie Mellon University
{xhou, pcarvalh, kk1u}@andrew.cmu.edu

ABSTRACT: Given the demonstrated prevalence of a "doer effect" showing that active practice is related to substantially larger learning gains than passive approaches, an important research goal is to investigate whether and how different active practice features promote students' learning outcomes. We investigated these questions in the context of an online learning platform that teaches e-learning design principles. In particular, we considered two different practice modes - practice activities inserted in the text (inline practice) and review practice quizzes - and compared their contributions to students' learning outcomes, in terms of module quizzes, periodic exams, and course projects. Our results showed that the different practice modes had distinct impacts on learning outcomes. Doing inline practice activities contributed to students' quiz performance at the first attempt and project performance while doing review practice quizzes helped students improve their periodic exam performance. We offer some instructional suggestions such as emphasizing practice activities that are more clearly linked with specific learning objectives for projects, and emphasizing review practice quizzes for exam preparation.

Keywords: Learning by Doing, Linear Mixed Models, Learning Outcome Prediction

1 INTRODUCTION

In the context of online learning platforms, one of the proven methods to reduce passive learning is to integrate interactive activities. A notable example is the Open Learning Initiative (OLI - Bier et al., 2014), which combines student-centered design and learning engineering approaches to provide more effective learning, such as interactive exercises embedded within the learning materials, as well as practice quizzes that allow for unlimited attempts. These activities have been shown to be more highly associated with learning outcomes than passive activities across several OLI courses, an effect known as the "doer effect" (Koedinger et al., 2015; Carvalho et al., 2017).

To extend on this prior work, it is important to further investigate how different OLI practice features contribute to learning outcomes. It is possible that some types of practice promote better learning that is more transferable, whereas other types of practice emphasize memorization and less transferable knowledge (Chi & Wylie, 2014). In this study, we compare the effect of two different types of practice activities on students' learning outcomes. To facilitate a holistic comparison, we also considered multiple assessment measures, including module-level quizzes, periodic exams, and projects. We explore our research question in the context of an OLI course: How do different kinds of practice activities impact students' quiz performance at the first attempt, periodic exam performance, and project performance?

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2 CONTEXT AND METHODS

In this work, we analyzed students' outcome data and log data from a hybrid graduate-level course, E-Learning Design Principles and Methods. The course was hosted on the Open Learning Initiative platform, and log data from the course is hosted on the DataShop repository. Our sample consists of a total of 32 students, including 14 in Fall 2018 and 18 in Fall 2019. The course was structured into 20 modules, students in this course had "flipped homework", where they needed to learn independently and finish a graded quiz via OLI system before class meetings. In addition, students were asked to complete periodic exams (two in 2018 and four in 2019 with similar content in total), and 2 projects using knowledge taught in the course.

In OLI, each record of the student interacting with an interface element is defined as an opportunity; multiple opportunities commonly appear within a problem. To address our research questions, we defined students' count of practice as their number of opportunities on the inline activities or review practice activities. Inline practice activities are formative assessments embedded in OLI text pages. Students get immediate feedback based on their entries and could ask for hints when stuck. The content of inline questions was non-identical but matched with the content of quiz and exam questions through their alignment with specific learning goals. Beyond multiple-choice questions, in-line questions also have other formats such as drag-and-drop and matching questions. Review practice quizzes are targeted questions provided in quiz format before each periodic exam. Students get feedback once submitting a quiz attempt but no hints are delivered.

We used z-scores (i.e., standardized the score values to have zero mean and unit standard deviation) for both outcome accuracy scores and frequency of interactions, which could assist in model interpretation. For each student during each time period (e.g., between two periodic exams), we computed their review practice count, inline practice count, and total practice count. All these metrics reflect the frequency of a student's interactions with the system's practice activities. Given that students did the pre-learning quiz voluntarily and some skipped it, we used students' intercept parameter from an Additive Factors Model (AFM) provided by Data Shop and treated the normalized intercept as a measure of prior knowledge.

We began our analysis by checking whether the AFM model intercept was a good representation of students' prior knowledge. We extracted 25 students who finished more than half of the pre-learning quizzes before doing post-learning quizzes and built a Pearson correlation analysis. Our result showed a significant positive correlation between students' AFM model intercept and their average pre-learning quiz score ($r = 0.78$, $p < 0.001$), which indicates that this intercept is a good depiction of students' prior knowledge. Therefore, we use it both because it is available for all 32 students and it likely provides more information (only 9 students did all 20 pre-learning quizzes).

3 RESULTS

For each assessment, we conducted a linear mixed model with the normalized assessment score as the dependent variable; different practice count variables and student's prior knowledge as fixed-effect predictors; assessment ID as the random effect (Quiz ID, Exam ID, Project ID, respectively). Table 1 shows the final model for each assessment after the stepwise feature selection. For quiz performance, the model showed that doing inner-module inline practice activities is a significant

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positive predictor of quiz performance at the first attempt. For exam performance, results indicated that doing practice activities before periodic exams is a significant positive predictor of students' exam performance. For projects, students' interaction with inline practice activities is a significant positive predictor of their project performance but not for review practice activities.

Table 1: Model parameter estimates (Quiz, Periodic Exam, and Project).

Model	Parameter	Coef.	Std. Error	z
Quiz (AIC = 1628.73)	(Intercept)	-0.098	0.039	-2.524*
	inline practice count	0.144	0.038	3.817***
	prior knowledge	0.447	0.050	9.023***
Periodic Exam (AIC = 284.32)	(Intercept)	-0.066	0.099	-0.664
	total practice count	0.241	0.097	2.489*
	prior knowledge	0.309	0.131	2.348*
Project (AIC = 182.13)	(Intercept)	-0.048	0.120	-0.397
	inline practice count	0.340	0.116	2.926**
	prior knowledge	0.229	0.155	1.479

*p<0.05; **p<0.01; ***p<0.001

4 DISCUSSION AND FUTURE WORK

While prior studies have established the doer effect, our work specifically investigates how different active learning activities contribute to learning performance. A particularly novel finding is that inline practice activity is a better predictor of project performance than other forms of practice. In our context, inline practice is the one form most strongly tied to explicit learning objectives. The more successful students do inline practice questions to bolster their knowledge in ways that appear strategically connected to their needs in project-based applications. In addition, the general support for active learning, while unsurprising to many, is still helpful in addressing explicit instruction biases that many stakeholders hold, as indicated by higher effort in using, developing, or analyzing passive learning materials (e.g., lecture videos and text). Moving forward, we plan to refine the existing practice activities from both content and distribution mechanics to amplify potential impacts.

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