Recommending Highlights on Students' E-Textbooks

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Abstract: Using highlighters on textbooks is considered as one of the important learning activities of students. Digital educational materials enable us to record such activities and analyze the relationships between the use of highlighters and academic performances. However, it is not well-understood how highlight recommendations on students' e-textbook affect their learning. This study reports the result of suggesting to students highlighting regions of digital materials in a university course that 2,653 first-year students took. We generated a set of regions to suggest based on last year's highlights, and give it to about 1,200 students of the course. We quantified the responses of the students, and performed comparative analysis. Although our analysis showed no significant difference in quiz scores, it revealed that suggestions could result in more highlighter usage. Furthermore, the importance of the way of teaching is indicated by the analysis comparing three classes.

Introduction

E-textbooks and presentation slides have been adopted as digital materials in educational contexts (Brown, 2013). While they solve the problems of many aspects of traditional textbooks such as expensiveness and portability, they also make it possible for us to teach and to learn in novel ways. In the past decades, researchers have studied the effectiveness of e-books in educational context, such as e-textbooks in education of children (Maynard & Cheyne, 2005), comparative study on traditional textbooks and e-textbooks (Rockinson-Szapkiw, Courduff, Carter, & Bennett, 2013), and the adoption of tablet and e-textbooks (Al-Mashaqbeh & Al Shurman, 2015).

One of the typical, important learning activities of students on textbooks is annotating pages. Such an activity includes adding notes and highlights for later references. E-textbooks usually provides such functionality. We investigated the most frequently used functions of our e-book system, and we found highlighter was the most popular function except for page-flipping and book-opening actions. (Tab. 1) shows the total counts of occurrences of actions on our e-book system recorded during the semester from April to September 2017.

The usefulness of annotation tools on an e-book system was studied by (Lim & Hew, 2014). Their e-book system with annotative and sharing capabilities was examined, and they reported the system was positively perceived by students. However, to our knowledge, studies trying to reveal the usefulness of highlighters in learning outcome or the effect of suggesting to students highlighting pages in large scale are limited and poorly understood.

Action	Frequency	(%)	Action	Frequency	(%)
Go forward	7,440,979	(63.49)	Jump to a page	69,338	(0.59)
Go backward	3,472,701	(29.63)	Note	27,508	(0.23)
Open a textbook	229,496	(1.96)	Add	17,800	(0.15)
Highlighter	97,990	(0.84)	Modify	8,236	(0.07)
Add	84,746	(0.72)	Delete	1,136	(0.01)
Delete	13,244	(0.11)	Jump	336	(>0.01)
Bookmark	88,986	(0.76)	Search	14,624	(0.12)
Jump	53,755	(0.46)	Query	9,249	(0.08)
Add	29,972	(0.26)	Jump	5,375	(0.05)
Delete	5,259	(0.04)	Open a URL	6,406	(0.05)
Close a textbook	78,268	(0.67)			

Table 1: The frequencies of actions on our e-book system during the semester from April to September 2017. The highlighter is the most often used function except for page-flipping or book-opening actions.

Our research question is "Does suggesting highlights change students' performances and/or activities?" To this end, this study attempts to suggest to students adding highlights on their pages. We target on a mandatory course for the first-year students of our university, and compare the effectiveness of the recommendation of highlights in large scale (roughly 1,200 students with recommendations vs. 1,400 students without recommendations). We measure the effectiveness with quiz scores and students' responses to the suggestions (ignoring, deleting, ant replacing them).

Method

Target Course

In this study, we targeted a course "Primary Course of Cybersecurity" in our university. This course is one of the mandatory courses held in the spring quarter for all the first-year students. In the course, students learn the primary matters about computer security, such as basic technologies, related laws, and morals. There are usually 15

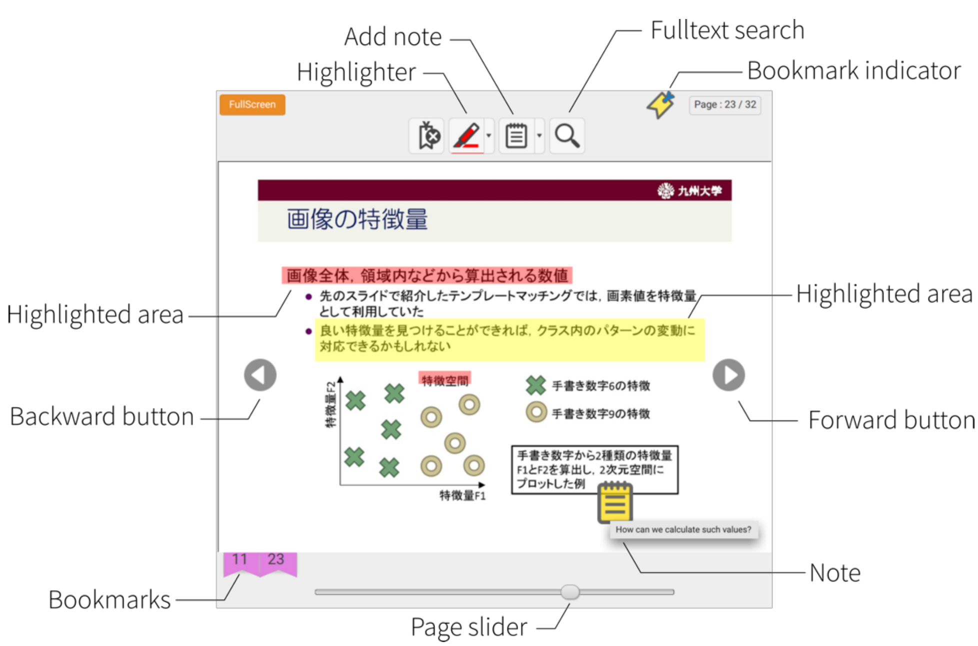

Figure 1: The user interface of the reader part of our e-book system BookRoll.

classes for the course, and more than 2,600 students take one of those classes, i.e. each class is taken by 140 to 220 students. In 2018, 11 teachers gave lectures, and 4 teachers taught in two classes. Basically, teachers talk about the same contents based on the same e-textbooks, and give students the common set of quizzes.

Our e-textbooks for the course are, in fact, presentation slides which are available via our Web-based e-book system called BookRoll (Ogata et al. 2017). (Fig. 1) show a screen capture of the reader user interface (UI) of the system. The UI provides basic functionality to move around pages, to add bookmarks, to search the textual contents, and to annotate pages. Currently, we provide two page-annotation tools: notes and highlighters. Highlighter is a tool to draw a semi-transparent rectangle on a page. Students can choose red or yellow when they draw a rectangle; they are instructed to use red for a portion of a page where they consider important, and to use yellow for an incomprehensible part of a page. Examples of highlights are presented at the center of (Fig. 1) (a yellow highlight and two red highlights).

The cybersecurity course started from 2017, and a set of highlighted regions made in 2017 can be used to generate recommendations for 2018. The course is composed of eight weeks of lectures, and different e-textbooks are used every week. Four e-textbooks for the first to fourth weeks were revised after 2017's classes, and the rest of textbooks were left unchanged. Thus, we decided to generate recommendations from the highlights of textbooks for the fifth to eighth weeks, and to suggest those to students in the same weeks of 2018.

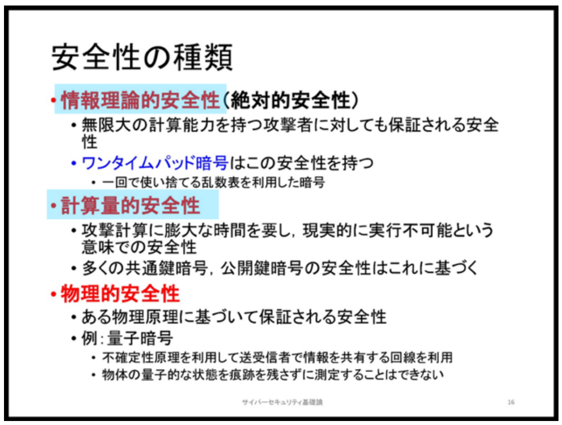

Figure 2: An example page of an e-textbook with two suggested highlights (light blue rectangles). These highlights are basically the same as usual ones except students cannot choose this color to add his or her own highlights.

We gave recommendation to a total of 1,203 students of 7 classes out of 15 classes held for the cybersecurity course in 2018. Recommended regions were automatically displayed in students' reader UI as shown in (Fig. 2). They look like regular highlighted regions except they are colored light blue which cannot be chosen by students when they use a highlighter. The authors gave a short instruction at the beginning of the classes of the fifth week. We introduced the highlighter tool to students and showed how to use it. We told them to utilize the tool actively and described the recommendations on their e-textbook pages. Students were told to delete a suggested highlight if he or she thought it was not necessary, and to replace with his or her own highlight if they thought it was needed. In other words, we told them not to leave any light blue highlights.

Generating Recommendations

We computed regions of pages to recommend from the past usage of highlighters. Regarding the past highlighting activities as "voting" parts of pages, it is possible to compute the importance of any position of pages. (Fig. 3) illustrates this concept. In the figure, individual page views are presented on the left side, where users' own highlights are shown. Aggregating these highlights, we obtain an image like one at the center of the figure. We split a page into 1,600 x 1,200 blocks and counted the number of overlapped highlights within each block as the support for the block. The larger the support is, the more important we consider the block is. Please note that we don't care about colors when counting overlapped highlights. This process results in the right-most picture showing the importance

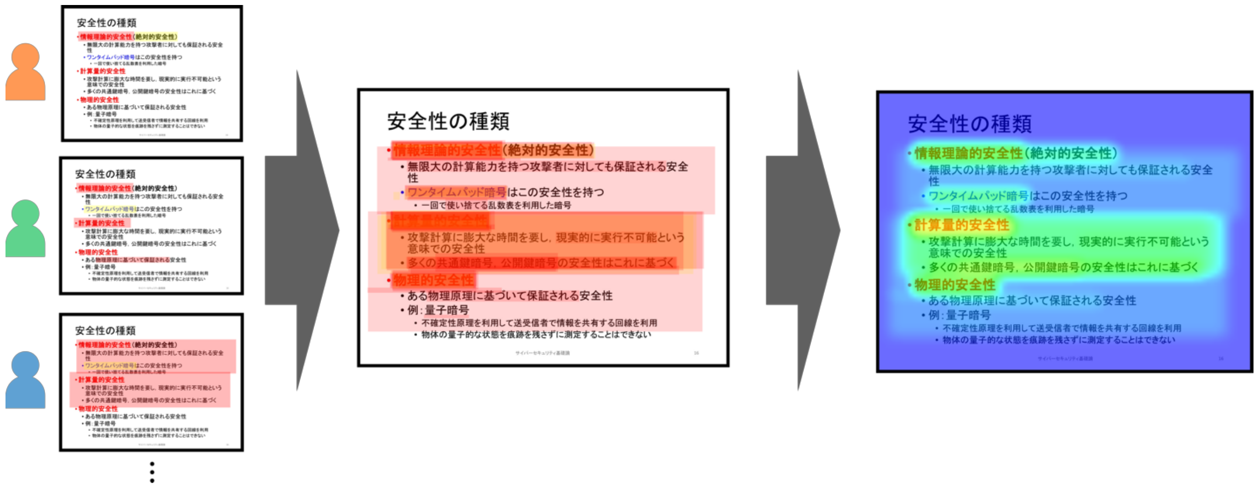

Figure 3: The generating process of recommendations. This picture shows especially the aggregation stage of the process. The right-most image shows an example of an importance heatmap of the page.

heatmap for the page. We then scanned the heatmap to find maximal continuous regions in which the support of any block is greater than or equal to a certain threshold value (minimum support). Because maximal regions are not always rectangular, we extracted the bounding boxes of such regions as recommendation candidates.

An optimal threshold value was determined for each e-textbook as follows. Starting from the threshold value of 200, we calculated the average number of recommendation candidates per page and decreased the threshold value until we got more than two candidates per page in average. We obtained the minimum support values of 13, 21, 15, and 4 for textbooks of the fifth, sixth, seventh, and eighth week, respectively. Furthermore, we refined candidates so that suggested regions are meaningfully large. Firstly, one of the authors removed such regions manually. Secondly, a program was executed to delete candidates whose width or height is less than 10. Finally, we gave students the remaining candidate regions as recommendations.

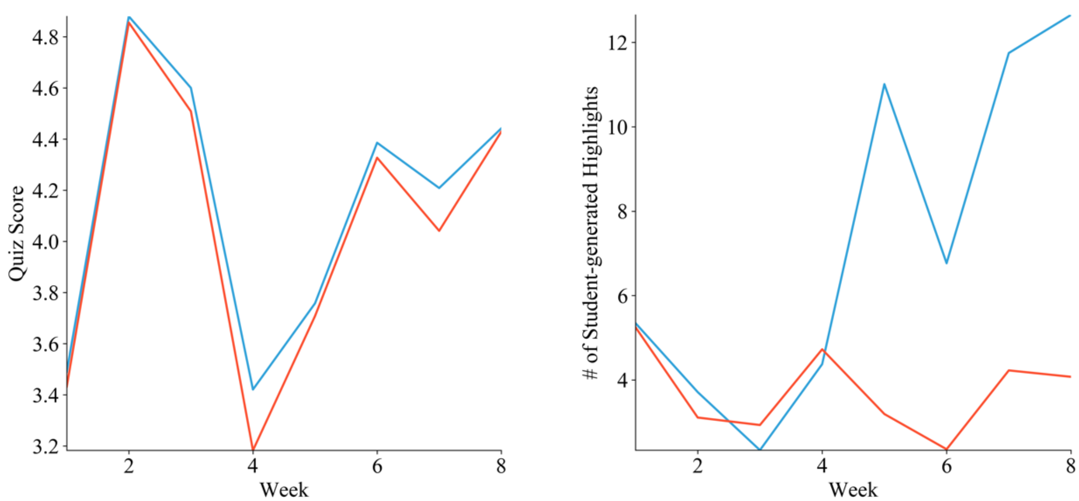

Figure 4: Plots showing temporal changes of quiz scores (left) and the number of highlights students made (right). Blue lines correspond to the group of students who were given recommendations, and red lines correspond to the opposite.

Results & Discussion

Our research question is “Does suggesting highlights change students’ performance and/or activity?” To answer this question, we compare the quiz scores and the number of highlights between two groups of students. (Fig. 4) shows the resultant plots; in the left plot, the horizontal axis shows the weeks, and the vertical axis presents the mean values of quiz scores of the group where students were given recommendations (blue line) and the group where students were not given any recommendations (red line) for each week. The plot shown on the right-hand side presents the same for the numbers of highlights excluding suggested ones. These plots were obtained from the analysis on the data of all 2,653 students. The values for the blue lines are average of 1,203 students and those for the red lines are average of 1,450 students. Please remember that students were given recommendations only for e-textbooks used in the fifth to eighth weeks.

From the figure, we cannot see any significant difference in the quiz scores. However, there is a large difference in the usage of highlights. The average numbers of highlights of the fifth to eighth weeks are 3.2, 2.5, 4.4, and 4.0 in the group without recommendations (red) and are 10.6, 6.4, 11.2, and 12.6 in the group with recommendations (blue). These are no small differences, and it seems that suggesting highlights has some impact on students’ behaviors.

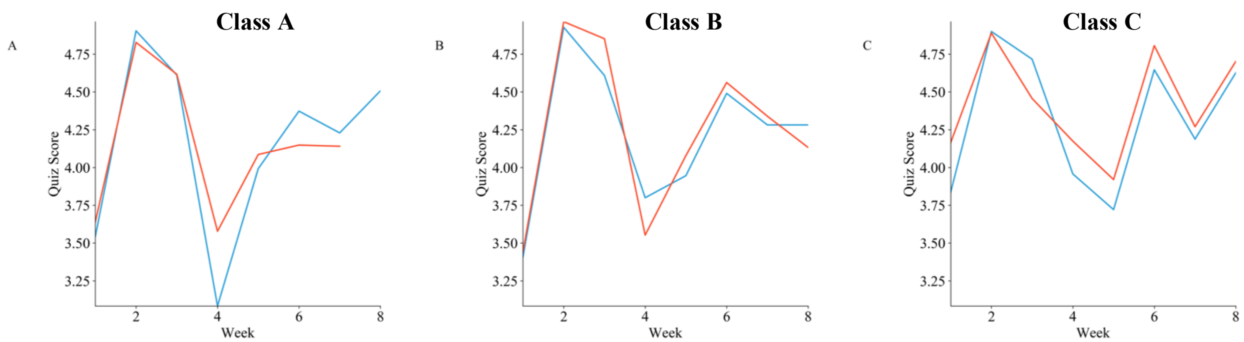

Figure 5: Separate plots for the classes of teacher A, B, and C. Each plot shows the temporal changes of quiz scores of a class with recommendations (blue lines) and those of another class without recommendation (red lines).

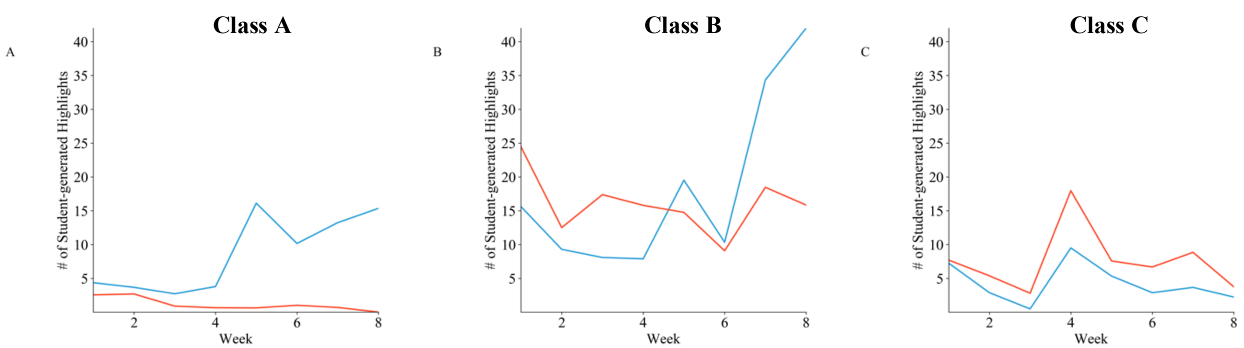

Figure 6: Separate plots for the classes of teacher A, B, and C. Each plot shows the temporal changes of the number of student-created highlights of a class with recommendations (blue lines) and those of another class without recommendation (red lines).

Furthermore, we analyzed more precisely focusing on six classes out of fifteen classes. These classes were taught by three teachers A, B, and C, and every teacher taught in a class with recommendations and another class without recommendation. Analyzing on these classes, we can eliminate the effects of different teachers. (Fig. 5) shows the temporal changes of quiz scores for the classes, and (Fig. 6) shows the same of the number of highlights. Blue lines and red lines correspond to the classes with recommendations and those without recommendation, respectively.

Compared to (Fig. 4), we can see the similar result in (Fig. 5) (quiz scores). There are no large differences between classes with and without recommendations. On the contrary, (Fig. 6) shows a somewhat different result. In the case A, it seems that suggesting highlights had a significant impact on students’ activities. This also applies to the

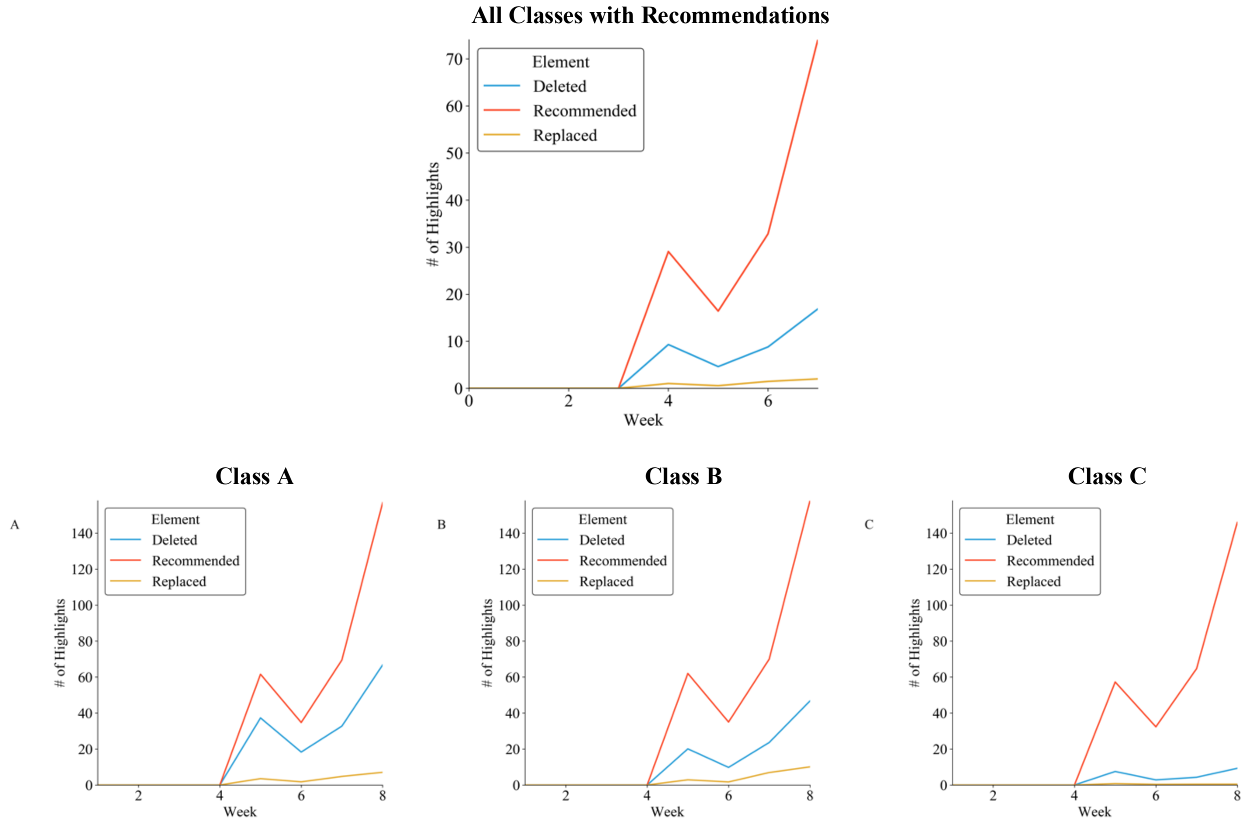

Figure 7: Plots showing students' average responses. The mean numbers of recommendations for each week is shown in red. The mean numbers of deleted highlights among those recommendations are shown in blue, and similarly the mean numbers of replaced highlights are shown in yellow. The top subfigure is for all classes with recommendations. The bottom subfigures are for class A, B, and C.

case B in seventh and eighth weeks, but not in the fifth and sixth weeks. The case C shows the completely different result in which no gain in the number of highlights was observed.

The students' responses to our recommendations are presented in (Fig. 7). These plots show the average numbers of actions, "delete" or "replace", per student. The numbers of recommendations for each week is shown in red. The mean numbers of deleted highlights among those recommendations are shown in blue, and similarly the mean numbers of replaced highlights are shown in yellow. The top subfigure is for all classes with recommendations, and the bottom subfigures are for class A, B, and C. We can see that more than a half of the recommendations remained, which means students didn't make any decisions on them to accept (replace) or reject (delete). The percentages of deleted highlights for the fifth to eighth weeks are about 32%, 28%, 27%, and 22%, respectively. Sixth week had the highest (4.4%) of acceptance (replacement) ratio, and eights week had the lowest ratio of 2.7%. In Class A, however, more than a half of recommendations were responded in the fifth, sixth, and seventh weeks, and, especially in the fifth week, around 55% were rejected (deleted but not replaced) and about 5.7% were accepted (replaced). The tendencies are different across classes. In Class C, as in (Fig. 6), we can observe less active responses compared to other two classes. We can say that the way of teaching has a significant impact on students' responses, and thus it is very important factor when we recommend highlights for students.

Unfortunately, we could discover no evidence that recommending highlights improves or hurts students' performance. However, we successfully affected the usage of highlighters by students. Additionally, teacher-level analysis gave us an insight that just suggesting highlights is not enough to change students' behaviors. The current limitations of this study include the simple recommendation algorithm and the rough analysis of the result. The former could be improved by personalization of recommendations. For the latter issue, we may be able to analyze in finer granularity by categorizing students based on their usual learning activity patterns, their learning strategies, and/or their academic motivations.

Conclusion

This study focused on the highlighter function of e-textbooks. We proposed suggesting to students adding highlights on their e-textbooks, and reported its effectiveness in quiz scores and highlighter-related learning activities. Our experiment was performed in large scale targeting a university course which 2,653 first-year students took. A set of highlight suggestions were generated based on last year's highlights and given to 7 classes (about 45% of all freshmen) out of 15 classes. From our analysis, we could not find any evidence that suggestions lead to a better performance. We also quantified the responses from the students. We observed that the average numbers of student-generated highlights increased only in the student group with recommendations while the ratios of acceptance or rejection of recommendations are very low. Furthermore, it was shown that the way of teaching affects the students' response significantly.

As future work, towards meaningful suggestions that could improve students' learning, we have to investigate what contributed to the gain in the number of highlights made by students in specific classes. Besides, considering that recommending the common set of highlighted regions doesn't affect quiz scores at all, we think some kind of personalization could improve the situation. For example, it will be helpful to refine recommendation to take into account students' individual understandings, learning strategies, and/or academic motivations.

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