Examining the effects of note-taking styles on college students' learning achievement and cognitive load

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This study investigated the effects of note-taking styles on college students' learning achievement and cognitive load in a 6-week lecture-based computer network course. Forty-two students were randomly assigned into one of three groups, which consisted of collaborative note-taking, laptop note-taking, and traditional longhand note-taking. The results showed that students in the collaborative note-taking group did better on learning achievement and cognitive load than students in the other two groups. Particularly, students in the collaborative note-taking group had a significantly higher rate of learning achievement and a significantly lower level of extraneous load than students in the longhand note-taking group.

Implications for practice or policy:

- College students can improve their learning achievement more effectively through collaborative note-taking style than individual note-taking style.
- College students can reduce extraneous load and improve germane load levels through collaborative note-taking.
- Instructors and administrators should encourage college students to take more collaborative notes during classroom instruction.

Keywords: collaborative note-taking, laptop note-taking, longhand note-taking, learning achievement, cognitive load

Introduction

Note-taking is a common, complex, and important activity, which requires the comprehension and selection of information, as well as written production processes in classroom learning (Piolat et al., 2005; Williams & Eggert, 2002). A wide range of empirical studies has confirmed that note-taking is a highly effective way to support learning processes. Di Vesta and Gray (1972) indicated that the functions of external storage and encoding are most beneficial for supporting learning, as these processes not only help learners to review and consolidate information but also encourage learners to focus on key ideas and organize the learning materials in a way that can be more efficiently processed. Note-taking engages the processes of active listening, connecting, and relating information to already available knowledge, as well as identifying questions that require clarification to improve one's comprehension of knowledge and ideas (O'Hara, 2005). Thus, it is not surprising that researchers show that people who take notes tend to perform better than those who do not engage in the practice (Peper & Mayer, 1978).

With the widespread use of personal computers and mobile devices in the classroom, the prevalence of digital note-taking has rapidly increased in higher education (Fried, 2008). Digital note-taking has shown several beneficial characteristics in comparison to the traditional handwritten or longhand note-taking process (H. H. Yang et al., 2020). For example, Kim et al. (2009) suggested that speed, legibility, and searchability are three positive attributes of digital note-taking. Moreover, with the support of a cloud-based note-taking system (CNS) developed by Tencent Inc., students can more easily take, share, and review notes in classroom settings (Orndorff, 2015).

Digital note-taking is mainly categorized as consisting of two different stylistic approaches: individualized note-taking on stand-alone laptops or other mobile devices (laptop note-taking), and collaborative note-taking on a CNS (collaborative note-taking). A number of studies have examined the style of note-taking on students' learning achievement. So far, some studies have been able to investigate the influence of different styles of note-taking on students' achievement, with very few studies simultaneously comparing the two types of digital note-taking with a traditional longhand group. Furthermore, the results of previous studies are inconsistent, which indicates that additional research is needed to clarify this critically important and widely prevalent phenomenon.

Bui et al. (2013) reported that laptop note-taking resulted in better overall performance in comparison to longhand note-taking. Meanwhile, other research has shown that longhand note-taking is more effective than laptop note-taking at supporting students' achievement (Mueller & Oppenheimer, 2014). In an effort to design a more comprehensive study capable of clarifying these inconsistencies, the present study sought to not only include three randomized groups (which consisted of the collaborative note-taking, laptop note-taking, and traditional longhand note-taking), as well as a secondary research variable (cognitive load), which is the main "explanatory mechanism behind the differing effectiveness of note-taking" (Jansen et al., 2017, p. 231).

Accordingly, this study aimed to examine the effects of all three styles of note-taking (longhand, laptop, and collaborative) on both students' achievement and cognitive load. With these considerations, it was designed to clarify the inconsistencies surrounding this important research gap and provide practical and theoretical insights that can be used to improve students' learning.

Related works

Note-taking style and learning achievement

Early studies on note-taking mainly focused on whether the external storage and encoding functions positively impact students' learning. For example, some studies indicated that students who engaged in longhand note-taking had significantly better learning performance than those who did not (e.g., Peper & Mayer, 1978). With the popularity of computers, a growing body of research has begun comparing the effects of laptop note-taking with longhand note-taking or collaborative digital note-taking with individualized digital note-taking on students' learning achievement.

In general, previous research has suggested that digital note-taking is usually faster than longhand note-taking, which allows students to actively bounce between note-taking tasks more quickly and allows them more time to focus on the lecture after taking notes. In this context, Schoen (2012) found that during a lecture laptop note-taking led to better performance on memory tests when compared to longhand note-taking. This view was supported by Bui et al.'s (2013) report that during short audio lectures laptop note-taking led to better performance compared to longhand note-taking. They indicated that laptop note-taking can assist students in taking greater quantities of notes and suggested that the more notes a student records, the stronger the influence on their learning as more information is being processed (Bui et al., 2013). However, this is only one interpretation of the phenomena. Mueller and Oppenheimer (2014) also identified that students who use laptop note-taking take greater quantities of notes, yet tend to take down information verbatim rather than through processing and rephrasing. As a result, students who use laptop note-taking perform worse on conceptual questions than students who use longhand note-taking.

Roschelle and Teasley (1995) defined collaboration as "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (p. 70). As such, collaborative note-taking is the way that students take and see notes jointly and simultaneously in small groups (Kam et al., 2005; Orndorff, 2015). Collaborative note-taking gives students the ability to share and compare their notes with peers in order to add missing information and to clarify important ideas when summarizing information (Y.-F. Yang & Lin, 2015).

Research indicates that collaborative note-taking can improve students' learning achievement. Kam et al. (2005) conducted an experiment in which students were randomly assigned to using LiveNote to take notes individually (laptop note-taking) or taking notes collaboratively in small groups of two to four students. They found that, compared to laptop note-taking, collaborative note-taking allowed students to develop a more comprehensive set of lecture notes, engage in a greater level of dialogue, and reflect a higher degree of internalization of the presented information. Further, Orndorff (2015) conducted an experiment that consisted of 51 students in the experimental group (using Google Drive for collaborative note-taking in small groups) and 197 students in the control group (taking notes individually). The results indicated that the experimental group performed better than the control group on course grades and independent learning outcome performance. Similarly, Y.-F. Yang and Lin (2015) found that students engaging in collaborative note-taking made greater progress on learning English as a foreign language than students without collaborative note-taking.

In summary, previous studies have shown that different styles of note-taking have different effects on students' learning achievement. Given the multiple varying results and interpretations of phenomena, it is likely that the dynamics of the situation require attention to additional variables that can help to better explain what is being observed. This paper includes the exploration of cognitive load because recent research has indicated that cognitive load may be the main factor influencing the differences in student performance (Jansen et al., 2017).

Cognitive load

Cognitive load theory (CLT) consists of multiple aspects of human cognitive architecture that are relevant to instruction, along with the instructional consequences that flow from that architecture (Chandler & Sweller, 1991, Sweller, 1988; Sweller et al., 2011). CLT differentiates cognitive load into three types: intrinsic load (IL), extraneous load (EL), and germane load (GL). IL is determined by the learner's prior knowledge and the natural complexity of the learning materials and tasks; EL is imposed by the instructional features that hinder students' learning; GL refers to the effort of the acquisition of knowledge by processing, construction, and automation of schemas (Leppink et al., 2013; Sweller et al., 1998, Sweller, 2010; Van Merriënboer & Sweller, 2005).

Cognitive load occurs when activities use up the resources of working memory, thereby decreasing the potential for additional learning (Bujak et al., 2013). According to CLT, the IL of a given instructional material cannot be manipulated. However, both EL and GL can be manipulated by the instructional design of the learning material (Brunken et al., 2003). Thus, to optimize cognitive load for learners, it is very important for instructional designers to "reduce extraneous cognitive load and redirect learners' attention to cognitive processes that are directly relevant to the construction of schemas" (Sweller et al., 1998, p. 265). For this reason, a number of studies have focused on various cognitive load effects and instructional strategies, including the completion-problem effect (F. G. W. C. Paas, 1992), worked-example effect (Cooper & Sweller, 1987), modality effect (Moreno & Mayer, 1999), split-attention effect (Chandler & Sweller, 1992) and expertise reversal effect (Kalyuga, 2009). With the increasing use of laptops in classrooms, some studies have also investigated the effect of information and communications technology on students' cognitive load and learning. These studies have shown that while information and communications technology brings benefits to classroom learning, it may also stimulate multitasking, especially related to non-academic tasks and activities. Such multitasking often distracts students' attention, increases extraneous cognitive load, and results in decreased levels of learning and retention of information (Calderwood et al., 2014; Sana et al., 2013).

With the popularity of digital note-taking, some researchers have probed different note-taking styles on students' working memory and cognitive load, thereby further explaining the difference in learning achievement (Jansen et al., 2017; Makany et al., 2008; Y.-F. Yang & Lin, 2015). However, few studies have measured cognitive load in different note-taking styles. Therefore, further research is warranted to test the effects of the note-taking style on cognitive load (Jansen et al., 2017).

This paper compared the different styles of note-taking on students' cognitive load and learning achievement. The following questions guided this study:

(1) What were the effects of longhand note-taking, laptop note-taking, and collaborative note-taking on students' learning achievement in classroom learning?
(2) What were the effects of longhand note-taking, laptop note-taking, and collaborative note-taking on students' cognitive load in classroom learning?

Methodology

Participants and setting

The present study was conducted from October 2019 to December 2019 at a university in central China. The participants of this study were 42 college students enrolled in a computer network course. All students were introduced to the purpose of the research before the study started. They were informed that their information would be used only for educational research. All responses would be given voluntarily and anonymously. As a result, all 42 students agreed to participate. Students were randomly assigned into one of three groups: the collaborative note-taking group, the laptop note-taking group, and the longhand note-taking group. Each group consisted of 14 students. In addition, the collaborative note-taking group was divided into four small teams, with each team consisting of three or four members. The three groups all shared the same physical environment and the same duration of contact time with the instructor. The same instructor, who had more than 10 years of teaching experience at the time that the study was conducted, taught all three groups.

Students in the collaborative note-taking group and laptop note-taking group were asked to bring their laptops, tablets, or smartphones to the classroom and use them to take notes during the class, given the fact that each student in these two groups has at least one certain type of mobile devices. Students in the longhand note-taking group were asked to use paper and pen to take notes during the class. Both the collaborative note-taking group and the laptop group used the CNS can obtain information efficiently and quickly, and the information can be shared and exchanged (Popescu et al., 2016). Thus, the CNS supports individualized laptop note-taking and collaborative note-taking. Participants in the collaborative note-taking group can take and view notes jointly and simultaneously. They can also take turns taking notes, allowing their teammates to attend to lectures more closely. Participants in the laptop note-taking and longhand note-taking group take notes individually without sharing and exchanging notes with peers.

Instrumentation

We co-designed the pre- and post-tests for learning achievement in collaboration with the course instructor. The pre-test consisted of six fill-in-the-blank and four multiple-choice questions, each with only one correct answer. The Kuder-Richardson reliability coefficient was calculated at 0.75. This finding suggested that the pre-test results are highly reliable with an acceptable level of internal consistency (Cortina, 1993). The post-test consisted of 15 multiple-choice questions, again with only one correct answer, as well as two free-response questions. The total potential score for both the pre-test and post-test was 100.

The Cognitive Load Scale (CLS) was modified from Leppink et al. (2013). We replaced the term *statistics* with *computer networks* in order to represent the subject relevant to the study's contextual setting. The CLS consisted of 10 items of three sub-scales: IL (three items), EL (three items), and GL (four items). The overall Cronbach's α value of the scale was 0.85, which indicated that the CLS possessed satisfactory reliability. This study used a 5-point Likert scale that consisted of responses from 1 = *strongly disagree* to 5 = *strongly agree*. A brief description of the CLS is shown in Table 1.

Table 1
Brief description of the CLS

CLS	No. of items	α	Example
IL	3	0.78	The activity covered formulas that I perceived as very complex.
EL	3	0.93	The instructions and/or explanations were full of unclear language.
GL	4	0.95	The activity really enhanced my understanding of the formulas covered.

Procedure

All students were asked to complete a pre-test which assessed their existing knowledge and was used for evaluating learning achievement. Students were also asked to fill out a pre-questionnaire related to the cognitive load within 30 minutes.

The instructor divided each 90-minute session into two parts. As shown in Figure 1, in the first part, 45 minutes of course time were spent on the instructor delivering the lecture to pass on the related knowledge and skills to students. The instructor presented the materials on a projector, explained concepts, terminologies, and key ideas using examples. Students were encouraged to process information in making their notes ‒ paraphrasing, selecting, and summarizing the materials either individually (laptop note-taking and longhand note-taking groups) or collaboratively (collaborative note-taking group).

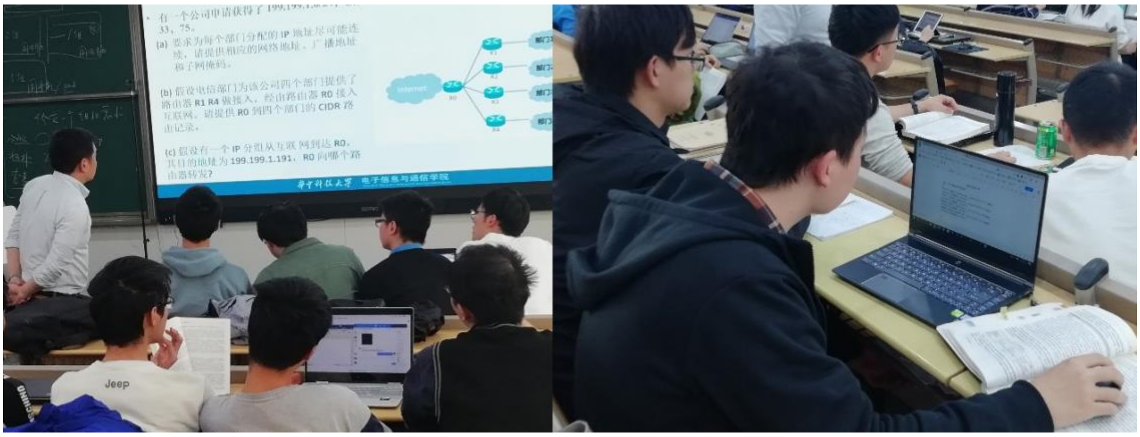

Figure 1. The instructor presents questions on the screen and students take notes individually or collaboratively.

As shown in Figure 2, in the second part, 45 minutes were spent on the students reviewing and practising what they had learned during the lecture. During this time, students were required to individually review their notes, answer the questions or solve the problems that the instructor put on the projector, through individual or group practice activities. In the meantime, the instructor could act as the facilitator providing quick feedback and responses to students' questions.

Figure 2. Students collaboratively reviewing notes and solving questions

The learning contents in the experiment were comprised of four sections of the computer network textbook for college students who major in electronics and information engineering. The four sections consisted of Routing, IPv6, TCP", and Application layer, and each session was conducted once a week for 6 weeks. At the end of the experiment, a post-test on learning achievement was conducted; the post-questionnaire on cognitive load was also filled out. SPSS software was used to conduct a one-way analysis of variance (ANOVA) and analysis of covariance (ANCOVA).

Results

Learning achievement

Before the teaching experiment began, a pre-test was conducted to determine the students' prior level of knowledge of computer networks. A one-way ANOVA was conducted on the three groups' scores of the pre-test. The independent variables in the ANOVA analysis were the three different styles of note-taking; the dependent variables were the pre-test scores of student learning achievements. As shown in Table 2, the results of the one-way ANOVA revealed no significant difference in the pre-test scores of the collaborative note-taking, the laptop note-taking, and the longhand note-taking groups ($F = 0.03$, $p > 0.05$). This indicated that there were no significant differences in the three groups' levels of existing knowledge prior to conducting the experiment.

Table 2
Pre-test ANOVA results for students' learning achievement

Variable		Sum of squares	df	Mean square	F
Pre-test	Between groups	14.33	2	7.17	0.03
	Within groups	11,400.07	39	292.31	
	Total	11,414.41	41		

At the end of the experiment, a post-test related to the learning contents of the course was conducted. This was done to assess students' learning achievements. To eliminate the interference effect of the pre-test scores, a one-way ANCOVA was conducted on the students' post-test scores, to examine the differences in the students' responses from three note-taking groups. Before the ANCOVA was conducted, Levene's test on the samples from the three groups was conducted. The homogeneity test showed no significant difference ($F = 2.29$, $p > 0.05$), which indicated that the ANCOVA could proceed.

In the ANCOVA, this study used the results of the pre-test as the covariance, the three types of note-taking as independent variances, and the post-test scores as the dependent variables. It should be noted that three students in the collaborative note-taking group did not answer two free-response questions in the post-test, which caused the standard deviation of this group to be prominently higher than those of the other groups. As shown in Table 3, the post-test score of the collaborative note-taking group's learning achievement was the highest, followed by the post-test score of the laptop note-taking group's learning achievement, and the post-test score of the longhand group's learning achievement was the lowest. The ANCOVA results were significant ($F = 3.89$, $p < 0.05$), which indicated that a significant difference existed between the three groups.

Table 3
Post-test ANCOVA results for learning achievement

Groups	N	Mean	SD	Adjusted mean	SE	F	η^2	Post hoc
Collaborative note-taking	14	54.43	13.79	54.51	2.77	3.89^{*}	0.17	(1) > (3)
Laptop note-taking	14	47.71	7.44	47.63	2.77			
Longhand note-taking	14	43.71	8.91	43.72	2.77			

$^{*}p < 0.05$.

To measure how much of the total variability is explained by the differences between the treatments, the effect size was computed by the η^2 (partial eta squared). According to Cohen (1988), if $\eta^2 > 0.14$, the effect size is thought to be a large effect. In the present study, the result of the η^2 was 0.17, which indicated a large effect size regarding the effects of collaborative note-taking on students' learning achievement. Therefore, a further post hoc comparison was conducted. The comparisons showed that the post-test score of the collaborative note-taking group is significantly higher than that of the longhand group ($p = 0.03 < 0.05$).

Cognitive load

Students' cognitive load was assessed using the CLS, both before and after the experiment. This was done to examine the different effects of the three note-taking styles. Before the learning experiment began, a one-way ANOVA had been conducted on the students' pre-test scores of the CLS. In the ANOVA, the independent variables were the three different note-taking styles, and the dependent variables were the pre-test scores for students' cognitive load. As shown in Table 4, no significant difference was found among the three groups' pre-test scores for cognitive load (IL: F = 1.19, $p > 0.05$; EL: F = 1.03, $p > 0.05$; GL: F = 0.54, $p > 0.05$). These results suggested that students in the collaborative note-taking group, the laptop note-taking group, and the longhand note-taking group all had a similar level of cognitive load before the experiment.

Table 4
Pre-test ANOVA results for cognitive load

Variables		Sum of squares	df	Mean square	F
Intrinsic load	Between groups	1.624	2	0.81	1.19
	Within groups	26.64	39	0.68	
	Total	28.27	41		
Extraneous load	Between groups	2.23	2	1.11	1.03
	Within groups	42.18	39	1.08	
	Total	44.40	41		
Germane load	Between groups	0.60	2	0.30	0.54
	Within groups	21.59	39	0.55	
	Total	22.19	41		

At the end of the teaching experiment, a post-test was conducted on the CLS, to assess students' cognitive load. A one-way ANCOVA was conducted on the students' post-test cognitive load scores to eliminate the interference effect of the cognitive load pre-test scores. A Levene's test was conducted, and the homogeneity test showed no significant differences (IL: F = 1.52, $p > 0.05$; EL: F = 0.20, $p > 0.05$; GL: F = 1.35, $p > 0.05$), so the ANCOVA could proceed. In the ANCOVA, this study used the results of the pre-test for the cognitive load as the covariance, the three note-taking styles as independent variances, and the post-test scores of cognitive loads as the dependent variables. While IL remained at the modest level and the average scores of all three groups' IL were around 3, the ANCOVA results showed the three types of note-taking style were different on EL and GL, as shown in Table 5.

Table 5
Post-test ANCOVA results for cognitive load

Variables	Groups	N	Mean	SD	Adjusted mean	SE	F	η^2	Post hoc
Extraneous load	Collaborative note-taking	14	1.98	0.76	1.90	0.21	3.92*	0.17	(1) < (3)
	Laptop note-taking	14	2.64	1.07	2.55	0.21			
	Longhand note-taking	14	2.50	1.01	2.68	0.21			
Germane load	Collaborative note-taking	14	3.59	1.00	3.50	0.25	0.20	0.01	
	Laptop note-taking	14	3.27	1.10	3.29	0.24			
	Longhand note-taking	14	3.38	0.89	3.45	0.25			

*$p < 0.05$.

On one hand, the collaborative note-taking group's EL was the lowest among the three groups. There were significant differences in EL ($F = 3.92$, $p < 0.05$) among the three types of note-taking. In addition, the η^2 was computed to measure how much of the total variability is explained by the differences between the treatments of the three groups. The value of the η^2 was 0.17, which suggested a large effect size regarding the effects of collaborative note-taking on students' EL. A post hoc comparison of the post-test of EL was further conducted. The results showed that, while the collaborative note-taking group's EL was notably lower than that of the laptop note-taking group, the collaborative note-taking group's EL was significantly lower than that of the longhand note-taking group ($p = 0.027 < 0.05$). On the other hand, although there was no significant difference in GL ($F(2, 38) = 0.20$, $p > 0.05$), the collaborative note-taking group's GL was the highest among the three groups.

Discussion and conclusion

To further understand the effects of note-taking styles on students' achievement, this study took a more comprehensive approach to examine the learning achievement of students in the collaborative note-taking group, laptop note-taking group, and longhand note-taking group on a computer network course, alongside students' cognitive load – the main factor suggested as influencing the various findings of learning achievement (Jansen et al., 2017). The findings of this study confirm the association between the note-taking styles and cognitive loads in students' learning achievement.

In this study, the collaborative note-taking style was observed outperforming the other two note-taking styles. Particularly, the students in the collaborative note-taking group were observed to have a significantly higher level of learning achievement than the students in the longhand note-taking group. The large effect size as shown by the partial eta squared also provided solid proof for this significant improvement of students' learning achievement in the collaborative note-taking group. These results are in line with those of previous studies investigating the effects of different note-taking styles on learning achievement (Kam et al., 2005; Orndorff, 2015; Y.-F. Yang & Lin, 2015). It should be noted that such differences could be related to the changes in cognitive load during learning. First, among the three note-taking groups, the post-test EL score of students in the collaborative note-taking group was much lower than the scores of the students in the laptop note-taking and the longhand note-taking groups. The large effect size as indicated by the partial eta squared showed robust evidence that the treatment in the collaborative note-taking group reduced students' EL significantly. Compared with students in the laptop note-taking group and the longhand note-taking group, students in the collaborative note-taking group could add new notes while other members were transcribing early lecture statements. They could also take turns taking notes so that others could listen more closely to the lecture (Kam et al., 2005). Thus, some general sources of extraneous cognitive load were dramatically reduced from the collaborative note-taking group, for example, the split-attention effect and the redundancy effect (Sweller, 2010) were much less prominent. Particularly, students in the collaborative note-taking group were seen to possess a significantly lower extraneous load than students in the longhand note-taking group. Consequently, students in the collaborative note-taking group were able to take lecture notes and encode information more efficiently and thoroughly. Second, the post-test GL score of students in the collaborative note-taking group was the highest among the three groups. Huang et al. (2017) believed that, in comparison to the individual note-taking styles, the collaborative note-taking style allows students to participate more actively in the learning process by engaging in discussions, sharing thoughts with fellow students, and listening to the different ways of thinking presented by their peers. Comparing and sharing notes with peers allowed students in the collaborative note-taking group to interpret, classify, differentiate, reorganize and restructure the important information and knowledge, which could stimulate germane processes and enhance recall from working memory (De Jong, 2019; Kam et al., 2005; Y.-F. Yang & Lin, 2015). As a result, under the combined effect of the decrease of EL and the increase of GL, the students in the collaborative note-taking group made greater progress on learning achievement than the students in the laptop note-taking group and longhand note-taking group.

This study showed that students' learning achievement score in the laptop note-taking group was notably higher than that of the longhand note-taking group. This finding tends to support Bui et al.'s (2013) study, which illustrated that when lecture material is complicated, and new information is continuously presented, the speed of laptop note-taking is more beneficial in comparison to traditional forms of longhand note-taking, which describe a slower documentation process. That is to say, digital note-taking on a laptop allows students to take notes more quickly, which effectively reduces the amount of time that students are required to divide their attention between either listening to the lecture or writing notes (Jansen et al., 2017). Therefore, it appeared that the post-test EL score of students in the laptop note-taking group was lower than the scores of the students in the longhand note-taking group. It is somewhat surprising that the post-test GL score of students in the laptop note-taking group was also lower than the scores of the students in the longhand note-taking. A possible explanation for this might be that "efforts to reduce high extraneous load by using linear formats may at the same time reduce germane cognitive load by disrupting the example comparison and elaboration processes" (F. Paas et al., 2004, p. 4). This finding also accords with Mueller and Oppenheimer's (2014) observations, which showed longhand note-takers are more inclined to process information and reframe it in their own words than laptop note-takers. Thus, students in the longhand note-taking group had higher GL than students in the laptop note-taking group.

The contributions of this manuscript should be recognized in consideration of some limitations. Firstly, this study utilized a relatively small sample size, because only one subject and one class were included in this initial study. In addition, 42 students from only one class were divided into three groups, further reducing the sample size of each group in terms of examining the effects of the intervention. More subject disciplines, such as English or science, technology, engineering, mathematics courses, and other classes with larger sample sizes are expected to be involved in future studies. Secondly, this study examined students' learning achievements and cognitive loads. We suggest that additional factors, such as motivation and self-efficacy, should be further examined to investigate the broader influence toward the digital note-taking styles. Finally, the duration of this experimental study was only 6 weeks; it seems possible that the potential benefits of the different note-taking styles could have not been fully activated; for example, this study did not find a significant difference in GL among the three groups, or it could have been influenced by novelty within this short of a duration. To this end, we suggest that future studies should examine longer durations of time.

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