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Investigating effects of mobile learning in familiar authentic environment on learning achievement and cognitive load

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Abstract: This study designed English as foreign language learning activities in a familiar authentic environment with mobile technological support. Students learned at school and then applied new knowledge to solve daily life problems by taking pictures of learning objects, describing them, and sharing their homework with peers. This study carried out two experiments in which 59 junior high school students participated. One class with 28 students served as the control group in the experiment 1 and as the experimental group in the experiment 2. The other class with 31 students served as the experimental group in the experiment 1 and as the control group in the experiment 2. Control students studied and completed each learning activity with traditional textbooks while the experimental group studied with an electronic textbook and a learning system installed in the tablet PCs. This study aimed to investigate effects of mobile learning in familiar authentic environment on learning achievement and cognitive load. This study discusses results, research findings, and implications along with conclusions and several suggestions for future development and research.

Keywords: Mobile learning, familiar authentic environment, learning achievement, cognitive load

1. Introduction

The rapid advancement of information and communication technology created new opportunities in the design of the instruction (Hwang et al., 2014; Shadiev, Hwang, Huang, & Yang, 2014). According to the related studies, for instance, mobile technology provides such advantages as learning anywhere and anytime, and how one likes (Hwang, Chen, Shadiev, Huang, & Chen, 2012). Chang, Tseng, and Tseng (2011) suggested that mobile technology creates an authentic learning environment in a real-world context in which learners adapt learning content to the context they find themselves in. Furthermore, mobile technology can be used as a cognitive tool to aid the learning by decreasing the cognitive load (Hwang, Wu, Zhuang, & Huang, 2013). Therefore, mobile-assisted learning has been successfully implemented in many studies to manage cognitive load and facilitate learning; for example, in a social science course (Hwang et al., 2013) or foreign language learning (Chen, Hsieh, & Kinshuk, 2008; Chang et al., 2011).

The literature review of this study revealed several issues that they need to be addressed appropriately. First, several studies were carried out to reduce cognitive load in English learning; however, focus of most of them was limited to vocabulary learning and reading and listening comprehension (Chang et al., 2011; Chen et al., 2008). Therefore, cognitive load associated with speaking and writing skills, was overlooked in related studies. Second, familiar context that creates advantages in comprehension, recall, and cognitive load and which can be found in authentic environment, was not considered in most related studies. An authentic learning environment was created in a local temple (Hwang et al., 2013), in a zoo (Chang et al., 2011), or a classroom Chen et al. (2008) by employing mobile technology but learning context there was not so familiar to students. Third, in most previous related studies, active application of knowledge did not get sufficient attention (Chang et al., 2011; Chen et al., 2008; Hwang et al., 2013). In these studies, a mobile learning system provided learning content, guided students to the learning targets, displayed questions, and students were asked to answer them. Such learning process facilitates only low level cognitive processes (i.e. information recall).

To address these issues, this study designed various learning activities supported by a mobile technology. In learning activities, students could learn in class and then freely apply what they learned to solve daily life problems in a familiar authentic environment (e.g. their home or a local convenience store). In this study, students took pictures of learning objects in a familiar authentic environment and described them by using English as a foreign language. This study aimed to investigate how mobile learning in familiar authentic environment effects learning achievement and cognitive load.

2. Cognitive load

Mayer and Moreno (2003) and Paas et al. (2003) argued that cognitive load is a central consideration in the design of the instruction. The reason is that a learner has limited cognitive capacity to accommodate demands imposed by learning task, due to working memory (Paas et al., 2003). According to Mayer and Moreno (2003) and Paas et al. (2003), learning performance can be negatively affected when cognitive load exceeds the limit of cognitive capacity. Three types of cognitive load were distinguished in related literature: intrinsic, extraneous, and germane (Brunken, Plass, & Leutner, 2003; Sweller, Van Merrienboer, & Paas, 1998). Intrinsic load is determined by the inherent nature of learning material, learners' expertise and an interaction between them; that is, the amount of information units that a learner needs to hold in working memory to comprehend the information. Extraneous load is referred to cognitive load caused by the format and manner in which information is presented and by working memory requirements required to do the instructional activities. Extraneous load can be imposed by improper instructional design. Germane load is determined by learners' effort to process and comprehend the learning material. This load is also associated with motivation and interest. Germane load is induced by appropriate instructional design and it can enhance learning.

3. Managing cognitive load in authentic learning environment

It is suggested that learning activities in authentic environment are likely to facilitate students' cognitive activity and conceptual change (Shadiev, Hwang, & Huang, in press). Furthermore, in authentic environment, cognitive tools, such as mobile multimedia applications, can aid the learning by decreasing the cognitive load. Hwang et al. (2013) introduced a mobile learning system to aid sixth grade students' local culture learning during field trip in the social science course. With the system, students accessed physical and virtual resources in authentic environment; the system presented the learning tasks, guided students to visit the real-world learning targets for exploration, and provided them with supplementary materials via the mobile devices. The effects of this approach on students' cognitive load and learning achievements were investigated. Results showed that students who learned with technological approach had better learning achievement and less cognitive load than those who learned with the traditional approach. Hwang et al. (2013) suggested that the mobile learning approach has positive effects on students' local culture learning.

Chen et al. (2008) explored how short-term memory and content representation type affect language learning in mobile learning environment. EFL university students were divided into verbal and visual short-term memory group and all of them learned 24 English words (with written annotation and pictorial annotation) delivered by Short Message Service or Multimedia Message Service to their mobile devices. Chen et al. (2008) found that providing vocabulary with pictorial annotation is helpful to learners with lower verbal and higher visual ability. The reason is that these learners find it easier to learn words presented in a visual rather than in a verbal form. However, providing vocabulary with both written and pictorial annotation can also help learners with both high verbal and high visual abilities. Chen et al. (2008) concluded that providing the basic learning material is more helpful to learners with low verbal and visual abilities as too much information may produce a high cognitive load and shorten concentration time.

Chang et al. (2011) examined the effects of English proficiency (low vs. high) and material presentation mode (single channel vs. dual channel) on English listening comprehension and cognitive load in a ubiquitous learning environment. In an experimental learning activity, university students studied zoo animals by using PDA. The system guided students to target animal areas and then displayed related material (i.e. text) and played audio guide (spoken messages). Students in a single channel group learned through spoken messages only, whereas students in a dual channel group learned by text and spoken messages. Results of the study revealed that high and low English proficiency learners in the dual channel group had better English listening comprehension than learners in the single channel group. Low English proficiency learners in the dual channel group possessed significantly lower extraneous load than those in the single channel group. Chang et al. (2011) concluded that dual channel presentation mode leads to an increased depth of information processing and different input modes reinforce one another.

4. Method

Two experiments were carried out in this study. A total of 59 junior high school students participated in two experiments. One class with 28 students served as the control group in the experiment 1 and as the experimental group in the experiment 2. The other class with 31 students served as the experimental group in the experiment 1 and as the control group in the experiment 2. Most students in both groups were thirteen years old with four to six years' experience of using computers and less than one to three years' experience of using tablet PCs.

The experimental procedure of this study is as follows. First, a pre-test was conducted before the experiment started. Then both classes had the same amount of hours of English course: three one-hour lessons a week. After lessons, students participated in learning activities to practice their skills and applied new knowledge in daily life situations. Lessons and learning activities taught in the two classes were guided by the same instructor and shared the same learning content. However, the control group studied and completed learning activities with traditional textbooks while the experimental group studied with an electronic textbook and learning system installed in the tablet PCs. Learning activities were three tasks; each lasted for two weeks. In the beginning of the experiment, every experimental student received tablet PC and students were taught how to use the e-textbook and system by the instructor. A post-test and cognitive load questionnaire survey took place in the end of the experiment with all students. Finally, interviews with experimental students were carried out one week later after the experiment.

This study designed learning activities that were focused on learning at school and applying knowledge learned in authentic environment outside of school with a wide range of daily life situations (e.g. at local convenience store or supermarket). Three topics from the textbook were chosen to design learning activities: (1) "Where Are You From?" (2) "You School Is Very Big," and (3) "Be Quiet and Sit Down, Please" for the first experiment and (1) "Which do you like – Healthy diet," (2) "How much / many do we need," and (3) "We were in different classes" for the second experiment. Learning activities were three tasks, and each corresponded to its topic. In each task, students were asked to take a picture of a learning object (e.g. a sign for Topic 3 of the first experiment or a meal for Topic 1 of the second experiment) and then to introduce and to describe it by using at least 6-10 sentences.

This study developed the learning system to support students to carry out the learning activity tasks. The following four main functions were designed in the system: (1) Annotating. Students could annotate important parts of learning material on tablet PCs. Besides, students could take photos and attach them to an annotation. (2) Recording. When students spoke out to describe a learning object, they could record their own voice and play it afterwards. Besides, students could record the instructor's lectures and listen to them. (3) Assistance. Students could get assistance from the system, such as (a) read text out loud (Text-to-Speech Recognition), (b) translate unfamiliar vocabulary and sentences (Translation), and (c) list of words in alphabetical order with their meaning and translation (Dictionary). (4) Sharing. Students could share their own annotations, photos, and audio recorded files with peers.

The following are research tools that were employed by this study. Students' prior knowledge was evaluated by a pre-test and students' learning achievement was measured by a post-test in two experiments. The items of the pre-test and post-test for both experiments were similar in structure but different in content. Thirty items were included in each test: (1) Match English word with the correct Chinese meaning – eight items; (2) Write down the Chinese meaning of English word – six items; (3) Fill in the blank – ten items; (4) Write down: a) a question based on a sentence; b) negative sentence from given one; and c) translation of a sentence – 5 items; and (5) Write down about yourself when you were at the first grade of the elementary school, then write about yourself at the moment, and finally, compare the difference between when you were at elementary school and now – 1 item. Students' answers to the tests were scored on a 100-point scale.

Cognitive load questionnaire (Huang, Huang, Liu, & Tsai, 2013) was developed with seven items: (1) Learning these materials was easy, (2) Learning these materials did not require a lot of mental effort, (3) Completing learning activities was easy, (4) Completing learning activities did not require a lot of mental effort, (5) I was concentrated during learning, (6) My mood was joyful during learning, (7) My frustration was low during learning. Items 1 and 2 of the questionnaire measured intrinsic cognitive load, items 3 and 4 measured extraneous cognitive load, and items 5, 6 and 7 measured germane cognitive load. All 59 students were asked to respond to the questionnaire and 59 valid answer sheets were obtained. Responses to the items were scored using a five-point Likert scale, anchored by the end-points "strongly agree" (1) and "strongly disagree" (5). The internal consistency of the survey was tested by employing Cronbach α; the values exceeded 0.80 demonstrating satisfied reliability of the items.

One-on-one semi-structured interviews were conducted with randomly selected ten experimental students from each experiment. Interviews aimed to explore students' learning experiences with the system and insights of their perceptions toward cognitive load. Each interview lasted for 20 minutes and students were asked the following questions: 1) Please describe your learning experience with the system; 2) Was the system useful for learning? If yes, please explain why.

5. Results and discussion

5.1 Effects of mobile learning in authentic environment on learning achievement

This study employed analysis of covariance to measure the difference in the learning achievement of students in the control and experimental students on the post-test with the pre-test as covariate. In the experiment 1, a significant difference was observed between the control (M=53.50, SD=13.21) and experimental group (M=65.45, SD=18.59) on the post-test, $F(1,56)=16.709$, $p=0.000$, partial eta-squared=0.236. In the experiment 2, the experimental group (M=70.32, SD=17.01) outperformed the control group (M=58.30, SD=22.67) on the post-test, $F(1, 56)= 20.345$, $p=0.000$, partial eta-squared=0.270.

Students were asked to introduce and describe some learning objects (e.g. signs and rules in the convenience store of their local community). The experimental students in two experiments completed assigned tasks better than the control students. This finding may suggest that learning activities in familiar authentic context supported by the system could facilitate students learning.

This study interviewed experimental students to provide subjective evidence that may support abovementioned objective evidence. In the interviews, students mentioned that learning activities could be completed more efficiently if using the system instead of traditional approach. Furthermore, the system enabled more effective practice of EFL skills. First, students took pictures of learning objects and recorded their own voice when describing learning objects. Students were fond of reviewing pictures and listening to their own recorded files, and if content quality of photos and recorded files was not satisfactory (e.g. mistakes in pronouncing some words), students would want to improve it. According to students, such learning behavior led to more frequent language practice as well as to better quality of language output. Similar reasons to using multimedia tools for language practice were reported in other research (Harmer, 2007; Hwang, Shadiev, & Huang, 2011; Hwang & Shadiev, 2014;). For example, students in the study of Hwang, Huang, Shadiev, Wu, and Chen (in press) and Hwang et al. (2011) took advantage of the technology in the same way of practicing the target language repeatedly and regularly. In the study of Harmer (2007), after students recorded their speeches, they listened to recordings, evaluated language performance, and monitored how much progress made. However, in contrast to other related research, this study focused not on learning the basic knowledge at school only, but the application of learned knowledge to solve wide range of real life problems in familiar authentic environment.

Second, students shared recorded files with peers. In this way, students could listen to peers' recorded files (i.e. usually to those who study hard and perform well) to get inspirational ideas to complete their own assignments or to learn how peers accomplished assignments and to improve their own homework. Students could exchange meaningful comments through sharing. That is, some students gave reflective comments and suggestions to a peer who did not complete homework correctly. Besides, students' comments were useful to revise or improve homework. Students highly thought of sharing mechanism of the system as they were able to learn from others, and then to locate and revise their own mistakes in homework. Hwang et al. (in press) and Hwang et al. (2011) argued that, with multimedia aids, students access more diverse learning objects and this may increase the richness of their language experience. They further suggested that sharing multimedia learning content with others not only increases practice opportunities but engages students in EFL contexts and allows their deeper reflection on learning content, discussion and collaboration.

Finally, students stated that the built-in dictionary was very handy when they needed to translate some unfamiliar vocabularies when completing assignments outside of school or at home. In this case, a dictionary could help to translate these words. Moreover, with a dictionary, students could find multiple meaning of a word and how it can be used in different contexts. Hulstijn and Laufer (2001) argued that the use of a dictionary positively affects vocabulary learning. Students look up target words in the dictionary during the reading session in order to find word meanings and to understand the main idea of texts. According to Hulstijn and Laufer (2001), those students who read foreign language texts and use a dictionary can understand texts better and remember more word meanings.

5.2 Effects of mobile learning in authentic environment on cognitive load

This study examined whether designed learning activities supported by the system brings extra cognitive load on students during learning. Therefore, cognitive load of the experimental and control students was measured and then compared by employing independent samples test. The means and standard deviations from the assessment with respect to seven items of the questionnaire and results of t-test are presented in Table 1. According to the table, the control students had higher cognitive load with regard to all seven items ($p<0.05$) than the experimental students. This finding suggests that learning activities supported by the system enabled students have less cognitive load compared to traditional learning setting.

Table 3: Cognitive load assessment and t-test results

Item	The experiment #1							The experiment #2						
	Control		Experimental		*t*	Sig. 2-tailed	MD	Control		Experimental		*t*	Sig. 2-tailed	MD
	M	SD	M	SD				M	SD	M	SD			
1.	1.90	0.94	1.48	0.51	2.097	0.042	0.413	2.10	0.76	1.50	0.64	3.247	0.002	0.600
2.	2.10	0.86	1.58	0.50	2.852	0.007	0.523	2.33	0.96	1.68	0.67	2.995	0.004	0.655
3.	2.07	0.84	1.61	0.50	2.535	0.015	0.456	2.27	0.91	1.61	0.74	3.025	0.004	0.660
4.	2.14	0.88	1.55	0.51	3.166	0.003	0.590	2.37	0.89	1.68	0.72	3.218	0.002	0.688
5.	2.21	0.82	1.77	0.43	2.544	0.015	0.433	2.50	0.68	1.68	0.72	4.452	0.000	0.821
6.	2.10	0.90	1.61	0.50	2.591	0.013	0.491	2.60	0.81	1.46	0.58	6.095	0.000	1.136
7.	2.03	0.87	1.58	0.50	2.464	0.018	0.454	2.37	0.72	1.54	0.64	4.647	0.000	0.831

This study further explored the changes of cognitive load in two groups of students across different approaches (learning activity with and without technological support). For example, the group A was the control group in the experiment 1 and used traditional method to complete the tasks; then, it became the experimental group in the experiment 2 and used technological support to complete the tasks. On the other hand, the group B was the experimental group in the experiment 1and it became the control group in the experiment 2. So this study investigated how students' cognitive load would change when approaches changed. Independent samples test was employed for such analysis. According to the results, there were significant differences in students' cognitive load between two different approaches. Compared to the control students, those who were in the experimental groups had lower load with respect to all seven items ($p=0.005$). This result confirms the previous finding of this study that learning activities supported by the system helped to reduce experimental students' cognitive load compared to control students.

One reason that may explain these two findings may be due to the nature of the learning material and activity for two groups. In this study, the learning materials and activities for the control and experimental students were identical apart from that the learning materials for the experimental students was in electronic form and they could take advantage of the system's functions mentioned earlier, such as (1) Annotating, (2) Recording, (3) Assistance, and (4) Sharing, to complete learning tasks.

The system functions helped to keep intrinsic load from being overloaded while experimental students learned with the electronic textbook. Students could annotate important parts of learning material (e.g. key concepts) by highlighting them or adding textual and multimedia explanation (e.g. a concept meaning and examples of its application in various contexts). Afterwards, these annotations helped students to find important concepts easily, to recall them, and to complete homework or to prepare for the exams. It is important to note that learning material and relevant annotations (i.e. text, photo, and audio) were located on the same screen. Students anchored their annotations to learning material which built a connection between the annotation and the learning material and gave students a clear picture of the whole learning scenario with an appropriate explanation of it. Mayer and Moreno (2003) called this form of presentation as integrated presentation; with such approach, learners would be more devoted to essential information processing, that is, more cognitive capacity would be activated. Apart from learning from the electronic textbooks, students could learn learning materials from peers' annotations. Studying shared annotations including photos, texts, and audios helped students to enhance their understanding of learning material, to get new ideas and inspiration, and to improve their own homework. Students could also get assistance from the system as Dictionary, translation or Text-to-Speech Recognition to find translation and correct pronunciation of unfamiliar vocabularies or sentences. If students needed to recall some important concepts taught by the instructor from previous classes, they could listen to recorded lectures. Related literature suggests that intrinsic load lies in the nature of learning material, learners' expertise and an interaction between them (Brunken et al., 2003; Sweller et al., 1998). It is argued that intrinsic load represents the amount of different types of information that students need to consider in acquiring new knowledge, i.e. how much information the working memory needs to deal with at the same time (Mayer and Moreno, 2003; Paas et al., 2003). Hwang et al. (2013) suggested that intrinsic cognitive load can be affected by the instructional learning material and students will be cognitively overloaded if the materials are poorly structured, difficult to read, or too complex. Based on the above-mentioned result and considering the fact that students in two groups learned with the same learning materials and tasks, this study suggests that the intrinsic cognitive load resulted from the method students used to access and to process the information. The interviews with students support this finding. Students mentioned in interviews that, compared to traditional approach, it was easier to learn with electronic textbooks and the system. Based on the abovementioned findings, this study concludes that, with the technological support, experimental students' intrinsic load was lower; it was easy for students, and it did not require a lot of mental effort to learn learning material.

It is suggested that extraneous load can be caused by improper instructional design. Thus, in order to reduce extraneous load, instructors need to organize, present and carry out learning information and activities appropriately. In this study, functions of the system helped to reduce extraneous load while students participated in learning activities. When they exposed themselves to the authentic learning environment outside of the school, taking pictures of learning objects and describing them with text or voice annotations worked like gathering their thoughts and then transforming them into artefacts. Hollan, Hutchins, and Kirsh (2000) called such transformation of thoughts as distributed cognition. Hollan and his colleagues argued that knowledge and cognition are not confined to an individual but distributed by placing memories, facts, or knowledge on the objects, individuals, and tools in the learning environment as a set of representations. Lu, Lai, and Law (2010) argued that technology plays an important role to handle intellectual tasks and to ease individual cognitive load. Later, when students were at home, they could have a more tranquil environment and study created artefacts (i.e. pictures and their textual and audio descriptions). These artefacts would help students to easily recall details of learning objects from authentic learning environment, to find out what they missed while completing the tasks, and what else can be improved in their homework. Otherwise, students had to hold a mental representation of the context in working memory over a period of time which was called representational holding (Mayer & Moreno, 2003). According to Mayer and Moreno (2003), when students attempt to engage in both information processing (i.e., selecting, organizing, and integrating learning material) and representational holding, cognitive overload occurs. Our finding is supported by the interview with students. Students claimed in interviews that, compared to traditional method, it was easier to participate in learning activities with electronic textbooks and the system. Students also mentioned that a familiar authentic environment helped them to recall some important vocabularies; the context was related to students' background and previous experiences and also very relevant to learning tasks. Therefore, this study may conclude that with technological support, experimental students' extraneous load in a familiar authentic environment was lower. Thus, completing learning activities with the support of the system a familiar authentic environment was easy and it did not require a lot of mental effort.

Related literature suggests that germane load is determined by appropriate instructional design and it can enhance learning. With the system support, this study attempted to direct students' attention to cognitive processes that are directly relevant to the learning material and tasks. The system functions enabled students to take pictures of learning objects in familiar authentic environment and then describe them with textual and voice annotations. Students could review their textual descriptions or listen to the audio recorded files afterwards. Students mentioned that completing the tasks in this way helped learning and made it more interesting. Furthermore, students claimed that learning in authentic familiar context and creating their own learning materials related to everyday life inspired students to engage in the materials and to try producing more meaningful output. Huang Chiu, Liu, and Chen (2011) suggested increasing students interest in learning and making them engaged in learning activities and tasks more by utilizing multimedia aids (e.g. pictures and audio). Furthermore, Caldwell (1998) argued that multimedia objects in learning stimulate students' imagination and helps bring out meaningful output. Some students, particularly of low ability, admitted that in the way they learn with the system, they could communicate in the target language with less anxiety of making mistakes. Chen and Chang (2009) argued that anxiety is a subjective feeling of worry, nervousness, or unease associated with arousal of the autonomic nervous system. Anxiety interferes with cognitive ability to absorb, process, and produce a foreign language. Furthermore, it negatively affects cognitive load. In contrast to traditional learning, experimental students learned with more confidence and their learning was more creative and enjoyable. The interview with students verified this finding. In interviews, students confirmed that learning content and activities in the electronic textbooks with a familiar authentic context were more interesting, fun, and engaging than that in traditional method. Therefore, this study may conclude that, with the support of the system, experimental students' germane load was higher in a familiar authentic environment. Experimental students concentrated more during learning in a familiar authentic environment; their mood was joyful and their frustration was low.

6. Conclusion

Two main findings were revealed in this study. First, the experimental students outperformed better than control students on post-test items in both experiments. Second, learning activities in a familiar authentic environment supported by the system enabled students to have less cognitive load compared to the learning setting without technological support. That is, the experimental students' intrinsic and extraneous load were reduced while germane load was increased compared to the control students.

Based on these findings, this study recommends educators to employ appropriate learning activity design and the system to facilitate students' learning achievement and their cognitive load management. In designing learning activities, the teacher has to consider how to make the best of the system to develop students' productive skills and managing cognitive load. For example, in this study, students took photos of learning objects and described them with text and voice. Photos and textual and audio descriptions were shared among students so that they could learn from each other and get some new ideas to improve their own homework. The system provided multiple channels for students to present their language output (i.e. taking pictures of learning objects and then describing them in written and oral ways) and gave students more opportunity to use the language. Thus, the teacher may organize learning activities in the way they were designed in this study. Furthermore, the teacher may encourage students to use the functions of the system, such as annotating, recording, assistance, and sharing, to reduce their intrinsic and extraneous loads and increase germane load. In this way, students can efficiently study learning material, complete the tasks, and enjoy the learning process at the same time. For example, students can take advantage of annotating to reflect on learning material and review reflections afterwards for better understanding of new concepts or for exam preparation. Students can also distribute their cognition to artifacts created in authentic environment with familiar context. Furthermore, the learning environment created by the system can reduce students' anxiety and help in giving meaningful output, especially low ability students.

There are several limitations found in the study that need to be considered. The first limitation concerns the relatively small sample size. The second limitation relates to short-term exposure of the technology to aid learning. For this reason, these findings cannot be generalized to a broader community based on this study alone or they have limited relevance to learning scenarios in which the technology long-term exposed in "real-world" conditions. These limitations will be addressed in a future study. In the future, our approach can be applied to other domains (e.g. Mathematics or Biology), and cognitive load can be measured objectively by observations of behavior or physiological conditions. The future study will also focus on how a familiar authentic context without mind tools can help to decrease cognitive load of students by comparing cognitive load of control and experimental groups.

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