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Effects of interactivity and instructional scaffolding on learning: Self-regulation in online video-based environments

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ABSTRACT

Online learning often requires learners to be self-directed and engaged. The present study examined students' self-regulatory behaviors in online video-based learning environments. Using an experimental design, this study investigated the effects of a newly designed enhanced video learning environment, which was designed to support or scaffold students' self-regulated or self-directed learning on students' learning behaviors and outcomes. In addition, correspondence between students' self-regulation strategies in traditional learning environments and observed self-regulated learning behaviors in the enhanced video environment were examined. A cross-sectional experimental research design with systematic random assignment of participants to either the control condition (common video) or the experimental condition (enhanced video) was utilized. Undergraduate and graduate students participated in the study ($N = 80$). Study results indicate that the newly designed enhanced video learning environment was a superior instructional tool than the common video learning environment in terms students' learning performance. In addition, there was correspondence between graduate students' self-reported self-regulation and observed self-regulation, with those high on seeking/learning information and managing their environment/behavior more likely to engage more in interactive note-taking.

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1. Introduction

Online learning often requires learners to be self-directed and engaged in their learning, particularly because there are often fewer sources of reinforcement and prompts from instructors or peers to keep learners on task with the learning objectives. Thus, learners are likely to optimize their learning and performance in online learning environments when design and development of online learning tools are informed by research on learners' self-regulation and motivation. Self-regulated learning (SRL) involves effective use of cognitions, behaviors, and emotions to achieve learning goals (Pintrich, 2000). Self-regulated learners know how and when to use meta-cognitive strategies such as self-monitoring and self-evaluation for optimal learning and successful performance (Pintrich & De Groot, 1990; Zimmerman & Martinez-Pons, 1990). Although the majority of previous studies on self-regulation and learning have been conducted in traditional learning environments such as traditional classrooms, there is reason to expect that self-regulated strategies can be transferred or generalized to the online learning environment. The purpose of the present study is to test whether self-regulation strategies in traditional learning environments are associated with self-regulated learning behaviors in an online learning environment. In addition, this study examines whether student's online learning is enhanced by interactive functions that support self-regulated learning. Because video is one of the most common method to deliver instructional content in online learning environments, this study focuses on the design and

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testing of an enhanced video-based learning environment embedded with functions to keep students actively engaged with macro-level activities (e.g., note-taking, supplemental resources, and practice questions) during the learning process.

2. Background and related work

2.1. Video-based learning and interactivity

Video-based distance education could be traced back, as early as the 1940s, to the introduction of television as an instructional medium. Since then, there have been numerous improvements in video technology, resolution quality, and delivery speed (Maniar, Bennett, Hand, & Allan, 2008), multimedia and communication (Wieling & Hofman, 2010; Zhang, Zhou, Briggs, & Nunamaker, 2006), and online video streaming (Hartsell & Yuen, 2006). As a result, video-based learning has advanced from passive linear broadcasting to an engaging interactive video experience for learners (Merkt, Weigand, Heier, & Schwan, 2011; Shephard, 2003).

Using interactive instructional videos has evolved based on learners' needs and new technologies. At one time, having functions to play, pause, forward, or rewind the video was considered adequate for the technology-based tool to be interactive for users. However, continuing advances in technology and theory-driven techniques afford users opportunities to exert greater choice and control over how the instructional content is presented to them (Kumar, 2010; Petty & Rosen, 1987). Embedded functions in interactive videos that are derived from self-regulation theory support learners' attention and involvement or engagement (Hannafin, 1985; Hartsell & Yuen, 2006). The present study focuses on provision of macro-level interactive tools for generative note-taking, seeking of supplemental resources, and self-evaluation through use of practice questions. These interactive tools allow users choice and self-direction in their learning. Furthermore, tools for note-taking, seeking of supplemental resources, and self-evaluation through practice questions scaffold users' metacognitive and self-regulatory strategies that target cognitive rehearsal, elaboration, and organization (Pintrich, 2002). Use of metacognitive and self-regulatory strategies are expected to enhance processing, recall, and learning of information. Studies show that self-directed generative note-taking, use of supplemental resources, and use of practice questions allow learners to reorganize and connect their ideas for deep learning (Cennamo, Ross, & Rogers, 2002; Kauffman, 2004; Ponce & Mayer, 2014). In addition to enhancing cognitive learning strategies, these interactive tools are expected to enhance motivational beliefs in self-regulated learning. Specifically, use of note-taking, supplemental resources, and practice questions afford learners opportunities for preparation and rehearsal that may be needed in order to experience success and mastery or self-efficacy (Kauffman, 2004; Pintrich, 2000). In contrast, poorly designed technology-based tools that neglect learners' self-regulation and motivational needs do not afford opportunities for users to be self-directed in their learning. For instance, videos with functions to play, pause, and forward or rewind may be interactive but limit self-directed learning by restricting users from directly accessing (or jumping to) particular parts of the video (Zhang et al., 2006). Hence, embedded functions such as note taking can scaffold video-based instruction process. Moreover, practice questions support students' self-regulation while watching instructional videos. It should be noted that simply providing learners interactive functions such as the option to jump to any given segment at any time does not guarantee that learners will know how to use the functions or have better learning performance (Merkt et al., 2011), because users may need training on how to use and benefit from the respective features (Merkt & Schwan, 2014).

2.2. Instructional scaffolding and self-regulated learning

According to Vygotsky (1978), learners improve when they are assisted by more advanced or knowledgeable sources of instruction (e. g., teachers or peers). Vygotsky's (1978) concept of *zone of proximal development* refers to "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). This external guidance or support could be in various forms including prompts, clues, modeling, explanation, and encouragement (Miller, 2002). *Instructional scaffolding* is a term used to explain the relationship and interaction between learners and their guides, and is a process that enables a novice to achieve a goal or objective, which would otherwise be unattainable without assistance (Wood, Bruner, & Ross, 1976). Instructional scaffolding is not one-way, but interactive and reciprocal process between the learner and the source of instruction (Bull et al., 1999). During this process, the learner is not passively receiving assistance but actively engaged in the learning process to benefit from the scaffolding in order to attain a higher level of achievement (Rogoff, 1990).

In the context of online learning environments, Vyotsky's concept of zone of proximal development and instructional scaffolding can be applied to support and optimize students' learning and achievement. Computer tools have been effectively used as scaffolds for learners (Yelland & Masters, 2007) and as tools to support the process of scaffolding (Bull et al., 1999). Examples of instructional scaffolds include web links or hyperlinks to additional resources, visual cueing, and adaptive release of instructional material. However, there are unique differences between instructional scaffolding in the traditional and online learning environments. Because learners do not have teachers or peers physically present in the online learning environment to serve as reinforcement or to offer assistance, online environments may need embedded functions to scaffold learners' self-regulation skills so they could remain engaged without the physical presence of teachers or peers. For example, Hadwin and Winne (2001) suggested the use of electronic notebook to scaffold students by using several embedded functions (e.g., glossary and note-taking) that support self-regulation in reading.

Although self-regulation is critical for online learning success, limited research exists on instructional scaffolding and self-regulated learning in online learning environments because it is an emerging area of research. A growing body of research shows that students have problems regulating their learning and fail to achieve conceptual or deep understanding in computer-based learning of complex topics when instructional scaffolds are not in place (see Azevedo & Hadwin, 2005). Importantly, different types of interactive tools may have different effects or impacts on learners and learning outcomes. In an experimental study, Zhang et al. (2006) found that students in the interactive video-based learning environment enjoyed their learning more and performed better than students in non-interactive environments. In another study, Merkt et al. (2011) found that secondary school students learned just as much information from interactive videos (embedded with functions to support self-regulated learning) compared to traditional textbooks. With adult learners, Sariscsany and Pettigrew (1997) found that pre-service teachers who were trained in an interactive video environment recalled more information than those trained with teacher-directed video or traditional lecture instruction. Beyond recall of information, research indicates that interactive video-based methods enhance learning to perform complex tasks. For example, Schwan and Riempp (2004) found that learners were more successful in learning how to tie nautical knots (a complex task) when using an interactive video instruction than when using non-interactive video instruction. In summary, studies suggest that video-based learning, particularly with interactive functions, enhance student learning and engagement. Hence, the purpose of this experimental study was to examine whether macro-level interactive functions that scaffold learners' use of generative note-taking, supplemental resources, and practice questions in an online video-based learning environment enhance their learning and performance. Additionally, we examine the relation between learners' self-regulation strategies and their self-regulated learning behaviors in an enhanced video environment.

3. Methodology

3.1. Research questions

Two broad research questions were addressed in this study on online video-based learning environments:

1. Do students recall more information and spend more time learning in the enhanced video-based learning environment compared to a common video-based learning environment?
2. Are learners' self-regulation strategies associated with self-regulated learning behaviors in an enhanced video-based learning environment?

3.2. Research design

To address the two research questions, the present study used a cross-sectional experimental design with one control group with a common video and one experimental group with an enhanced video. Merkt et al. (2011) described the term *common video* as having functions enabling micro-level activities, and the term *enhanced video* as having both micro-level and macro-level activities. In the control group, the content was provided to the students by a common video, which had micro-level interactive functions such as play, pause, and rewind/forward. For the experimental group, an enhanced online video-based learning environment was designed to support student' self-regulated learning through embedded both micro-level and macro-level interactive functions. The macro-level functions were including note-taking, supplemental resources, and practice questions. The purpose of using two different video conditions was to test the effectiveness of interactivity level by comparing students' learning performance in the control group and experimental group.

3.3. Participants

Participants were undergraduate and graduate students recruited from university courses and from flyers at a university located in southern Texas in the United States. Participation was voluntary, and informed consent was obtained from all participants.

Systematic random assignment procedures were utilized to assign participants into the control group or experimental group, with every fifth student being assigned to the control group. Data from two participants were excluded from the analysis because they had familiarity with the instructional material for this study, which could bias their performance. For example, one student majored in environmental science, while the other student had previously taken multiple courses in environmental science. As a result, a total of 80 students participated (i.e., 16 students were assigned to the control group and 64 students were assigned to the experimental group). The assignment procedures were conducted to acquire sufficient sample size in the experimental group to test whether learners' self-regulation strategies were associated with self-regulated learning behaviors in the experimental condition.

3.4. Instruments

Data was collected using three primary measures: (a) a survey of student self-regulation in traditional learning environments (using the Self-regulation Strategy Inventory (SRSI); Cleary, 2006), (b) a recall test of video-based content, (c) the frequency of students' usage of the functions embedded in the enhanced online video-based learning environment (situational self-regulation).

The SRSI (Cleary; 2006), consists of 28 items with three subscales: (a) Seeking and Learning Information (8 items: Cronbach's α for this study = .72), a sample item: "I think about the types of questions that might be on a test", (b) Managing Environment/Behavior (12 items: Cronbach's α for this study = .82), a sample item: "I quiz myself to see how much I am learning during studying", and (c) Maladaptive Regulatory Behaviors (8 items: Cronbach's α for this study = .64), a sample item: "I give up or quit when I do not understand something" Cleary (2006). Items in the Maladaptive subscale were reverse-scored to reflect "Adaptive" Regulatory Behaviors in analyses.

In order to assess students' performance after video-based instruction, a recall test was developed based on the video-content. First, authors designed several sample items, and a test development expert reviewed the test items. After the review process, some items were revised and some items were dropped from the test. The final version of the test consisted of 20 items. Then, the test was pilot tested with seventeen students and achieved adequate reliability (Cronbach's alpha = .74).

Students' situational self-regulation was measured by continuously tracking how frequently students used the embedded self-regulatory functions during the instruction. For students in the experimental group, three situational self-regulation scores were calculated based on (a) frequency of viewing supplemental resources, (b) frequency of answering practice questions, and (c) number of added interactive notes. Additionally, data on amount of time on instructional material using the video-based learning environments was tracked during the instruction.

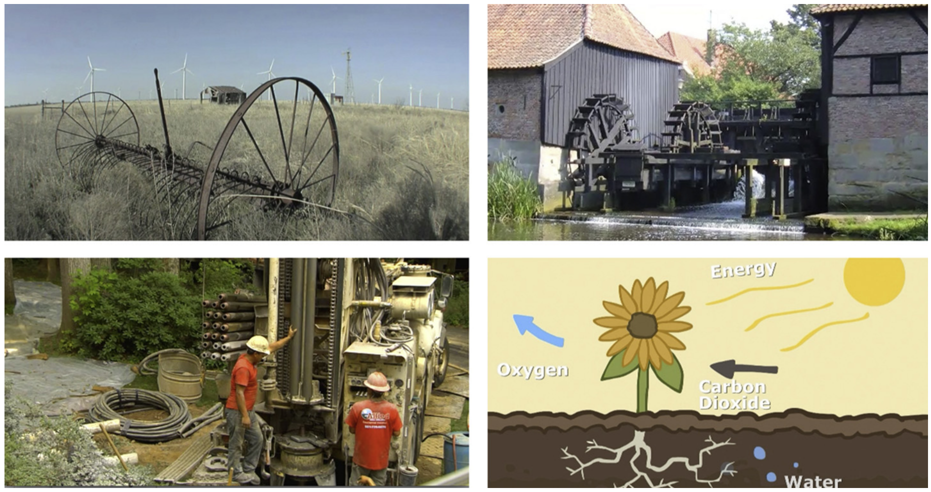

Fig. 1. Scenes from the instructional video.

3.5. The instructional video

During the study, an instructional video was used, which consisted of the combination of six educational videos related to renewable energy sources. The length of the final video was approximately 16 min. These videos were taken from energyNOW!, a website designed to inform and engage the public about energy issues using an online news magazine format.

Permission to use the instructional video for academic and research purposes was granted by energyNOW!. The video content was selected for this study because it contained many facts that could be learned by the participants during the instruction. The video covered six different renewable energy sources including hydropower, wind energy, geothermal energy, biomass energy, biofuel energy, and solar power. Fig. 1 shows several sample scenes from the video.

3.6. Design and development of the enhanced video environment

Consistent with a social cognitive model of self-regulated learning (Bandura, 1989; Zimmerman, 1989), this study focuses on provision of interactive tools for learners' self-regulated learning. Specifically, macro-level interactive tools for generative note-taking, seeking of supplemental resources, and self-evaluation through use of practice questions were provided. These macro-level interactive tools were designed to scaffold students' use of metacognitive and self-regulatory strategies while supporting their self-efficacy (Pintrich, 2002). In the

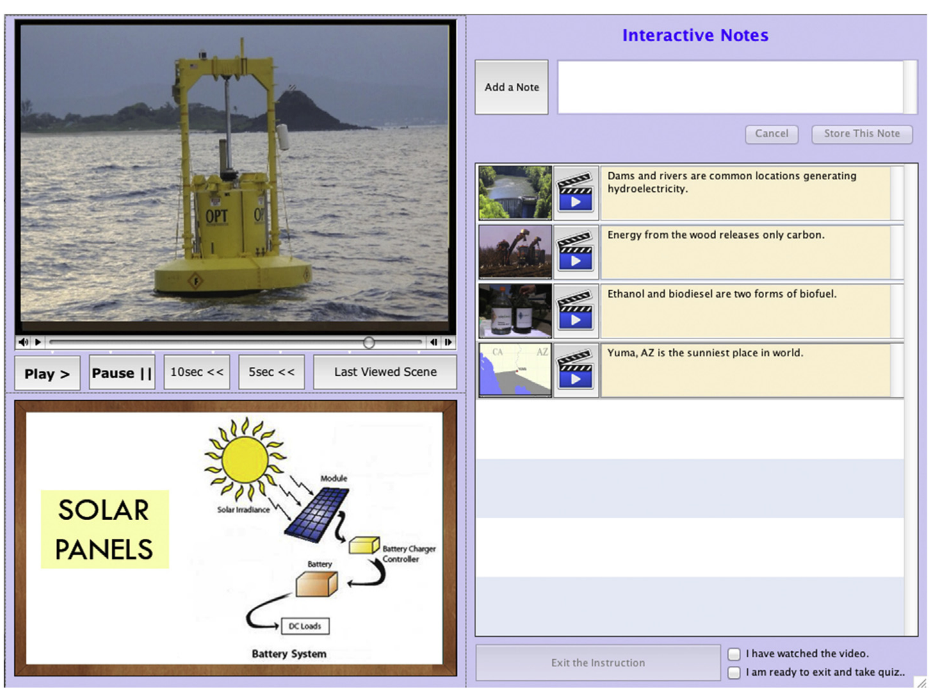

Fig. 2. The enhanced video with embedded functions.

enhanced video, macro-level interactive tools or functions were limited to three to avoid potential cognitive load of students (Schwan & Riempp, 2004). Fig. 2 shows the enhanced video with embedded functions.

The enhanced video consisted of several components including video viewer, interactive notes, supplemental resources, and practice questions. The video was presented via a video viewer, which was enriched with several embedded control buttons (play, pause, 5 s backward, 10 s backward, and last viewed scene). An interactive note-taking component was embedded to the learning environment to allow learners to create interactive notes while watching the instructional video. As they clicked the Add a Note button, the tool captured the scene in the video and mapped it to the interactive notes component with a play button and a text box next to it. As students typed their individualized notes in the text box and clicked the Store This Note button, the note was added to the interactive notes list and sorted or synchronized according to its corresponding video-frame. Another embedded function was supplemental resources. In some parts of the instructional period, the video stopped and the video player asked students whether they wanted to view an available supplemental resource related to the video content. These resources did not give clues about recall test questions or extra information that students did not get in the control group. Instead, information in some sections of the video was emphasized by images and charts. Viewing the supplemental resources was voluntary. Thus, this allowed learners to exert choice, sense of autonomy, and self-direction in their learning. The last embedded function was the practice questions feature. Students were asked several practice questions while watching the video. These questions were related to the video content, and immediate feedback was given after each question (an example practice question: In 2009, of all electricity in the United States, what percentage was generated by hydropower?). Embedded questions mapped onto the self-evaluation component of self-regulation. Thus, students were able to evaluate their own learning and monitor their own progress during the instruction. It should be noted that practice questions were not asked in the recall test. Hence, students in the interactive group did not have any known advantage over students in the control group from viewing practice questions when taking the recall test.

The control group was given the same video content with a common video. The common video included micro-level interactive features such as play, pause, and rewind/forward. Students in both groups could watch the content, as many times they wanted.

In other words, the main difference in two conditions was the level of interactivity. In the control group, a common video was used, which included micro-level functions that are commonly used in most video platforms. By contrast, in the experimental group an enhanced video was used, which included both micro-level and macro-level functions to support students' self-regulation.

3.7. Procedures

Participants were randomly assigned into the control and experimental groups, and all participants provided information on their self-regulation in traditional learning environments using the SRSI – Self-report (Cleary, 2006). Control and experimental sessions were conducted separately. Students in the control group were instructed via a common video, while students in the experimental group were instructed via a newly designed enhanced video tool (Fig. 2). After the instruction ended, each student took a recall test about the video content. Data on students' situational self-regulatory behaviors and recall test performance were continuously recorded throughout the experimental sessions by the computer.

3.8. Data analysis

The data was analyzed by using IBM SPSS 20 statistical software. Means, frequencies, and other descriptive statistics were calculated and reported for major variables. To examine whether performance differed across the control group and the experimental group, an independent-samples *t*-test was calculated based on the recall test scores to compare students' performances in both groups. Furthermore, correlations were conducted to examine the relationships between students' test scores and amount of time on instructional material.

Correlations were conducted to examine the association between self-regulation in traditional learning environments and situational self-regulatory behaviors in the enhanced video environment. In order to examine if results differed based on students' education or maturation, correlations were conducted separately for undergraduate and graduate students.

4. Results and discussion

In this section, first, descriptive statistics are presented followed by findings for the two research questions, which are presented in Sections 4.1 and 4.2. For each research question or within each of the two sections, we present findings combined with discussion.

Descriptive statistics are presented in Table 1. Data on self-regulation in traditional learning environments, recall test, and time were collected from all participants ($N = 80$), whereas data on situational self-regulatory behaviors in the enhanced video environment was collected from those in the experimental group ($n = 64$).

4.1. Effects of interactivity on learning outcomes

One goal of this study was to test students' recall performance and learning time difference in the common video and the enhanced video environments. To test whether the control group and experimental group differed on their recall test scores, an independent samples *t*-test was conducted. Results indicate that the experimental group had significantly higher recall test scores ($M = 16.50$, $SD = 2.06$) than the control group ($M = 14.81$, $SD = 2.88$), $t(78) = 2.692$, $p < .05$.

According to Thompson (1994), *p*-values are very sensitive to sample size. That is, just considering a significant *p*-value sometimes may lead researchers to misinterpret study results. Thus, according to the APA Task Force on Statistical Inference (Wilkinson, & APA Task Force, 1999), reporting an effect size estimate along with *p*-values is recommended. Thus, *Cohen's* standardized effect size value (Cohen, 1992) was also calculated with pooled standard deviation ($d = 0.75$), indicating a moderate to high practical significance for this study's finding on students performing better in the enhanced video environment than the common video environment.

Table 1
Means and standard deviations of major variables.

	Mean	*SD*	95% CI around the mean	
			Lower	Upper
Self-regulation[a]				
Manage	3.60	0.57	3.47	3.72
Seek info	3.77	0.57	3.64	3.90
Adaptive	3.88	0.43	3.78	3.97
Recall test[a]				
Total score	16.16	2.33	15.64	16.68
Time[a]				
Total time (minutes)	22.20	6.27	20.80	23.60
Self-regulatory behaviors[b]				
Supplemental resources	5.42	1.62	5.02	5.83
Practice questions	3.78	0.90	3.56	4.01
Interactive notes	11.64	10.86	8.93	14.35

[a] $n = 80$.
[b] $n = 64$.

In addition to recall test, we also examined whether students in the control group and experimental group spent different amounts of time with the instructional material. Based on an independent samples *t*-test, results indicate that students in the experimental group spent more time with the instructional material than students in the control group, $t(71.335) = 9.311$, $p < .05$, $d = 1.34$.

Given that time spent with instructional material differed across control group and experimental group, with an almost 50% greater average time spent by experimental group compared to control group, we conducted auxiliary analysis to examine if the amount of time spent had effects on students' recall test scores. Results from a one-way analysis of covariance on recall test scores, with amount of time on instructional material as the covariate, indicate that amount of time on instructional material did not have a significant effect on students' recall test scores, $F(1,77) = 1.770$, $p = .187$ (see Table 2).

Results for the first research question suggest that the newly designed enhanced online video-based learning environment was a more effective and superior instructional tool when compared to the common video environment. The enhanced video was designed to scaffold learners' self-regulated learning. Thus, students' use of self-regulatory behaviors likely contributed to more engaged learning and better retention of information. Our results are consistent with research by Sariscsany and Pettigrew (1997) and Zhang et al. (2006), indicating that interactivity in video-based instruction benefits students' learning.

Interactivity of the learning tool in this study was supported with embedded functions designed to keep students active during the instruction and to scaffold them to activate self-regulated learning behaviors while watching the instructional video. It is likely that students in the experimental group kept themselves more engaged with the instructional material by using macro-level functions and, as a result, retained more information. As evidenced in Table 1, students used all three embedded functions. In particular, students chose to view supplemental resources and answer practice questions. This is consistent with Santhanam, Sasidharan, and Webster (2008) who note that when students are supported and guided to use self-regulatory learning strategies, they tend to engage in deep learning processes. In addition, each student created an average of 12 interactive notes while watching the instructional video. The act of note-taking affords students opportunities to actively seek and process information using the embedded self-regulatory functions in the enhance video learning environment. Future studies are needed to further identify the types and levels of features that contribute both to self-regulated learning and to learning outcomes.

Using the embedded self-regulated learning functions (macro-level activities) also engaged students in a way that afforded them more time to engage in the instructional material. Students in the experimental group spent more time than students in the control group in their learning process, with 7.4 min difference between the groups. In the experimental condition, students were offered instructional scaffolding to activate self-regulated learning behaviors. Students were given the choice to use those functions or not. Such instructional scaffolding provided students opportunities to invest significantly more time in their learning when compared to the common video learning environment. However, it was not clear how students actually allocated the amount of time spent on instructional material because they were not physically observed. Thus, conclusions cannot be made regarding whether students used their time in on-task or off-task behaviors. For instance, it is plausible that some participants may have engaged in off-task behaviors such as stopping the video for checking their email account, which may have increased the amount of time with instructional material but in an unproductive way. On the other hand, some participants may have stopped the video to take notes in the experimental group or to elaborate on the contents more deeply in the control group (productive way).

With regard to the first research question, it might be concluded that students could have more active roles in online video-based instruction when they are provided purposeful interactive functions. Hence, they can perform self-regulation activities throughout online learning and improve their learning performance, accordingly. Moreover, students have to be self-disciplined and avoid distractions when they study online. Thus they need to be self-directed and self-regulated learners. For these reasons, embedding macro-level self-regulatory

Table 2
Analysis of covariance for recall test scores by time.

Source	*SS*	*df*	*MS*	*F*	*p*
Time	9.02	1	9.02	1.77	0.187
Recall test	27.45	1	27.449	5.39	0.023
Error	392.42	77	5.096		
Total	21,327	80			

Table 3
Descriptive statistics for SRSI and self-regulatory behaviors.

		N	*Mean*	*SD*	Skewness	Kurtosis
SRSI	Seek info	64	3.76	.593	−0.368	−0.382
	Manage	64	3.60	.599	−0.215	−0.548
	Adaptive	64	3.90	.407	−0.355	0.247
SR Behaviors	Suppl. resources	64	5.42	1.621	−2.312	5.081
	Pract. questions	64	3.78	.899	−3.063	10.107
	Int. notes	64	11.64	10.856	1.919	5.630

functions in video-based learning environments may scaffold students to remain persistent and engaged in learning. It is important to note that integrating self-regulatory activities into online learning may be more time consuming, but using those strategies and investing more time in the learning process may yield better learning outcomes.

4.2. Correspondence between self-regulation in traditional and enhanced video environments

The second goal of this study was to examine the associations between learners' self-regulation strategies in traditional learning environments and their self-regulated learning behaviors in an enhanced video environment. Only data from the experimental group were included for analyses from this point forward because only the experimental group had observed data for situational self-regulated learning behaviors. Descriptive statistics are shown in Table 3.

Situational self-regulated learning behaviors were coded as the frequencies of cases that students used the embedded self-regulatory functions of Supplemental Resources, Practice Questions, or Interactive Notes during the instruction. It is important to note that although there was little variation in *Supplemental Resources* and *Practice Questions*, there was variation in the size of *Interactive Notes* ($min = 0$, $max = 60$). Skewness and issues with normality of distribution is not uncommon with behavioral or observed data, and logarithmic data transformations (a method to improve normality of skewed variables; Osborne, 2002) was conducted with the scores on the situational self-regulatory behaviors (i.e., use of Supplemental Resources, Practice Questions, and Interactive Notes). From this point forward, transformed variables were used in analyses.

Correlations amongst the SRSI subscales and situational self-regulatory behaviors were calculated and presented in Table 4. Results indicate that there were no associations between self-regulation strategies in traditional learning environments and self-regulated learning behaviors in the enhanced video environment.

The experimental group consisted of undergraduate students ($n = 32$) and graduate students ($n = 32$), and auxiliary analyses were conducted to explore whether there associations between students' situational self-regulatory behavior in using the enhanced video environment and their SRSI subscales for undergraduate and graduate students separately. As indicated in Table 5, among graduate students, number of added Interactive Notes was positively correlated with SRSI Seek Info subscale and with Manage subscale. No significant associations were found for undergraduate students.

Results indicate that graduate students who rated themselves highly on the Seeking and Learning Information and Managing Environment/Behavior subscales of the Self-regulation Strategies Inventory, were those who took more interactive notes during the instruction. Items for "Seeking and Learning Information" and for "Managing Environment/Behavior" primarily tapped study habits and study organization. These results confirmed that graduate students' self-regulatory behaviors in the enhanced video environment were correlated to their self-regulation strategies in specified ways. This result was expected because self-regulation strategies have some relations with enacted learning behaviors. Particularly, the present study's results imply that specific self-regulation strategies in traditional education settings are likely to transfer and utilized as specific learning behaviors in the online learning environment for graduate students.

According to Pintrich (2002), note-taking is an organizational strategy that is highly preferred by self-regulated learners to elaborate and deeply process what they learn by making connections between presented contents. Researchers have studied potential benefits of note-taking in both traditional (Peverly, Brobst, Grham, & Shaw, 2003) and computer-based or online learning environments (Hadwin & Winne, 2001; Lee, Lim, & Grabowski, 2010; Winters, Greene, & Costich, 2008). Moreover, students use other self-regulation strategies, such as seeking and learning information, and managing their environment or behaviors to understand information in a way that they prefer. That is, students utilize their individualized strategies to comprehend the most important details, and these strategies are most likely interrelated. It is important to note that being capable of using multiple strategies is an advantage for students and may permit them to choose the most appropriate or effective strategy during the learning process. Thus, learning environments need to offer opportunities to use adequate self-regulated strategies without causing potential cognitive load.

When students take notes, they process and organize the presented information so that the learning process becomes effective through the action of note-taking (Kauffman, 2004; Ponce & Mayer, 2014). Thus, interactive note component was embedded in the enhanced video environment in order to scaffold students' self-regulation. Specific types of self-regulation strategies were associated with greater use of the note-taking function in the enhanced video environment. However, the Supplemental Resources and Practice Questions functions were unrelated to self-regulation strategies, perhaps because they are less active and less engaged forms of learning relative to the action of note-

Table 4
Correlation results of SRSI subscales and situational self-regulatory behaviors.

		Supplemental resources	Practice questions	Interactive notes
Seek info	Correlation	−.211	−.033	.214
Manage	Correlation	.008	.122	.188
Adaptive	Correlation	.018	.007	.185

Note. No correlations were statistically significant at $p = .05$.

Table 5
Correlation results of SRSI subscales and self-regulatory behaviors for undergraduate and graduate students.

	Supplemental resources	Practice questions	Interactive notes
Undergraduates			
Seek info	−.270	−.322	−.039
Manage	.182	.094	.014
Adaptive	.185	.067	.057
Graduates			
Seek Info	−.114	.261	.417*
Manage	−.192	.204	.357*
Adaptive	−.246	−.062	.335

Note. *$p < .05$ (2-tailed).

taking. Furthermore, most of the students viewed the supplemental resources and answered the practice questions regardless of their self-regulation level. The reason might be the way these functions were embedded into the learning environment. Viewing supplemental resources and answering practice questions were suggested and directed by video viewer. In contrast, taking interactive notes was not prompted or suggested by the video viewer. Thus, note-taking was more self-directed than the other two strategies.

5. Conclusions and implications

The study findings support that embedded macro-level interactive functions could be provided to learners in video-based learning environments to support their self-regulation and learning performance. There are several strengths of this study. For instance, experimental research design was pursued, and students from different areas and levels were included to the study. However, study results need to be interpreted in light of several limitations. The small sample size of the present study reduces statistical power to detect potential effects. Furthermore, the study was not part of a required course and participants were volunteers and did not have strong incentives to take the learning activities or the recall test seriously. Thus, findings may differ if the study was conducted as part of a real online course. This also limits the generalizability of this study. In addition, the quantity but not the quality of students' self-regulation strategy use was assessed. For example, future studies could code and analyze the quality of elaboration and organization in students' note-taking to examine whether it is associated to learning performance (also see Kobayashi, 2005). Although the present study is not examining the effectiveness of the macro-level functions individually, it is necessary to disentangle the specific effects of note-taking, practice questions, and supplemental materials in future studies. In addition, future research could incorporate methodologies that provide finer-grained observations of students' motivations and behaviors in online learning environments. For instance, eye-tracking technologies that focus on human–computer interaction (see Jacob & Karn, 2003, for more details) could be used with online video-based interactive learning environments to examine learners' motivational and attentional processes. These are directions that future studies need to explore.

In summary, results highlight the importance of macro-level interactivity and self-directed (student-centered) learning features (e.g., note-taking, supplemental resources, and practice questions) in online learning environments. The general findings suggest that when an online video-based learning environment is designed and developed, embedding supplemental functions, with potential users' needs in mind, could enhance learning by making the environment more interactive. Instructional designers need to build learning environments with interactivity in mind. Study results suggest that learning environments with macro-level interactive functions provide students with affordances to become actively engaged in their learning and to invest or spend more time in the learning process, resulting in enhanced or superior learning outcomes. Especially when the content is delivered via video in an online environment, it is essential that students maintain visual engagement in order to benefit from instruction (Zhang et al., 2006). Thus, embedded functions served primary purposes of keeping students attentive and actively engaged via scaffolding and prompting students to use self-regulated learning behaviors.

The embedded functions undoubtedly were part of what made the learning environment more interactive, with interactivity being a primary contributor to superior learning performance in this study. Interestingly, the use of the embedded functions was associated with graduate, but not undergraduate, students' self-regulation strategies in traditional learning environments. This suggests correspondence between graduate students' self-regulation strategies in traditional learning environments and their situational self-regulation in an enhanced video environment. For undergraduate students, such correspondence was not found. It is plausible that this difference may be related to cohort effects. Furthermore, it is plausible that undergraduate students may have substantially different learning experiences from graduate students due to maturation differences resulting in less transfer or correspondence between traditional and online learning for undergraduate than for graduate students. It is also plausible that graduate education select for students with effective learning strategies. Additionally, students who choose to pursue graduate education may be more goal-oriented and self-regulated in their learning and achievement.

It is also important to note that self-regulation strategy use could be increased by training (Azevedo & Cromley, 2004) and giving students opportunities to practice self-regulatory activities. For example, Keller (1968, 1974) developed *personalized system of instruction* to improve students' self-regulation in online environments using self-paced learning modules. Thus, students learn to be responsible and monitor their own learning as they progress from one module to the next. In a recent study, Merkt and Schwan (2014) suggested that training is necessary for students to benefit from the enhanced video's embedded functions such as searching. Advances in self-regulation training and scaffolding methods are burgeoning and have been effectively implemented in traditional and online learning environments (Molenaar, Roda, van Boxtel, & Sleegers, 2012; Rabipour & Raz, 2012). Such models of individualized instruction and self-regulated learning may help transform education in the 21st century by scaffolding not only higher, but deeper levels of learning and understanding. In conclusion, learners benefit from instructional design of learning environments that afford them instructional scaffolding to choose to activate self-regulated learning behaviors and become actively engaged in their learning.

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