Learning Effects of Attention Guidance in Online Discussions

Full paper

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Abstract

This paper reports on the design and learning effects of an awareness mechanism integrated into an anchored discussion system. Drawing on social constructivist literature, the design aims to attract, retain, and if necessary reacquire students' attention on instructional materials' central principles in document-based asynchronous online discussions. To form a holistic picture, we operationalized learning across three dependent variables: perceived learning, knowledge gain, and learning efficiency. We performed an experimental study (N=64) across two sections of a blended-format human-computer interaction course to evaluate our design. Results show that the proposed design increased students' perceptions of learning. However, the difference in knowledge gain scores was marginally significant, and represented a medium effect size. Interestingly, we found that our design afforded more efficient learning. Moreover, we discovered students' perceptions of learning to be a significant predictor of their learning efficiency. Theoretical and practical implications are also discussed.

Keywords

Design science, attention guidance, social constructivism, anchored discussion, learning efficiency.

Introduction

Tightly aligning a software application with an organization's strategic and tactical intentions is a knowledge intensive endeavor. Competitive business advantages resulting from this alignment require strong technical skills as well as a solid business background. Therefore, collaboration between developers and business users can be instrumental to the success of software development projects. According to recent estimates, over 80% of Fortune 500 companies require developers and business users to work effectively in teams to produce software applications that can add value and support business strategies (Dunaway, 2013). Consequently, students majoring in technical fields, including information systems (IS), should not only be technically competent, but also prepared to collaborate effectively in face-to-face and virtual team settings. Collaborative learning is a popular pedagogy in the IS model curriculum 2010 to prepare students to work effectively in teams (Topi et al., 2010). The underlying mechanisms of collaborative learning in IS education and teamwork in professional settings are similar because both methods involve expressing and discussing ideas in order to construct mutually acceptable explanations.

Computer-supported collaborative learning (CSCL) systems offer rich affordances for students to express and discuss ideas in order to construct mutually acceptable explanations. Asynchronous online discussion (AOD), in particular, provides time to prepare, reflect and search for additional information before contributing to a discussion, allowing students to express more articulate ideas in written form. As a specialized form of AOD, anchored discussion links or anchors messages to specific highlighted and numbered passages in a text, which helps to contextualize students' ideas. This tight coupling makes anchored discussion especially suitable for the collaborative processing of academic literature. Prior research demonstrates that the above mentioned tight coupling facilitates a close spatial proximity between an instructional material and its associated discussion, which increases the communicative efficiency of AODs (Eryilmaz et al., 2013a). Along this line, Eryilmaz et al. 2013b showed that the increase in communicative efficiency allows students to dedicate more time and effort in refining articulated ideas that favor gains in individual learning outcomes.

Despite these beneficial affordances, the learning effects of online discussion are still controversial because learning holds variance on many factors (for a comprehensive list see Kirschner et al. 2004). A major challenge consistently noted by a succession of studies is the students' shallow processing of central principles from instructional materials (e.g., Peters and Hewitt, 2010; Slakmon and Schwarz, 2014). Specifically, quantitative analysis of online discussion threads shows that as subject matter difficulty increases, students are apprehensive in asking questions that may expose their lack of understanding (Eryilmaz et al., 2015; Paus et al., 2012). Furthermore, prior research using heat map analysis to measure students' attention suggests that students gravitate towards familiar topics and avoid challenging ones in order to meet participation requirements (Eryilmaz et al., 2014). As Kim and Hannafin (2011) remark, under such conditions, students develop robust and oversimplified misconceptions. This challenge underscores that merely contextualizing students' ideas in AODs does not produce satisfactory learning outcomes because they may overlook crucial information from instructional materials.

Attention guidance can help students not to overlook crucial information in an open learning environment where they can express their own ideas. Drawing on social constructivist literature, we propose to address the challenge at hand by designing an unobtrusive attention guidance functionality that aims to attract, retain, and if necessary reacquire students' attention on instructional materials' central principles in document-based AODs. Our study makes a notable contribution to the literature by addressing the following questions:

1. What are the effects of an attention guidance functionality in anchored discussion on:
    a. students' perceived learning of instructional materials?
    b. students' knowledge gain?
    c. students' learning efficiency?
2. How do students' perceived learning of instructional materials relate to their learning efficiency?

The paper is organized as follows. First, we present our theoretical background for understanding the concept of attention guidance in online discussions. Next, we describe the development of an unobtrusive attention guidance functionality based on the theoretical background. We then outline the research questions, methodology, and empirical results. Finally, we conclude by discussing our findings and their implications for research and practice.

Theoretical Background

Social constructivism considers that learning is deep when students sustain engagement in task-oriented reading of instructional materials and discuss their ideas to interpret the meaning of those materials. This engagement, as stated by Scardamalia (2003), helps students identify mistakes in their original ideas, and it can guide the formation of correct ones. From the lens of social constructivism, we consider students' ideas as knowledge objects that are improved continually through collaboration by discussing inconsistencies and resolving doubts (Lipponen et al., 2004). In short, social constructivism asserts that collaboration can promote conscious development of cohesive ideas that no single individual could have developed alone. Thus, pedagogically, we can view students as active constructors of knowledge who capitalize on each other's reasoning to gradually refine ambiguous, figurative, and partial understandings of important concepts.

Task-oriented reading or functional reading (as defined by Gil et al., 2015) in CSCL refers to students' strategic engagement with instructional materials to fulfill the requirements of a learning task. In our study, we are particularly interested in utilizing academic research papers to supplement learning objectives in hands-on IS undergraduate courses. Since these papers do not offer a visual aid of the central domain principles, students must apply their own reading strategies to answer comprehension questions. For example, students need to make decisions about how to read (e.g., scanning, search reading, skimming), when to refer back to those questions to monitor their understanding of a task, and what part of a text to re-read to identify important information such as contradictory propositions. These strategic decisions underscore that some information within a text will be more important than others (Gil et al., 2015). Consequently, students have to distinguish the task-relevant information by doing a back-and-forth reading between instructional materials and comprehension questions. Thus, task-oriented reading is not so much a linear process, but cyclical, where students adjust their reading activity for a particular goal by re-reading relevant information and pausing to think about what they are reading.

From a cognitivist perspective, reading comprehension occurs as a student constructs concrete evidence-based explanations by extracting facts, descriptions, and principles from a text. At the heart of this perspective, as maintained by Mayer (1999), lies the process of 1) selecting relevant information, 2) organizing selected information into a coherent representation, and 3) integrating a newly-built coherent representation with existing knowledge. This active cognitive process indicates that selecting relevant information supports subsequent knowledge construction activities by directing a student's attention toward deep processing of task-relevant information from a text. In this regard, Lorch et al. (1995) showed that attention guidance slows down students' reading of task-relevant information. As demonstrated by prior research, students can allocate this extra time to the detection and repair of coherence breaks in selected information, which in turn allows them to integrate a more coherent newly-built representation with their existing knowledge (for a review see Amadieu et al, 2009).

Social constructivism can enhance reading comprehension by allowing students to take their partners' opinions into account while reflecting on task-relevant information through document-based discussions. One core premise of social constructivism, as described by Jordan et al. (2014), is that students often experience learning as "a lifting of fog or clearing of muddy waters" (p.453). Drawing on Stahl's (2000) collaborative knowledge building model, we can consider the above mentioned active cognitive process as a catalyst to materializing tacit understandings into shared, visible, and persistent knowledge objects. This materialization allows students to take up each other's ideas and elaborate upon them. Accordingly, we can say that knowledge objects evolve nonlinearly through document-based discussions as ideas focusing on task-relevant information interact and mutually influence one another. Therefore, we can view selecting relevant information as a prerequisite to focus students' joint effort on task-relevant information in document-based discussions.

However, social constructivism does not always produce satisfactory learning outcomes. As shown by Kintsch and Dijk (1978), students new to a particular domain, where knowledge is often lacking, face difficulty in allocating attention to relevant information in a text and monitoring their own comprehension. To compensate for this, prior research has demonstrated that students with low domain knowledge require some form of attention guidance, which helps them separate relevant from irrelevant information (Kirschner et al. 2004). Within the context of individual reading comprehension, attention refers to focusing the active cognitive processing of selection, organization, and integration on instructional materials' central principles (Kintsch and Dijk, 1978). According to cognitive psychology, attention can shift exogenously by the appearance of an unexpected stimulus (De Koning et al., 2009). One way to achieve this shift is to make task relevant information more salient by increasing the font size of central principles. As demonstrated by De Koning et al. (2009) in their text-processing research, font size is an effective visual property to capture students' attention in an involuntary or obligatory fashion without altering the meaning or content of instructional materials. When applied to social constructivism, attention emphasizes students' awareness that they focus on the same important topic with the same intent (Schneider and Pea, 2014). In this regard, attention guidance can attract, retain, and if necessary reacquire students' attention on instructional materials' central principles in document-based discussions. After reviewing social constructivist literature on possible forms of guidance in general, we have identified two relevant forms that may effectively support learning outcomes.

One form of guidance, scaffolding (Kirschner et al. 2004), is guidance initiated by an instructor, which fades when students become more proficient in knowledge construction. The premise behind the second form of guidance, peer-to-peer, is to encourage students become more active and responsible within the collaboration process by supporting two learning mechanisms as noted by King (1998): monitoring peers' explanations of what they think are central principles and providing focused feedback on those explanations. Prior research demonstrates that both forms of guidance effectively prompt students to reflect on and monitor their cognitive processes while reading information they deemed important from instructional materials (Eryilmaz et al., 2016). Regarding scaffolding, prior research shows that it can encourage students to openly acknowledge their common confusions and ask topic-related questions in document-based discussions (Eryilmaz et al., 2015). However, the flip side of this coin is that students do not always understand the reasons behind the importance of central principles suggested by their instructor and tend to end their discussion threads prematurely when the first plausible explanation surfaces instead of collaboratively diagnosing and resolving potential misconceptions. (Eryilmaz et al., 2015). This problem purports that students can jump to conclusions, which are often inconsistent with the instructional materials' central principles (Kim and Hannafin, 2011). Regarding peer-to-peer guidance, Eryilmaz et al. (2015) found that it supports negotiation of differences in explanations (i.e., logical justifications and concrete evidences). But, interactivity graphs with this guidance technique show that such negotiations take time to cultivate because students can be reluctant to critique or be critiqued for the fear of making mistakes (Eryilmaz et al., 2015). Given these advantages and limitations, this study will combine both approaches to guidance in order to design an attention guidance functionality. The proposed design aims to help students gain a deeper, more comprehensive understanding of instructional materials' central principles from document-based discussions.

Artifact Development

Design science research (DSR) in IS emphasizes creating new knowledge through construction and evaluation of IS artifacts. To meet the requirements derived from the theoretical background, we developed a modular, flexible, and extensible anchored discussion system that can embody an unobtrusive attention guidance functionality as a component. The purpose of our system is to sustain students' interpretive activities in document-based AODs. To achieve this purpose, our system first converts PDF-based instructional materials to a more flexible HTML format via the Poppler, an open source PDF rendering library. The user interface of our system binds the instructional material and its related discussion in a single window. Threaded discussion represents the discourse structure by using subject headings and reply relations. We utilized HTML formatted instructional materials as the basis for the Marginalia, a browser independent open source Javascript program, to enable fine-grained annotations. Marginalia has two features conducive to creating a close coupling between the instructional material and its related discussion. The first feature distinguishes which discussion thread corresponds to which annotated passage by lighting up both elements in red when either element is under the cursor. The second feature embeds a student's key idea (i.e., justification for making an annotation) in the direct context that elicited it by inserting a pop-up sticky note that appears only when the cursor is on an annotated passage.

Attention Guidance Functionality

The main objective of our attention guidance functionality (Figure 1) is to attract, retain, and if necessary reacquire students' attention on instructional materials' central principles, while at the same time offering students an open learning environment in which they can choose their own topics and express their own ideas. This interface works by 1) a user (instructor or student) highlighting a passage, 2) clicking on the importance button on top of the instructional material, and 3) selecting a level of importance (i.e., critical, high, normal). Depending on the selected level of importance, the importance button either increases or decreases the font size of the highlighted passage. The cascading style sheet associated with this functionality includes three font sizes: default, big, and bigger. To begin with, the default font size represents a medium level importance. Next, the big font size represents a high level of importance determined by the individual. Finally, the bigger font size depicts consensus on collaboratively decided important themes. This visual contrast enables central ideas to become more noticeable and stand out against the rest of the text. We developed our attention guidance functionality in a manner that prevented the same user from marking a passage repeatedly and thus artificially inflating its importance. We took this approach to eliminate the risk of a single user biasing the group's consensus on collaboratively decided important areas.

Our software operationalizes both forms of attention guidance. Regarding scaffolding, instructors can gradually decrease the number of their visual marks from text. This gradual decrease facilitates transfer of responsibility to the students because students have to distinguish central principles from text independently after fading the instructor's guidance. Regarding peer-to-peer guidance, it supports two learning mechanisms as mentioned in the previous section. First, it supports monitoring peers' explanations of what they think are central principles because students can move the cursor over an annotated passage with the big or bigger font size to monitor such explanations. Second, it supports providing focused feedback on those explanations because each feedback makes reference to an annotation as depicted in Figure 1.

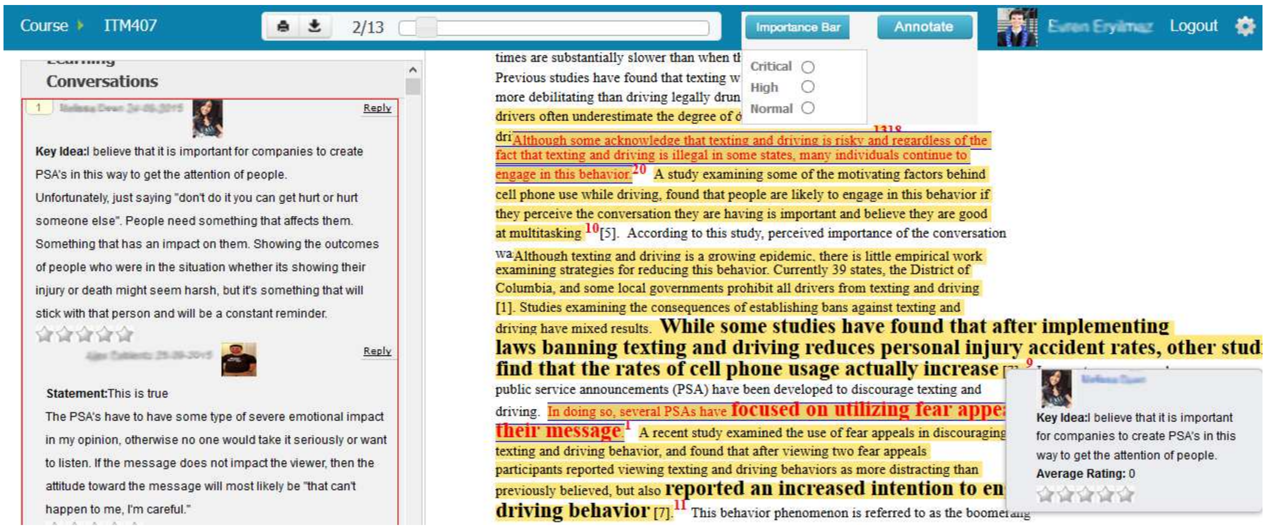

Figure 1. Attention Guidance Functionality

Control Software

In order to isolate the effects of the attention guidance functionality, we developed a control version of the new anchored discussion system without that functionality. Figure 2 displays the user interface of the control software system.

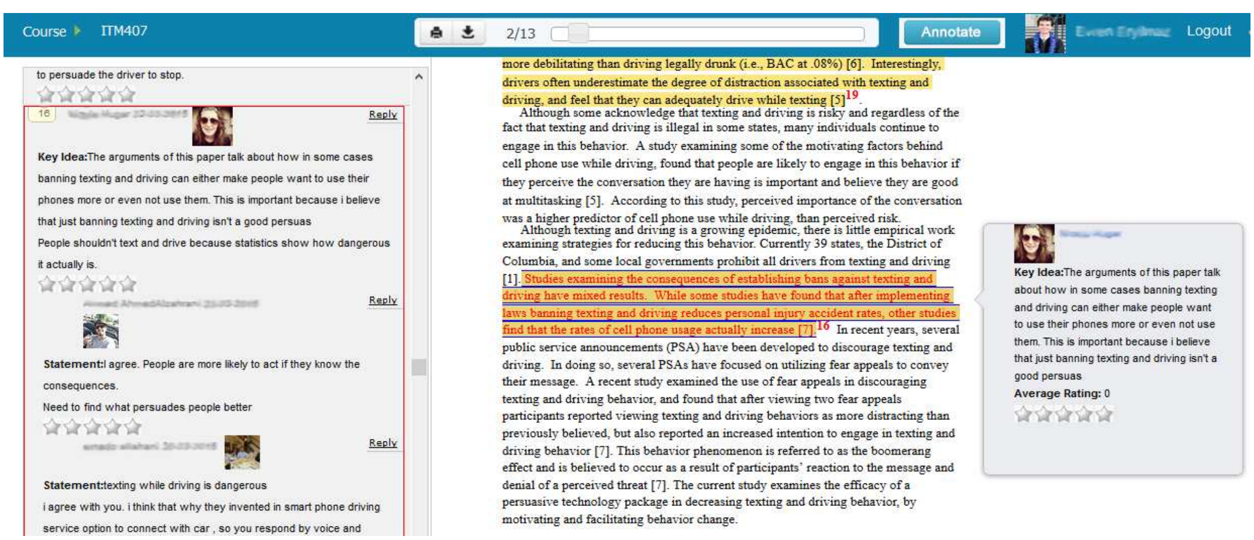

Figure 2. Control Software

Research Questions

Based on the theoretical background, we formulated two research questions to investigate the learning effects of the developed attention guidance functionality.

1. What are the effects of an attention guidance functionality in anchored discussion on:
    a. students' perceived learning of instructional materials?
    b. students' knowledge gain?
    c. students' learning efficiency?
2. How do students' perceived learning of instructional materials relate to their learning efficiency?

Methodology

To answer these research questions, we conducted an experimental study. This study took place in two sections of a blended-format human-computer interaction course offered at a public university in the northeastern-United States. The learning objective of the course was to equip students with knowledge on how to design and evaluate interactive systems. Participants were 64 undergraduate college students split across two sections of the same course. The mean age of the participants was 22.04 (*SD* = 1.36). Each section had 32 students and the same instructor taught both sections. We randomly assigned one section to the experimental group and the other to the control group. The experimental group had access to the attention guidance functionality, whereas the control group used the control software. The instructional topic for the purpose of this experiment was persuasive technologies. This topic included two research papers, which we arranged in the following sequence. Paper one was "Creating Persuasive Technologies: an Eight-step Design Process"; and Paper two was "Examining the Efficacy of a Persuasive Technology Package in Reducing Texting and Driving Behavior." Each paper was covered during a two-week online discussion period. The learning task for both groups included two discussion activities. The first discussion activity asked students to annotate these papers' central principles by constructing evidence-based explanations. The second discussion activity asked students to refine each other's ambiguous, figurative, and partial explanations by analyzing relevant annotations. Participation in online discussions was compulsory and part of students' regular curriculum.

All participants were required at minimum to annotate two passages per paper and respond to at least two fellow students' messages for that paper. The instructor's visual marks in the experimental group was intended to scaffold students' focused processing of central principles which otherwise might be overlooked. For example, what factors prevent a right audience from performing a target behavior in an interactive system? The design of the attention guidance functionality allowed the experimental group students to adjust the instructor's visual marks. In order to keep the conditions equal, we merely introduced and offered the attention guidance functionality to the experimental group without requiring them to make use of it. For the control group, the instructor did not add visual marks to the papers.

Perceived Learning Measurement

Learning, as noted by Kirschner et al. (2004), is a complex multidimensional construct that cannot adequately be measured with a single scale. Therefore, we measured learning in two different ways. First, we measured perceived learning. We asked students to self-report their perceived learning from online discussions based on an eleven item, five point Likert-type scale developed by Wu and Hiltz (2003). Students' responses ranged from 1 (strongly disagree) to 5 (strongly agree). Students were asked to complete the questionnaire at the end of the learning task.

Knowledge Gain Measurement

Second, we measured knowledge gain with knowledge pre- and post-tests. The pre-test evaluated individual understanding of persuasive technologies after participants read the instructional materials individually, but before they discussed it with peers by using the anchored discussion system. Thus, the pre-test gave an objective assessment of students' domain-specific prior knowledge. The post-test analyzed whether individual understanding of the instructional topic improved through online discussion. Both the pre-test and the post-test required students to look at two research papers from multiple perspectives through an open-ended comprehension question: "Explain the difference between persuasion and manipulation as it relates to the design of interactive systems. To the extent possible use the vocabulary of human-computer interaction. Where you can refer to specific authors, arguments in favor, as well as any critiques and counter arguments." Each student had 20 minutes to write a short reflective essay alone without consulting any resources. To avoid any biases, three trained coders independently scored each essay without knowing each student's assigned condition. The coders followed a rubric developed by Jamaludin et al. (2009). The minimum score for an essay was 0 points and the maximum was 12 points. We computed knowledge gain scores by subtracting pre-test scores from post-test scores. The main goal of this approach was to examine whether students were able to improve their initial ideas via online discussions.

Learning Efficiency Measurement

Parallel to Lin and Atkinson (2011), we calculated learning efficiency as follows: $E = (Z_{\text{performance}} - Z_{\text{learning time}})/\sqrt{2}$. We mined web logs to discover students' learning task completion times in the anchored discussion system. Since students' post-test scores were in relation to the learning task, we used post-test scores as a direct measurement of their performance (for a similar approach see De Jong, 2009). The two data were then standardized because they were scored with different scales.

Results

Perceived Learning

The Cronbach's alpha coefficient for the eleven items was 0.77, suggesting that the items had adequate internal consistency. We created a composite score for perceived learning by computing the mean of the eleven items making up the scale. Table 1 presents descriptive statistics and the results of independent samples t-tests. According to Table 1, experimental group students reported significantly higher perceptions of learning than control group students.

Item	Control Group (n=32)		Experimental Group (n=32)		Test Statistics	
	M	SD	M	SD	*p* value	Cohen's *d*
1. Learned great deal from peers	3.25	2.00	3.84	0.65	0.04	0.40
2. Improved integration skills	2.91	1.70	3.53	0.52	0.02	0.49
3. Improved generalization skills	3.00	1.61	3.63	0.76	0.03	0.50
4. Learning quality was improved by online discussion	3.13	1.7i3	3.75	1.10	0.04	0.43
5. Improved communication skills	3.56	1.09	4.13	0.69	0.02	0.62
6. Online discussion provided useful social interaction	3.22	1.21	3.81	0.80	0.02	0.58
7. Provided a great chance to share opinions among peers and instructor	3.16	1.43	3.69	0.48	0.03	0.50
8. Broadened my knowledge	3.44	1.48	4.00	0.52	0.03	0.50
9. Online discussion was useful to my learning	3.25	1.42	4.00	0.52	0.003	0.70
10. Most peers' comments were not very valuable	3.38	0.48	2.97	0.31	0.01	1.01
11. Online discussion decreased my learning quality	3.38	0.31	2.88	0.82	0.01	0.81
Full composite scale	3.24	0.66	3.64	0.26	0.003	0.80

Table 1. Perceived Learning Results

Knowledge Gain

The Krippendorff's alpha inter-rater reliability measure for the coding of knowledge pre- and post-tests was 0.80 which indicates high inter-coder reliability. Table 2 provides the descriptive statistics and the results of independent samples t-tests. As demonstrated in Table 2, there was no statistically significant difference between the control and experimental groups with regards to the pre-test. We computed knowledge gain scores by subtracting pre-test scores from post-test scores. The difference in knowledge gain scores was marginally significant, and reflected an effect size of 0.53.

Knowledge Test	Control Group (n=32)		Experimental Group (n=32)		Test Statistics	
	M	SD	M	SD	*p* value	Cohen's *d*
Pre-test	5.63	3.98	5.97	4.22	0.50	0.08
Post-test	8.97	3.52	9.69	2.03		
Knowledge gain score	3.34	0.43	3.72	0.92	0.07	0.53

Table 2. Knowledge Gain Results

Learning Efficiency

We computed learning efficiency by using the formula $E = (Z_{\text{performance}} - Z_{\text{learning time}})/\sqrt{2}$. With regards to students' learning task completion times, there was a marginally significant difference between the control group and the experimental group. We transformed raw performance and learning time data to z scores because they were scored with different scales. The difference in learning efficiency was significant between the groups.

Depended Variable	Control Group (n=32)		Experimental Group (n=32)		Test Statistics	
	M	SD	M	SD	*p* value	Cohen's *d*
Task completion time (minutes)	103.25	41.22	87.94	27.64	0.09	0.44
Learning Efficiency(based on z-scores)	8.97	3.52	9.69	2.03	0.01	0.63

Table 3. Learning Efficiency Results

Relation between Perceived Learning and Learning Efficiency

A simple linear regression was calculated to predict learning efficiency based on aggregate perceived learning scores. Preliminary analyses were performed to ensure there was no violation of the assumption of normality and linearity. A significant regression equation was found $F(1, 61)=22.95$, $p<0.001$, with an R^2 of 0.27. The regression equation was students' learning efficiency = -3.39+0.09 * aggregate perceived learning score.

Conclusion

Derived from the proposed theoretical background, we asked two original research questions to investigate the learning effects of an unobtrusive attention guidance functionality. The main purpose of our attention guidance functionality was to attract, retain, and if necessary reacquire students' attention on instructional materials' central principles in document-based AODs. We now summarize and interpret the most important results of our study and then tie each result back to the theoretical background.

Regarding research question 1a, we found that experimental group students reported significantly higher perceptions of learning than control group students. This result underscores that experimental group students actively reflected on the guidance in order not to overlook crucial information from instructional materials. From the lens of our theoretical background, this cognitive process, as indicated by Mayer (1999), is vital to the emergence of AOD threads that focus on the progressive development of tentative ideas in areas where students struggle to gain deep understanding. Consequently, a potential explanation of this important finding is that experimental group students were able to maintain their focus on the crucial information and they perceived this focus conducive to learning. Contrasting with perceived learning findings, the difference in knowledge gain scores between the two groups was marginally significant, and represented a medium effect size. This discrepancy could be due to our experimental design. In order to provide students with opportunities to prepare, reflect and search for additional information before contributing to a discussion, each instructional material was covered during a two-week online discussion period. Hence, students in both groups had a substantial amount of time to complete the learning task. Accordingly, knowledge gain scores suggest that as control group students discovered and diagnosed their misconceptions of key concepts, they gradually allocated their attention in more favorable ways to fine-tune their understandings. This explanation conforms to Eryilmaz et al.'s (2015) time-based findings. Therefore, students in both groups reached the same level of gain in knowledge scores.

Regarding research question 1c, we found that experimental group students learned more efficiently than control group students based on a moderate to high practical significance. While both groups dedicated similar amounts of time to the completion of the learning task, experimental group students were better equipped to filter out salient, but unimportant information. From a social constructivist perspective, this striking finding provides evidence that the orientation of experimental group students' attention towards central principles reduced potential distractions and prevented irrelevant information from intruding into the learning task (Schneider and Pea, 2014). This reduction in potential distractions was exactly the goal of our attention guidance functionality because students can attend to only a limited number of things at once. In this vein, the empirical result at hand supports the view that our IT artifact provided affordances for experimental group students to encourage and facilitate each other's efforts to reach the group's goals more efficiently. This collaboration skill, which can be transferable to computer-supported collaborative work settings, is particularly important to cultivate in IS courses as employers increasingly ask their employees to work in virtual teams. Finally, a simple linear regression showed that students' perceived learning accounted for 27% of the variance in their learning efficiency. This result corroborates Kirschner et al.'s (2004) argument that learning holds variance on many factors.

We acknowledge that our study has certain limitations. First, given the effect sizes for knowledge gain scores and task completion times, our small sample size might have prevented the results for these dependent variables from reaching significance. Future research with larger sample size is required to validate the results for these dependent variables. Second, our regression model utilized aggregate perceived learning scores as a single predictor. Conducting a multiple regression with other predictors such as online discussion message quality and task oriented reading of instructional materials can shed more light on the learning effects of online discussions.

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