How Design Science Research Helps Improve Learning Efficiency in Online Conversations

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Abstract:

In this design science research paper, we report on our constructing and evaluating an attention-guidance system that we integrated into a computer-supported collaborative learning system. Drawing on social constructivist literature, our proposed design focuses on attracting, retaining, and, if necessary, reacquiring users’ attention on task-relevant information in online collaborative literature processing. The investigation involved an experiment across two sections of students in a human-computer interaction course. Results show that the new design allowed users to consistently reflect and evaluate the content of a text as they capitalized on one another’s reasoning to resolve misconceptions. Moreover, we found that the new system increased users’ perceptions of learning. However, the difference in knowledge gain scores was marginally significant and represented a medium effect size. Interestingly, we found that the attention-guidance system supported more efficient learning. Finally, we discovered that task-oriented reading of text, revisions of incomplete or incorrect ideas, and perceptions of learning mediated the relationship between software system and learning efficiency. We discuss the theoretical and practical implications.

Keywords: Design Science Research, Computer-supported Collaborative Learning Software, Learning Efficiency, Common Factor Analysis, Mediation Analysis.

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1 Introduction

Tightly aligning a software application with an organization’s strategic model is a knowledge-intensive endeavor that requires strong technical skills and a solid business background. Therefore, collaboration between software developers and business users can be instrumental to the success of software development projects. Accordingly, over 80 percent of Fortune 500 companies require software developers and business users to work effectively in teams to produce software applications that can add value and support business operations (Dunaway, 2013). Moreover, in Aasheim, Li, and Williams’ (2009) survey of industry perceptions and needs, one can see that effective collaboration is an important interpersonal skill for an entry-level software developer’s professional growth in an organization regardless of whether they wish to remain an entry-level developer or to advance to a more senior role. Students who major in technical fields must possess strong technical knowledge and strong collaboration and communication skills in face-to-face and virtual settings (i.e., communicating the impact of software applications on an organization’s business processes, culture, values, and structure). Collaborative learning is a core pedagogical concept in information systems (IS) model curriculum, which prepares students to work effectively in teams (Topi et al., 2010). Additionally, collaborative learning plays a vital role in curriculum recommendations for information technology (Lunt et al., 2008), computer science (Joint Task Force on Computing Curricula Association for Computing Machinery and IEEE Computer Society, 2013), computer engineering (Join Task Group on Computer Engineering Curricula Association for Computing Machinery and IEEE Computer Society, 2016), and software engineering (Joint Task Force on Computing Curricula IEEE Computer Society Association for Computing Machinery, 2014).

From a human-computer interaction (HCI) perspective, we adopt the notion that computer-supported collaborative learning (CSCL) systems provide users with opportunities to grow ideas and complete learning tasks. Asynchronous online discussions (AOD) support CSCL and provide users with the time to prepare, reflect, and search for additional information before contributing to a discussion, which allows them to express more articulate ideas in written form. As a specialized form of AOD, anchored discussion links or “anchors” messages to highlighted and numbered passages in a text, which helps users to contextualize their ideas. This tight coupling makes anchored discussion especially suitable for users when collaboratively processing 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 (e.g., Eryilmaz et al., 2013a; van der Pol et al., 2006). Along this line, Eryilmaz, van der Pol, Ryan, Clark, and Mary (2013b) show that the increase in communicative efficiency allows users to dedicate more time and effort in refining articulated ideas that favor gains in individual learning outcomes (for similar learning findings, see Mary, 2014).

However, online discussions are not a panacea that ensures learning because learning depends on many factors (for a comprehensive list, see Kirschner, Martens, & Strijbos 2004). Studies have consistently noted that one major challenge concerns a learner’s processing central principles from instructional materials at a shallow level (e.g., Jeong & Hmelo-Silver, 2010; Peters & Hewitt, 2010; Slakmon & Schwarz, 2014). Specifically, from quantitatively analyzing AOD threads, researchers have found that, as the subject matter increases in difficulty, students become less comfortable asking questions that expose their lack of understanding and revising incomplete or incorrect ideas (Eryilmaz, Chiu, Thoms, Mary, & Kim, 2014; Paus, Werner, & Jucks, 2012). Moreover, in the same line of research, Eryilmaz, Thoms, Mary, Kim, and van der Pol (2015) found that discussion threads that focus on challenging concepts have a tendency to quickly fade, which leaves little opportunity for learners to diagnose and revise their misconceptions. As Kim and Hannafin (2011) remark, under such conditions, students can develop robust and oversimplified misconceptions that prove highly resilient to change. Thus, merely linking or “anchoring” online discussion messages to highlighted and numbered passages in a text does not always produce satisfactory learning outcomes. Two factors give rise to this problem. First, students can report feeling overwhelmed and not knowing where to start when everything looks important in a text (Scheiter & Gerjets, 2007). Second, some evidence suggests that, when students associate seeking help as a threat to self-esteem or autonomy, they do not effectively use the help facilities that online learning environments offer (Karabenick, 2011). Taken together, both factors may inhibit students from acquiring a deeper understanding of core learning materials. Therefore, designing an attention-guidance system that unobtrusively focuses a learner’s attention on the progressive development of tentative ideas in areas where they struggle to gain deep understanding from instructional materials can be instrumental for enhancing the learning effects of online conversations.
Drawing on social constructivist literature, we implement the design science research framework to construct an unobtrusive attention-guidance system and integrate it into an anchored discussion system. With this consideration in mind, we designed this guidance system to attract, retain, and, if necessary, reacquire users’ attention across instructional materials’ central principles while simultaneously offering them an open learning environment in which they can choose their own topics and express their own ideas.

Thus, to examine 1) the effects that the attention-guidance system has on users’ task-oriented reading of instructional materials, online discussion message scores, perceptions of learning, knowledge gain, and learning efficiency and 2) how users’ task-oriented reading of instructional materials, online discussion message scores, and perceptions of learning relate to their learning efficiency, we conducted an experiment in which we compared two versions of an anchored discussion system: one with attention-guidance system and one without it. Empirical findings show that the attention-guidance system supported more efficient learning. Moreover, we found that users’ task-oriented reading of instructional materials, negotiation message posts, and perceptions of learning were significant predictors of their learning efficiency. These findings have implications for both design science researchers who design CSCL systems and teachers/practitioners who use online discussions to foster collaboration skills.

The paper proceeds as follows. In Section 2, we synthesize a social constructivist perspective with the general assumption of attention from cognitive psychology in the context of online discussions. In Section 3, we drawing on this theoretical background and describe how we developed an unobtrusive attention-guidance system as our instantiation artifact. In Section 4, we present our research questions. In Section 5, we discuss our methodology and, in Section 6, our empirical results. In Section 7, we discuss our results, their implications and limitations, and directions for future research. Finally, in Section 8, we conclude the paper.

2 Theoretical Background

Social constructivism underscores that students learn deeply when, for a sustained period, they engage in reading instructional materials to complete a learning task and in improving ideas valuable to a community. This engagement, as Scardamalia and Bereiter (2003) state, helps students to revise their incorrect or incomplete ideas to address their comprehension problems. In other words, this engagement provides great opportunities to enculturate students to see ideas as having an important role for solving real-world problems. From a social constructivist perspective, we can consider students’ ideas as knowledge objects that they improve continually through collaboration by asking questions and proposing explanations based on evidence and reasoning (Lipponen, Hakkarainen, & Paavola, 2004). In short, social constructivism asserts that collaboration can encourage and help learners to consciously develop cohesive ideas that no single individual could have developed alone. Accordingly, we can view students as active constructors of knowledge who capitalize on one another’s reasoning to gradually refine ambiguous, figurative, and partial understandings. Hence, learning and knowledge building share a close relationship.

In CSCL, task-oriented reading or functional reading (as defined by Gil, Martinez, & Vidal-Abarca, 2015) refers to students’ strategic engagement with instructional materials on a screen to complete a learning task. Scientific research papers are a crucial source of information to help students see the real-world value of the skills they learn (e.g., identifying, modeling, communicating, and documenting a system’s requirements). Since these papers do not offer a visual aid that makes central principles “pop out” as in textbooks, students must apply critical reading strategies to answer comprehension questions. For example, students need to make decisions about how to read the text (e.g., entirely and carefully, scanning, search reading, or skimming), when to refer back to comprehension questions to monitor their understanding of a learning task, and what part of a text to read again to identify important information such as contradictory propositions. These kinds of strategic decisions not only provide insight into students’ different levels of intellectual engagement with a text but also underscore that some information in a text will be more important than others (Gil et al., 2015). Consequently, students have to distinguish between relevant and less-relevant or irrelevant information by reading back and forth between instructional materials and comprehension questions. In this sense, task-oriented reading is not so much a linear process but a cyclical one in which students take an active role in adjusting their reading strategies to complete a learning task.
Focusing on reading strategies, Cerdán, Vidal-Abarca, Martinez, Gilabert, and Gil (2009) found that carefully reading most of a text initially before reading comprehension questions helps students form a coherent mental representation. This mental representation helps students in two ways: first, they answer easy comprehension questions accurately without searching text, and, second, they are better at searching for relevant information to answer difficult comprehension questions, which allows them to monitor their search decisions more accurately. Thus, when students with a coherent mental representation refer back to a text, they spend less time on selecting and more time on processing relevant information. In a similar vein, Ingelbrecht and Foong (2013) show that the time young individuals today spend reading text on a screen is almost equal to the time they spent reading printed text. However, many studies have asserted that students lack the ability to read deeply and sustain engagement when reading online. For example, Liu (2005) found that, when reading text on a screen, students mostly skim it or read it at a shallow level (i.e., reading that is faster than 6.5 words per second) (Hewitt, Brett, & Peters, 2007). Studies have also found that learners generally rate the usability of printed text higher than text on a screen (for an overview, see Huang, Chen, & Ho, 2014). Drawing on this line of reasoning, Carr (2010) shows that the fragmentary nature of hypertext reduces students’ sustained reading and results in shallow reading. Given these problems, Ackerman and Goldsmith (2011) emphasize printed text as more suitable for effective learning and digital reading as a tool for skimming email, news, and notes.

Cognitive theories on individual learning have long held to the view that reading comprehension is an act of reading between the lines while making connections that a text does not explicitly state. As Mayer (1999) shows, a student can comprehend central principles from a text through a cognitive process of 1) selecting relevant information, 2) organizing selected information into a coherent representation, and 3) integrating this representation into existing knowledge. This active process indicates that students need to constantly reflect on and evaluate a text’s content by assessing its arguments with supporting evidence from the text itself, outside resources, or their own knowledge in order to develop understanding of information. At its heart, this process contains the idea that selecting relevant information supports subsequent knowledge-construction activities by directing students toward deeply processing task-relevant information. To this end, in cognitive theories on individual learning, attention’s main function is to select relevant information is to select relevant information for further processing while inhibiting less-relevant or irrelevant information from being processed (Pashler, 1998). From the lens of this active cognitive process, Cull (2011) demonstrates that students’ reading text on a screen (e.g., distractibility, non-linear reading, keyword spotting) differs from reading printed text (e.g., cognitive focus, concentrated reading, reading speed) (for a similar finding, see Coiro & Dobler, 2007).

Resonating from Stahl’s (2004) 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 expand, refute, or modify one another’s ideas. From this standpoint, we can view selecting relevant information as a prerequisite to focus students’ joint effort to grapple with the meaning and utility of task-relevant information. Therefore, when applied to social constructivism, attention emphasizes students’ awareness that they focus on the same important topic with the same intent (Schneider & Pea, 2014). In sum, we can state that knowledge objects evolve non-linearly when learners collaboratively process academic literature because ideas that focus on task-relevant information interact and mutually influence one another.

While one might argue that many activities have the potential to foster this knowledge-construction approach to learning (for an overview, see Gunawardena, Lowe, & Anderson, 1997), two stand out as particularly beneficial and influential: 1) considering divergent ideas via considering questions that reveal insufficient understanding or 2) openly acknowledging confusions and revisions of incomplete or incorrect ideas. Focusing on the first activity, prior research showed that facing disparity serves as a trigger for further information search about a topic (e.g., Graesser et al., 2007; Johnson & Johnson, 2009). According to Gress, Fior, Hadwin, and Winne (2010), this further information search can stimulate students to recognize their own trouble spots. Thus, as Peters and Hewitt (2010) note, we can consider online discussions genuinely knowledge advancing when students focus on topics they struggle to understand rather than only contribute to familiar and safe topics. Despite the importance assigned to the first activity, prior research underscores that students are often hesitant to disagree with their peers and reveal their lack of understandings for the fear of losing face. For example, Golanics and Nussbaum (2008) demonstrate that students’ fear of losing face in online discussions impedes their own progress at developing better understanding of a topic. Schwarz and De Groot (2007) also present evidence that the fear of losing face from fellow students’ discussing one’s incomplete or erroneous idea can cause a student to engage in self-esteem defensive behavior. In this manner, the second activity emphasizes
students’ conscious efforts to deconstruct and reconstruct their understanding of difficult or unfamiliar issues. Importantly, Erkens, Jaspers, Prangsma, and Kanselaar (2005) show that the more students engage in the first activity, the more they can engage in the second activity. Thus, learning becomes an active process of elaborating ideas based on a whole community’s collaborative effort. Although, the first activity is fundamental to the second activity, it does not guarantee it (Jeong, 2013). As Jeong and Hmelo-Silver (2010) demonstrate, students often struggle with sustained elaboration of ideas and get lost or overwhelmed by the large amount of information in learning resources.

2.1 Attention Guidance

We need to acknowledge that no silver bullet for learning exists and that social constructivism does not always help students develop a deeper understanding of what they are learning. As Kintsch and Dijk (1978) show, students who are new to a particular domain and lack even introductory knowledge face difficulty in allocating attention to relevant information and monitoring their own comprehension. To compensate for this deficiency, 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). Clark, Nguyen, and Sweller (2006) define attention guidance as the “use of cues and signals to focus attention to important visual or textual content” (p. 77). Attention guidance becomes unobtrusive when it makes relevant information more salient without adding new-content related information. As De Koning, Tabbers, Rikers, and Paas (2009) demonstrate 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. In this regard, attention guidance can attract, retain, and, if necessary, reacquire students’ attention on instructional materials’ central principles when collaboratively processing academic literature.

To the best of our knowledge, no prior work has tried to build an attention-guidance system in CSCL in the context of students’ online literature processing. Prior studies have mostly studied attention guidance in the context of multimedia learning. For instance, in one important study, Lorch and Lorch (1995) found that attention guidance slowed down students’ reading of task-relevant information. In line with this finding, De Koning et al. (2010) found that attention guidance encouraged students to look more often and for longer periods of time at cued than non-cued contents (for similar findings, see Schnitz & Lowe, 2008). Furthermore, Irwin, Colcombe, Kramer, and Hahn (2000) found that students looked at cued contents first even if they were no more important than non-cued contents. Taken together, the findings from these prior studies suggest that attention guidance can offer students an indirect way of focusing their collaboration on the processing of central principles from instructional materials. But, does attention guidance improve learning outcomes in a systematic way? On the one hand, Boucheix and Lowe (2010) show that attention guidance helps learners to construct a mental model of causal chains in cued areas. Similarly, De Koning, Tabbers, Rikers, and Paas (2007) found that attention guidance improved retention and transfer performance. On the other hand, Kriz and Hegarty (2007) failed to find better learning outcomes for cued compared to non-cued instructional materials. Along this line, Lowe (2004) found that attention guidance prompted students to process information in isolated ways without addressing the overall aspects of a learning task. Thus, the existing literature has a discrepancy concerning the learning effects of attention guidance. This discrepancy underpins that guiding students’ learning in an online discussion is as much of a challenge as it is in a regular classroom.

After reviewing social constructivist literature on possible forms of guidance in general, we identified two relevant forms that may improve students’ learning outcomes: 1) scaffolded guidance and 2) peer-to-peer guidance. We discuss these two forms of guidance in Sections 2.1.1 and 2.2.2, respectively.

2.1.1 Scaffolded Guidance

Consistent with Wood, Bruner, and Ross (1976) and Vygotsky’s (1978) views, we define scaffolding as assistance from an instructor that helps students to focus their collaborative literature processing on important information that they might otherwise overlook. As van de Pol, Admiraal, and Simons (2010) note, scaffolding has three key characteristics crucial to its success: contingency, fading, and transfer of responsibility.

Contingency refers to instructors’ calibrating their assistance to students’ current level of competence. For our purposes here, the most important aspect of this characteristic concerns whether instructors introduce their assistance without destroying the exploratory and creative potential of students’ collaborative literature processing. For instance, Race (2013) reports that students have a tendency to switch off
mentally if an instructor’s assistance provides them all the answers. In a similar vein, Zahn, Krauskopf, Hesse, and Pea (2012) state that students can feel overwhelmed or become bored by an instructor’s extensive instructions before they really start doing anything. In accordance with De Koning, Tabbers, Rikers, and Paas (2009), an instructor can provide contingent assistance by increasing the font size of central principles from instructional materials. In this respect, an instructor’s contingent assistance helps students to identify what they need to understand from instructional materials (Kim & Hannafin, 2011). Given that attention allows students to begin processing online literature (Schneider & Pea, 2013; Stahl, 2013), this form of guidance can implicitly invite students to justify, defend, and revise their ideas by focusing on central principles from instructional materials.

Fading refers to instructors’ gradually withdrawing their assistance as students become more capable in accomplishing their learning goals. Without fading, students do not internalize and appropriate the desired competencies. For example, Oliver and Hannafin (2001) discuss how students became dependent on an instructor’s assistance and could not perform the learning tasks independently once the instructor removed it. Thus, fading’s defining feature is that it forces learners to acquire skills.

Transfer of responsibility strongly relates to fading. Via fading, the locus of responsibility shifts to students. We conceptualize responsibility in this study as students’ task-oriented reading of instructional materials and their reasoned contributions to a coherent online discussion that can advance their understanding of those materials.

Prior research shows that scaffolding can encourage students to openly acknowledge their common confusions and ask topic-related questions in online discussions (Eryilmaz et al., 2015). However, on the flip side, students do not always understand the reasons behind the importance of the central principles that their instructors suggest 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 that are often inconsistent with the instructional materials’ central principles (Kim & Hannafin, 2011). In the light of this disparity, we describe a second form of guidance that relies more on the students themselves below: peer-to-peer guidance.

2.1.2 Peer-to-peer Guidance

The term “peer-to-peer” underscores a group of equal-status students’ collective responsibility to determine instructional materials’ central principles on their own rather than relying on instructors as the only available help source. In this way, it encourages students to reflect on their own and on the community’s progress in understanding by asking questions such as: “Are we addressing common and pertinent problems of understanding?”, “Are we making progress on answering how and why questions?”, “Are we getting stuck?”, and “How can we move forward?”. Thus, as Resendes, Scardamalia, Bereiter, Chen, and Halewood (2015) point out, peer-to-peer guidance entails students’ formative evaluation to recognize trouble spots and altering discursive practices to improve their learning outcomes. Thus, the term peer-to-peer we use in this study is conceptually similar to “knowledge creation” as practiced in computer-supported collaborative work settings (Nonaka & Takeuchi, 1995; Paavola & Hakkarainen, 2005).

From a theoretical standpoint, peer-to-peer guidance supports two learning mechanisms (King, 1998): 1) monitoring peers’ explanations and 2) providing focused feedback on peers’ explanations. Monitoring peers’ explanations prompts students to discriminate the most critical information from the less important information by using their peers’ explanations as a resource for learning. For example, students who report feeling overwhelmed and not knowing where to start when everything looks important in a text can stay focused on their task by monitoring peers’ explanations (Caldwell, 2007). Hence, we can consider monitoring peers’ explanations as an active rather than a passive activity that connotes openness when considering dissonant views (Wise, Hausknecht, & Zhao, 2014). Through monitoring, students can identify gaps in thinking, which paves the way for the second mechanism.

Providing focused feedback on peers’ explanations underscores that reading instructional materials to complete a learning task and assessing community members’ different points of views are intimately interrelated activities in the knowledge-creation metaphor of learning (Paavola & Hakkarainen, 2005). Since asynchronous online discussions do not occur in real time, they provide opportunities for students to thoughtfully consider a text and refer to one another’s explanations in meaningful ways. That is to say, as students read and re-read instructional materials in their own time, they can revise one another’s incorrect
or incomplete ideas in order to address their comprehension problems. However, if students disregard reading instructional materials to complete a learning task (or do so in unproductive ways), they may receive low-quality feedback, which can result in a shallow and disjointed online discussion (Wise et al., 2014). Hence, research considers the second mechanism to highly influence students’ learning outcomes (Baker, 1999).

Eryilmaz et al. (2015) found that peer-to-peer guidance helps students to compare and contrast their own different explanations in order to improve tentative ideas. However, interactivity graphs with this guidance technique show that such comparisons take time to cultivate because students can be reluctant to critique or to be critiqued for the fear of making mistakes (Eryilmaz et al., 2015). In this vein, Tsai, Lin, and Yuan (2002) found that students may regard the second mechanism above as too time-consuming and demanding. According to Ballantyne, Hughes, and Mylonas (2002), some students may even regard the second mechanism as a duty of an instructor rather than themselves.

Given the advantages and potential problems of scaffolding and peer-to-peer guidance, we explore the possible synergistic impacts of combining two forms of guidance in an instantiation artifact to enhance the learning effects of online conversations. Having devised a set of design guidelines, we turn our focus to the design process in Section 3.

3 Artifact Development

Design science research (DSR) is a problem-solving paradigm that involves creating new knowledge through building and evaluating IT artifacts (Hevner, March, Park, & Ram, 2004). The term artifact, as Gregor and Hevner (2013) define it, refers to any “thing that has, or can be transformed into, a material existence as an artificially made object” (p. 341). In this paradigm, an IT artifact draws knowledge from existing justificatory theories that relate to the goals of its intended purposes. One creates new knowledge from rigorously evaluating the IT artifact’s utility, quality, and efficacy. One then effectively communicates this resulting new knowledge back to key stakeholders.

In this study, the attention-guidance system constitutes the primary instantiation artifact. From conducting a needs analysis on the pertinent literature, we realized how threads in online discussion boards have the tendency to quickly fade, which leaves little opportunity for students to diagnose and revise their incomplete or incorrect ideas (e.g., Eryilmaz et al., 2015; Jeong & Hmelo-Silver, 2010; Paus et al., 2012; Peters & Hewitt, 2010; Slakmon & Schwarz, 2014). An attention-guidance system can solve this problem by attracting, retaining, and, if necessary, reacquiring students’ attention on instructional materials’ central principles while simultaneously offering them an open learning environment for choosing topics and expressing ideas. The artifact’s design considers De Koning et al.’s (2009) discovery that font size is an effective visual property for capturing students’ attention in an involuntary or obligatory fashion without altering the content or meaning of instructional materials. To the best of our knowledge, no existing attention-guidance systems designed explicitly for online literature processing exist. We put our attention-guidance system to use by integrating it into a standalone anchored discussion system, which allows students to view discussion threads alongside the literature they are discussing. This design contrasts starkly with existing learning management systems (e.g., Blackboard, Canvas, Angel), which typically offer instructional materials and their associated discussions through separate links or windows. This separation, as social constructivism demonstrates (e.g., Eryilmaz, Chiu, Thoms, Mary, & Kim, 2013a; Huang et al., 2014; Jeong, 2013; Kim & Hannafin, 2011), requires students to toggle attention back and forth across multiple windows, which is not conducive to focusing their attention on processing task-relevant information from instructional materials. In determining the font size that would yield the greatest visual impact on students’ attention, we conducted a pilot study. Given the discrepancy in the existing literature about the learning effects of attention guidance as we note in Section 2, our main study involved an experimental design methodology (i.e., measuring our artifact instantiation across multiple student populations and evaluating levels of improvement against existing anchored discussion systems). Thus, we had students in a realistic academic setting use the instantiation artifact to complete tasks typical of online discussion systems. In the DSR knowledge-contribution framework, we position this research in the improvement quadrant as defined by Gregor and Hevner (2013). As such, this study contributes to the prescriptive knowledge base in the form of a situated (or level one) instantiation. Furthermore, our evaluating the instantiation artifact contributes to the descriptive knowledge base in the form of expanded understanding of student learning outcomes across online collaborative literature processing. Table 1 more completely describes the DSR criteria.
Table 1. Design Science Research Guidelines (Hevner et al., 2004)

<table>
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<tr>
<th>Guideline</th>
<th>Description</th>
<th>Application to this research</th>
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<tbody>
<tr>
<td>1. Design as an artifact</td>
<td>DSR must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.</td>
<td>The attention-guidance system integrated in an anchored discussion system served as the instantiation artifact.</td>
</tr>
<tr>
<td>2. Problem relevance</td>
<td>DSR focuses on developing technology-based solutions to important and relevant business problems.</td>
<td>The design addresses the problem in asynchronous online discussions where online discussion threads that focus on central concepts from instructional materials have the tendency to quickly fade, which leaves little opportunity for students to diagnose and revise their incomplete or incorrect ideas (e.g., Eryilmaz et al., 2015; Jeong &amp; Hmelo-Silver, 2010; Peters &amp; Hewitt, 2010; Paus et al., 2012; Slakmon &amp; Schwarz, 2014).</td>
</tr>
<tr>
<td>3. Design evaluation</td>
<td>One must rigorously demonstrate the utility, quality, and efficacy of a design artifact via well-executed evaluation methods.</td>
<td>A pilot study served as a case study in identifying the font size to be an effective visual aid for keeping students’ attention. The primary study used a classical experimental design to isolate the effects of the attention-guidance system in students’ online collaborative literature processing from the anchored discussion system’s baseline features.</td>
</tr>
</tbody>
</table>
| 4. Research contributions        | Effective DSR must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies. | Our work contributes to:  
• The prescriptive knowledge base in the form of situated implementation of an artifact (or level one) and  
• An expanded understanding of students’ learning outcomes from online collaborative literature processing. |
| 5. Research rigor                 | DSR relies on one’s applying rigorous methods in both constructing and evaluating the design artifact. | Rigorous methods that we applied for the research include:  
• Designing a new system that followed existing theoretical knowledge on social constructivism and the  
• Evaluating this design through validated instruments based on existing research. |
| 6. Design as a search process     | The search for an effective artifact requires using available means to reach desired ends while satisfying laws in the problem environment. | The process for an effective instantiation artifact began with a search to discover unobtrusive ways to focus students’ attention on processing central principles from instructional materials in online discussions and to discover how font size as a visual property can capture students’ attention in an involuntary or obligatory fashion without altering the meaning or content of instructional materials. |
| 7. Communication of research     | One must effectively present DSR to both technology-oriented and management-oriented audiences. | We have shared research results in the form of scientific publications in academic conference proceedings and journals. |

To meet the requirements derived from the theoretical background, we extend a modular, flexible, and extensible anchored discussion system with an unobtrusive attention-guidance system. When compared to regular online discussion software, anchored discussion software links or “anchors” highlighted messages and numbered passages in a text to contextualize students’ ideas. This tight coupling, which lies at the heart of anchored discussion, presents students with an intuitive means to collaboratively process academic literature. Accordingly, our system converts PDF-based instructional materials to a more flexible HTML format via 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 used HTML-formatted instructional materials as the basis for Marginalia (an open source JavaScript Web-annotation system) to enable fine-grained annotations. Marginalia has two features conducive to creating a tight-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. This red font, as Figures 1 and 2 depict below, represents a discussion thread that focuses on an annotated text. Because students share both asynchronous online discussions and instructional materials in anchored discussions, this representation
is particularly useful for recovering the portion of a conversion about a given part of a text. 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. We took this approach in order to prevent sticky notes from interfering with students’ task-oriented reading of a text. Taken together, both features facilitate contextualized group communication.

Moreover, given a possible lack of social identity in mediated textual communication (Faraj, Kudaravalli, & Wasko, 2015), our system allows students to present themselves with profile photos similar to social networking sites. Finally, we incorporated a simple five-star rating schema into the anchored discussion system to allow students to rate to one another’s online discussion messages because prior research (e.g., Schwarz & De Groot, 2007) has shown that ratings play a vital role in building students’ identity through establishing their reputation. Consequently, average ratings provide insight into which students provide the most valuable contributions.

3.1 Attention-guidance System

We designed our attention-guidance system (i.e., instantiation artifact) to attract, retain, and, if necessary, reacquire students’ attention on instructional materials’ central principles while simultaneously offering them an open learning environment in which they can choose their own topics and express their own ideas. Figure 1 displays the user interface of the developed system. This interface works by 1) a user’s (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. 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 system includes three font sizes: default, big, and biggest. To begin with, the default font size represents a standard level of importance. Next, the big font size represents a single individual’s regarding the text to have high importance. Finally, the biggest font size depicts consensus on collaboratively decided important themes. This visual contrast enables central principles to become more noticeable and stand out against the rest of the text. We developed our attention-guidance system 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’s biasing the group’s consensus on collaboratively decided important areas.

We consider the attention-guidance system an innovative and purposeful instantiation artifact. It is innovative because it extends users’ interactions with instructional materials beyond making annotations by allowing them to manipulate the font size of passages to indicate their perceived importance (for characteristics of existing anchored discussion systems, see Wolfe, 2008). Moreover, it suits our goal because it supports the three key characteristics of scaffolding (van de Pol et al., 2010) and two mechanisms of peer-to-peer guidance (King, 1998). As for scaffolding, it supports contingency because students have the freedom to annotate any passage they deem important. If they annotate central principles with the big font size, then they still have to refine their own key ideas. Second, it supports fading because instructors can gradually decrease the number of central principles with the big and biggest font sizes from text. Third, it supports transfer of responsibility because students have to distinguish central principles from the text independently after the instructor fades their guidance. As for peer-to-peer guidance, it supports monitoring peers’ explanations of what they think are the central principles from instructional materials because students can move the cursor over an annotated passage with the big or biggest font size to read such explanations. Second, it supports providing focused feedback on peers’ explanations because each feedback makes reference to an annotation as Figure 1 depicts.
How Design Science Research Helps Improve Learning Efficiency in Online Conversations

Although testing and driving is a growing epidemic, there is little empirical work examining strategies for reducing this behavior. Currently 38 states, the District of Columbia, and some local governments prohibit all drivers from texting and driving [5]. Studies examining the consequences of enacting bans against texting and driving have mixed results. While some studies have found that after implementing laws banning texting and driving reduces personal injury accident rates, other studies find that the rates of cell phone usage actually increase.

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Figure 1. Screenshots of the Attention-guidance System
3.2 Control System

In order to isolate the effects of the attention-guidance system that we present above, we developed a control version of the new anchored discussion tool that included the Marginia JavaScript program but without the attention-guidance system. Figure 2 displays the user interface of the control software system.

![Figure 2. Screenshots of the Control Software](image_url)
4 Research Questions

In accordance with the theoretical background, we formulated two main research questions to investigate the effectiveness of the developed attention-guidance system.

RQ1: What are the effects of the attention-guidance system on users’:
   a. Task-oriented reading of instructional materials?
   b. Online discussion message scores?
   c. Perceptions of learning?
   d. Knowledge gain?
   e. Learning efficiency?

RQ2: How do users’ task-oriented reading of instructional materials, online discussion message scores, and perceptions of learning relate to their learning efficiency?

5 Methodology

5.1 Research Design and Participants

We evaluated the attention-guidance system in three phases. In the first phase, we conducted a pilot study to determine which big and biggest font sizes would yield the greatest visual impact on students’ attention. In the second phase, we assessed the construct validity of the scales to measure students’ task-oriented reading of instructional materials and perceptions of learning. Finally, in the third phase, we conducted the main study to answer our research questions. We conducted all studies at a public university in the Northeastern United States.

In the first phase, we conducted a case study in an introductory Android application-development course for information system majors. The course included hands-on programming experience in the form of exercises. Moreover, students actively participated in online discussions that used scientific research papers to help them see the real-world value of the skills they learned. In all, 12 second-year undergraduate students participated in the case study. Of the 12 participants, 53 percent were female and 47 percent were male. The mean age of the participants was 19.47 (SD = 1.02). The instructional topic for the purpose of the pilot study was mobile commerce. This topic included two research papers, which we arranged in the following sequence: 1) “Designing Mobile Business Applications for Different Age Groups” (Gurtner, Reinhardt, & Soyez, 2014) and 2) “Explain the Intention to Use Smartphones for Mobile Shopping” (Agrebi & Jallais, 2015). We covered each paper during a two-week online discussion period. At the end of each discussion theme, we asked the pilot study participants to identify and report the font size that exerted the most visual influence on their attention. Based on their input, we set the big font size to be 150 percent larger than the default font size. In order to be consistent with the font size, we set the biggest font size to be 150 percent larger than the big font size. Thus, the pilot study helped us in the “design an artifact” criterion (Hevner et al., 2004) as Table 1 notes.

In the second phase, we conducted a case study in a management information systems course that all business majors had to take. The course focused on helping students to understand how the management and uses of information and information technologies help managers to accomplish organizational goals and provide strategic advantage for businesses. In all, 200 second-year undergraduate students participated in the case study. Of the 200 participants, 58 percent were female and 42 percent were male. The mean age of the participants was 19.53 (SD = 1.08). The instructional topic for the purpose of the case study was decision support systems. This topic included two research papers, which we arranged in the following sequence: 1) “Barriers and Facilitators to Clinical Decision Support Systems Adoption: A Systematic Review” (Devaraj, Sharma, Fausto, Viernes, & Kharrazi, 2014) and 2) “Lessons Learned from Implementing Service-oriented Clinical Decision Support at Four Sites: A Qualitative Study” (Wright et al., 2015). We covered each paper during a two-week online discussion period. At the end of the second discussion theme, we asked the participants to complete the task-oriented reading of instructional materials and perceptions of learning questionnaires.

In the third phase, we conducted an experiment in two sections of a HCI course that all information system majors had to take. The course focused on developing in students a user-centered design perspective that they could use to optimally frame the logical and physical design of information systems
in a variety of information use environments. The course particularly emphasized usability for website engineering. To take the course, students had to have achieve a grade of “C” or better in another course called the Fundamentals of Web Development. Students worked intensively to design and construct user-centered websites. Moreover, students actively participated in online discussions that used scientific research papers to supplement the above-mentioned course focus. In all, 64 undergraduate fourth-year students who majored in information systems participated in the experiment. Of the 64 participants, 45 percent were female and 55 percent were male. The mean age of the participants was 22.04 (SD = 1.36). We split all participants into two sections of the same course. Each section had 32 students. The same instructor taught both sections, and they followed the same schedules to eliminate confounding factors. We randomly assigned one section to the experimental group and the other to the control group. We informed neither section whether they were part of the experimental group or the control group to avoid the Hawthorne effect and John Henry effect (Holden, 2001). The experimental group had access to the attention-guidance system, whereas the control group used the control system. This experimental design isolated the effects of the attention-guidance system in students’ online collaborative literature processing from the anchored discussion system’s baseline features. Prior to the experiment, we provided training in a face-to-face class session to ensure that all students could work with the respective software system. Furthermore, we used this class session to teach students the structural components of an argument based on the Toulmin (2003) argumentation framework in order to increase the quality of online discussions in both groups. The instructional topic for the purpose of the experiment was persuasive technologies. This topic included two research papers, which we arranged in the following sequence: 1) “Creating Persuasive Technologies: An Eight-step Design Process” (Fogg, 2009) and 2) “Examining the Efficacy of a Persuasive Technology Package in Reducing Texting and Driving Behavior” (Miranda et al., 2013). We covered each paper 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 their own explanations based on evidence and reasoning. The second discussion activity asked students to refine one another’s ambiguous, figurative, and partial explanations by analyzing the annotations. All students had to participate in the online discussions, and such discussions formed part of their regular curriculum. All participants had to make at least two annotations per paper and provide focused feedback to at least two fellow students’ explanations for that paper. Both groups in our experimental design received scaffolding in the form of the instructor’s annotations on text because prior research underscores that students who are new to a particular domain and lack even introductory knowledge face difficulty in allocating attention to relevant information and monitoring their own comprehension (Kintsch & van Dijk, 1978). The instructor used scaffolding to help participants determine information pertinent to the learning task (e.g., principle factors in the Fogg’s (2009) behavioral model, characteristics of successful triggers, identification of problems in persuasive technologies that fail to achieve the intended outcomes, and ethical aspects of persuasive technologies). The design of the attention-guidance system allowed the experimental group students to make any information they deemed important from text (e.g., peers’ and instructor’s annotations) more prominent. Thus, in this study, we examined how changes in the font size of task-relevant information via the developed attention-guidance system influenced students’ learning outcomes in real educational practice. In order to help ensure that students used the attention-guidance system in a natural way and to keep the conditions equal, we merely offered the attention-guidance system to the experimental group without requiring them to use it.

5.2 Measures

5.2.1 Task-oriented Reading of Instructional Materials

We start our analyses with students’ task-oriented reading of instructional materials because students who are new to a particular domain and lack even introductory knowledge face difficulty in purposeful and active reading (Gil et al., 2015). Thus, analyzing this theoretical construct can help one to determine how students read the text (i.e., skimming it or reading it more deeply). We adopted a questionnaire developed by Sheorey and Mokhtari (2001) to measure students’ task-oriented reading of instructional materials. The questionnaire included the following five items: 1) “I adjust my reading speed according to what I am reading from an article”, 2) “I try to get back on track when I lose concentration”, 3) “I read slowly and carefully to make sure I understand what I am reading”, 4) “When text becomes difficult, I re-read it to increase my understanding”, 5) “I stop from time to time and think about what I am reading”. We
administered the questionnaire at the end of the learning task. We asked students to complete the questionnaire by using a five-point Likert scale (1 = strongly disagree; 5 = strongly agree).

5.2.2 Online Discussion Message Scores

Next, we measured students’ online discussion message scores because one can see these shared, visible, and persistent knowledge objects (as Stahl (2004) defines them) as the only building blocks for collaborative knowledge construction in the knowledge-creation metaphor of learning (Paavola & Hakkarainen, 2005). Patton (2002) define content analysis as “any qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings” (p. 453). In content analysis, one codes online discussion messages (or elements of messages) according to a well-specified coding scheme to investigate knowledge collaboration in online communities. We employed Gunawardena et al.’s (1997) content-analysis instrument based on the aforementioned principles to assess students’ online discussion message scores. The unit of content analysis was each complete message posted in the online discussion because students’ messages were rather short and mainly comprised only one type of knowledge-construction phase (for the suitability of this analysis unit in similar settings, see Eryilmaz et al., 2013a). This unit presented an unambiguous basis for segmentation. Table 2 summarizes five phases of knowledge construction based on Gunawardena et al.’s (1997) content-analysis instrument.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharing information</td>
<td>Statement of initial interpretation of a topic</td>
<td>I think this technique of using smaller achievable goals is very similar to Japanese technique of developing a habit, it’s called 1 minute. If there is something that you want to start doing but cannot start, you always try to postpone, you can start doing it only 1 minute a day. For example, jogging only 1 minute. It doesn’t take a lot of time and energy, and everyone is able to do that. Even this small accomplishment can encourage you to do jogging every day, and you will increase time gradually. That’s how you develop a habit. I think new behavior means developing a new habit.</td>
</tr>
<tr>
<td>Exploring dissonance</td>
<td>Identification of areas disagreement among interpretations</td>
<td>I don’t understand why you think these small matters are really important. It seems like the major goals of persuasive technology in the long run is to have an affect [sic] on some serious issues and behaviors. Is it even worth it to spend time and money on focusing on small things that may not make a difference? Those small persuasive technology projects would likely need to be funded by a company with some direct interest in the topic like Google.</td>
</tr>
<tr>
<td>Negotiating meaning</td>
<td>Modification of initial interpretations or clarification of different viewpoints</td>
<td>Hmmmm so think about this. The user is the central hub where information radiates inward and outward from that hub. For example, a user on Facebook is bombarded with websites and they find a topic that they “like.” That action triggers other websites to bombard the user, as well as showing your choice of topics with other Facebook users.</td>
</tr>
<tr>
<td>Testing proposed synthesis</td>
<td>Evaluation of proposed synthesis against received facts, personal experience, or other sources</td>
<td>A really good point brought up in this discussion is that we have to be a little bit psychologist to understand the people we target. Relating to what we have learned in class, I think this would be a perfect situation for conducting surveys to determine the reason or combination of reasons as to why users are not motivated to perform the behavior that the team is looking for. Once the data is collected, it would provide the design team with visible trends and patterns describing why they are not reaching their desired result. If nothing else, it would provide valuable data on people’s thinking that could possibly be used for other projects.</td>
</tr>
<tr>
<td>Agreeing on new knowledge</td>
<td>Summarization of agreement(s) as a result of group discussion</td>
<td>I agree with your statement. No process will be exactly the same to another when designing a new technology. These 8 steps Fogg talks about is simply a framework to get you started.</td>
</tr>
</tbody>
</table>

5.2.3 Perceptions of Learning

Subsequently, we measured learning outcomes because task-oriented reading of instructional materials and online discussion message scores are theoretically interrelated constructs (Baker, 1999; Wise et al.,
2014) that allow students to achieve a deep conceptual understanding. Consequently, measuring learning outcomes helps one in determining students’ internalization of task-oriented reading of instructional materials and their diagnosed and resolved misconceptions. However, learning, as Kirschner et al. (2004) note, is a complex multidimensional construct that cannot adequately be measured with a single scale. In order to portray a nuanced picture, we measured learning outcomes in three different ways. First, we adopted a questionnaire that Wu and Hiltz (2003) developed to measure students’ perceptions of learning from online discussions. As Wu and Hiltz (2003) note, self-reported perceptions of learning is a good approximation of a student’s capacity to process information. The questionnaire included eleven items. We asked students to complete the questionnaire at the end of the learning task by using a five-point Likert scale (1 = strongly disagree; 5 = strongly agree).

5.2.4 Knowledge Gain
Second, we measured knowledge gain with knowledge pre- and post-tests. The pretest evaluated students’ individual understanding of persuasive technologies after they read the instructional materials individually but before they discussed it with peers using the anchored discussion system. Thus, the pre-test objectively assessed students’ domain-specific prior knowledge. The post-test analyzed whether the students’ individually understanding of the instructional topic improved through online discussion. Both the pre-test and the posttest 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 software 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 that Jamaludin et al. (2009) developed. 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. We primarily used this approach to examine whether students could improve their initial ideas via online discussions.

5.2.5 Learning Efficiency
Third, 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 related to the learning task, we used post-test scores as a direct measurement of their performance (for a similar approach, see De Jong, 2010). We then standardized the pre- and post-test scores because they used different scoring scales.

5.2.6 Control Variables
Finally, we measured user demographics and perceived system quality as control variables to ensure that they were constant between the groups. Nelson, Todd, and Wixom (2005) define user demographics as a non-technical characteristic that plays an important role in influencing users’ behaviors. Hence, we should not neglect users’ demographics when studying the effectiveness of the attention-guidance system. Drawing on our theoretical background, we focus on four specific demographic variables: gender, grade point average (GPA), computer self-efficacy, and prior experience with guidance systems. Gender has been associated with online discussion message scores. For example, Ding, Bosker, and Harskamp (2011) found that females tend to raise more questions than males in order to open or elicit a discussion. Various studies have shown that GPA to be associated with knowledge gain scores (see Lee & Wu, 2013, for a meta-analyses), and, therefore, we included it as a demographic variable. Given the context of information technology artifact implementation, we controlled for computer self-efficacy and prior experience with guidance systems in the context of CSCL. Participants completed a preliminary survey two weeks before the experiment to provide their demographic information. We measured computer self-efficacy by using the scale from Venkatesh (2000). We also asked the students to rate the amount experience they had with guidance systems in the context of CSCL along a five-point Likert scale (1 = “hardly any”; 5 = “very much”).
Islam (2012) defines perceived system quality as an object-based belief, which represents users’ evaluation of a CSCL system from technical and design perspectives. Prior research found that users’ perceived system quality affects their CSCL system usage (e.g., Freeze, Alshare, Lane, & Wen, 2010; Islam, 2011). Therefore, analyzing this object-based belief helps one in examining the influence of anchored discussion system’s design characteristics on participants’ system usage. After implementing the anchored discussion system to fulfill the aforementioned learning task, we examined students’ general perception of system quality with three prominent features as Islam (2012) demonstrates: perceived access, perceived ease of use, and perceived reliability. Perceived access refers to the degree of accessibility, responsiveness, and availability of the anchored discussion system. Perceived ease of use indicates the degree to which a user perceives using the anchored discussion system as free of effort. Perceived reliability underscores the dependability of the anchored discussion system. The questionnaire included eight items. We measured each item using a seven-point Likert scale (1 = strongly disagree; 7 = strongly agree). We adopted all items from the prior studies with only minor changes in the wording to reflect the anchored discussion system. Table 3 shows the questionnaire.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived access (Lee, Shin, &amp; Lee, 2009)</td>
<td>The anchored discussion system quickly loads all the text and graphics</td>
</tr>
<tr>
<td></td>
<td>The anchored discussion system provides good access</td>
</tr>
<tr>
<td>Perceived ease of use (Venkatesh, 2000)</td>
<td>My interaction with the anchored discussion is clear and understandable</td>
</tr>
<tr>
<td></td>
<td>Interacting with the anchored discussion system does not require a lot of mental effort</td>
</tr>
<tr>
<td></td>
<td>I find the anchored discussion system to be easy to use</td>
</tr>
<tr>
<td></td>
<td>I find it easy to get the anchored discussion system to do what I want to do</td>
</tr>
<tr>
<td>Perceived reliability (Wixom &amp; Todd, 2005)</td>
<td>The anchored discussion system is stable</td>
</tr>
<tr>
<td></td>
<td>The anchored discussion system operates reliably</td>
</tr>
</tbody>
</table>

### 6 Results

We report our results in the order of our research questions. First, we examine the effects that the attention-guidance system in anchored discussions has on users’ task-oriented reading of instructional materials, online discussion message scores, perceptions of learning, knowledge gain, and learning efficiency. Second, we assess how users’ task-oriented reading of instructional materials, online discussion message scores, and perceived learning relate to their learning efficiency.

#### 6.1 Task-oriented Reading of Instructional Materials

Initially, we examined the factorability of the items in the relevant questionnaire with 200 participants (students at a public university in the Northeastern United States) who did not participate in the main study. We used several well-recognized criteria for the factorability of a correlation. First, all items correlated at least 0.3 with at least one other item, which suggests reasonable factorability. Second, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.82, above the recommended value of 0.6, and Bartlett’s test of sphericity was significant ($\chi^2 (10) = 2110.59, p < 0.001$). The diagonals of the anti-image correlation matrix were all over 0.5, which supports our including each item in the factor analysis. Finally, the communalities were all above 0.3 (see Table 4), which further confirms that each item shared some common variance with other items. Given these overall indicators, we conducted factor analysis with all five items. We used common factor analysis because we wanted to represent the common variance in the set of items and because researchers frequently use common factor analysis in exploratory factor analysis (Floyd & Widaman, 1995). Initial Eigen values indicated that one factor explained 90 percent of the variance. The results of the factor analysis confirmed the construct validity of the task-oriented reading scale.
We examined the internal consistency of the scale in the main study (N = 64) using Cronbach’s alpha. The accepted value for Cronbach’s alpha is 0.70 or greater (Nunnally, 1978). The alpha value for the five items was 0.80, which suggests good scale reliability. We could have achieved no substantial increase in alpha for the scale by eliminating items. To examine RQ1a, we conducted a multivariate generalized linear model (GLM) with the group as a fixed factor and the five-item scale of task-oriented reading of instructional materials as dependent variables. The results of the multivariate test were marginally significant \( F(5, 58) = 2.29, p = 0.057, \eta^2_{\text{partial}} = 0.165 \). Table 5 presents descriptive statistics and the results of independent samples t-tests. As Table 5 shows, we found statistically significant differences between groups for each scale item with exception of the second item (i.e., “I try to get back on track when I lose concentration”) such that students in the experimental group reported higher scores than students in the control group.

<table>
<thead>
<tr>
<th>Scale item</th>
<th>Control group ( (n = 32) )</th>
<th>Experimental group ( (n = 32) )</th>
<th>( p ) value</th>
<th>Cohen’s ( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I adjust my reading speed according to what I am reading from an article</td>
<td>3.69 (0.69)</td>
<td>4.06 (0.67)</td>
<td>0.031</td>
<td>0.54</td>
</tr>
<tr>
<td>I try to get back on track when I lose concentration</td>
<td>3.84 (0.52)</td>
<td>4.09 (0.59)</td>
<td>0.075</td>
<td>0.45</td>
</tr>
<tr>
<td>I read slowly and carefully to make sure I understand what I am reading</td>
<td>3.69 (0.54)</td>
<td>4.00 (0.57)</td>
<td>0.027</td>
<td>0.56</td>
</tr>
<tr>
<td>When text becomes difficult, I re-read it to increase my understanding</td>
<td>3.81 (0.64)</td>
<td>4.19 (0.47)</td>
<td>0.010</td>
<td>0.68</td>
</tr>
<tr>
<td>I stop from time to time and think about what I am reading</td>
<td>3.72 (0.46)</td>
<td>4.03 (0.54)</td>
<td>0.015</td>
<td>0.62</td>
</tr>
</tbody>
</table>

6.2 Online Discussion Message Scores

We recorded 252 messages (M = 7.88, SD = 0.49) from students in the treatment group and 238 messages (M = 7.44, SD = 0.72) from students in the control group. In total, 64 students posted 490 messages. We trained two independent coders who did not know about the study’s purpose to use Gunawardena et al.’s (1997) content-analysis instrument with a random sample of 100 messages. After training, each coder independently coded all messages in the data set. The inter-coder Krippendorff’s alpha reliability was 0.82, which exceeds the 0.67 threshold (Krippendorff, 1980) and indicates a satisfactory agreement beyond chance. The two coders solved all disagreements via discussion after the Krippendorff’s alpha measurement.

To examine RQ1b, we created five message scores for each student based on data from the content-analysis ratings. We computed message scores as the proportion of students’ posts in each message type. For example, if a student posted a total of 10 messages and the coders coded two of those posts as sharing-information posts, the sharing information message score for the participant was 2/10 or 0.20. Table 6 presents descriptive statistics and the results of independent samples t-tests. As Table 6 shows,
the experimental group students had higher exploring dissonance and negotiating meaning message scores than control group students but lower sharing-information message score.

### Table 6. Content Analysis Results

<table>
<thead>
<tr>
<th>Phase</th>
<th>Control group (n = 32)</th>
<th>Experimental group (n = 32)</th>
<th>Test statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Sharing information</td>
<td>0.58</td>
<td>0.18</td>
<td>0.40</td>
</tr>
<tr>
<td>Exploring dissonance</td>
<td>0.20</td>
<td>0.11</td>
<td>0.30</td>
</tr>
<tr>
<td>Negotiating meaning</td>
<td>0.17</td>
<td>0.11</td>
<td>0.25</td>
</tr>
<tr>
<td>Testing proposed synthesis</td>
<td>0.03</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>Agreeing on new knowledge</td>
<td>0.02</td>
<td>0.04</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### 6.3 Perceptions of Learning

Initially, we examined the factorability of the items in the relevant questionnaire with 200 participants (students at a public university in the Northeastern United States) who did not participate in the main study. We used several well-recognized criteria for the factorability of a correlation. First, all items correlated at least 0.3 with at least one other item, which suggests reasonable factorability. Second, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.82, above the recommended value of 0.6, and Bartlett’s test of sphericity was significant ($\chi^2(55) = 4674.06, p < 0.001$). The diagonals of the anti-image correlation matrix were all over 0.5, which supports our including each item in the factor analysis. Finally, the communalities were all above 0.3 (see Table 7), which further confirms that each item shared some common variance with other items. Given these overall indicators, we conducted factor analysis with all five items. We used common factor analysis because we wanted to represent the common variance in the set of items and because researchers frequently use common factor analysis in exploratory factor analysis (Floyd & Widaman, 1995). Initial Eigen values indicated that one factor explained 75 percent of the variance. The results of the factor analysis confirmed the construct validity of perceptions of learning scale.

### Table 7. Factor Loadings Based on a Common Factor Analysis for 11 Items from the Perceived Learning Scale (N = 200)

<table>
<thead>
<tr>
<th>Perceived learning</th>
<th>Factor loadings</th>
<th>Communality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved communication skills</td>
<td>0.98</td>
<td>0.96</td>
</tr>
<tr>
<td>Online discussion decreased my learning quality</td>
<td>0.99</td>
<td>0.98</td>
</tr>
<tr>
<td>Learn great deal from peers</td>
<td>0.99</td>
<td>0.98</td>
</tr>
<tr>
<td>Improved integration skills</td>
<td>0.96</td>
<td>0.92</td>
</tr>
<tr>
<td>Most peers’ comments were not very valuable</td>
<td>0.81</td>
<td>0.66</td>
</tr>
<tr>
<td>Online discussion provided useful social interaction</td>
<td>0.76</td>
<td>0.58</td>
</tr>
<tr>
<td>Online discussion was useful to my learning</td>
<td>0.75</td>
<td>0.56</td>
</tr>
<tr>
<td>Learning quality was improved by online discussion</td>
<td>0.73</td>
<td>0.53</td>
</tr>
<tr>
<td>Provided a great chance to share opinions among peers and instructor</td>
<td>0.81</td>
<td>0.66</td>
</tr>
<tr>
<td>Broadened my knowledge</td>
<td>0.86</td>
<td>0.73</td>
</tr>
<tr>
<td>Improved generalization skills</td>
<td>0.85</td>
<td>0.72</td>
</tr>
</tbody>
</table>

We examined the internal consistency of the scale in the main study (N = 64) using Cronbach’s alpha. The alpha value for the 11 items was 0.77, which indicates acceptable scale reliability. We could have achieved no substantial increase in alpha for the scale by eliminating items. To examine RQ1c, we created a composite score for perceived learning by computing the mean of the eleven items in the scale. Table 8 presents descriptive statistics and the results of independent samples t-tests. As Table 8 shows, experimental group students reported significantly higher perceptions of learning than control group students.
Table 8. Perceived Learning Results

<table>
<thead>
<tr>
<th>Item</th>
<th>Control group (n = 32)</th>
<th>Experimental group (n = 32)</th>
<th>Test Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Improved communication skills</td>
<td>3.56</td>
<td>1.09</td>
<td>4.13</td>
</tr>
<tr>
<td>Online discussion decreased my learning quality</td>
<td>3.38</td>
<td>0.31</td>
<td>2.88</td>
</tr>
<tr>
<td>Learned great deal from peers</td>
<td>3.25</td>
<td>2.00</td>
<td>3.84</td>
</tr>
<tr>
<td>Improved integration skills</td>
<td>2.91</td>
<td>1.70</td>
<td>3.53</td>
</tr>
<tr>
<td>Most peers’ comments were not very valuable</td>
<td>3.38</td>
<td>0.48</td>
<td>2.97</td>
</tr>
<tr>
<td>Online discussion provided useful social interaction</td>
<td>3.22</td>
<td>1.21</td>
<td>3.81</td>
</tr>
<tr>
<td>Online discussion was useful to my learning</td>
<td>3.25</td>
<td>1.42</td>
<td>4.00</td>
</tr>
<tr>
<td>Learning quality was improved by online discussion</td>
<td>3.13</td>
<td>1.73</td>
<td>3.75</td>
</tr>
<tr>
<td>Provided a great chance to share opinions among peers and instructor</td>
<td>3.16</td>
<td>1.43</td>
<td>3.69</td>
</tr>
<tr>
<td>Broadened my knowledge</td>
<td>3.44</td>
<td>1.48</td>
<td>4.00</td>
</tr>
<tr>
<td>Improved generalization skills</td>
<td>3.00</td>
<td>1.61</td>
<td>3.63</td>
</tr>
<tr>
<td>Full composite scale</td>
<td>3.24</td>
<td>0.66</td>
<td>3.64</td>
</tr>
</tbody>
</table>

6.4 Knowledge Gain
To examine RQ1d, we conducted knowledge pre- and post-tests. To ensure we reliably analyzed the knowledge tests, the instructor together with three independent coders independently coded 20 randomly selected knowledge tests. The inter-rater reliability for the coding of these tests had a Krippendorff’s alpha coefficient of 0.87, which indicates very good inter-rater reliability. As the inter-rater reliability was very good, the three coders independently coded the rest of the knowledge tests. The Krippendorff’s alpha coefficient was 0.80, which indicates high reliability in the scoring of the knowledge tests. The disagreements among the coders mainly resulted from differences in semantic interpretations, and they resolved them via discussion. Table 9 provides the descriptive statistics and the results of independent samples t-tests. As Table 9 shows, we found no statistically significant difference between the control and experimental groups with regards to the pre-test. Hence, we found no reliable a priori difference between the two groups with respect to this important learning prerequisite. We computed knowledge gain scores by subtracting pre-test scores from post-test scores. The difference in knowledge gain scores was not statistically significant. This result suggests that the experimental group students did not gain a deeper understanding of the instructional topic after online discussions compared to the control group students.

Table 9. Perceived Learning Results

<table>
<thead>
<tr>
<th>Knowledge test</th>
<th>Control group (n = 32)</th>
<th>Experimental group (n = 32)</th>
<th>Test statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Pre-test</td>
<td>5.63</td>
<td>3.98</td>
<td>5.97</td>
</tr>
<tr>
<td>Post-test</td>
<td>8.97</td>
<td>3.52</td>
<td>9.69</td>
</tr>
<tr>
<td>Knowledge gain score</td>
<td>3.34</td>
<td>0.43</td>
<td>3.72</td>
</tr>
</tbody>
</table>

6.5 Learning Efficiency
To examine RQ1e, we used the following formula: $E = (Z_{\text{performance}} - Z_{\text{learning time}})/\sqrt{2}$. With regards to students’ learning task completion times, we found no significant difference between the control group and the experimental group. We transformed raw performance and task completion time data to z scores because they used different score scales. Table 10 presents descriptive statistics and the results of
independent samples t-tests. As Table 10 shows, experimental group students learned more efficiently than control group students.

<table>
<thead>
<tr>
<th>Depended variable</th>
<th>Control group (n = 32)</th>
<th>Experimental group (n = 32)</th>
<th>Test statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M  SD</td>
<td>M  SD</td>
<td>p value   Cohen's d</td>
</tr>
<tr>
<td>Task completion time (minutes)</td>
<td>103.25 41.22</td>
<td>87.94 27.64</td>
<td>0.09 0.44</td>
</tr>
<tr>
<td>Learning efficiency (based on z-scores)</td>
<td>8.97 3.52</td>
<td>9.69 2.03</td>
<td>0.01 0.63</td>
</tr>
</tbody>
</table>

While describing a relationship between software systems and learning efficiency results is valuable, we also need to understand what variables may account for the observed group differences in learning efficiency results (Fiedler, Schott, & Meiser, 2011). If the attention-guidance system in an anchored discussion tool aided the experimental group students, it may be because the system attracted, retained, and, when necessary, reacquired students’ attention on instructional materials’ central principles when they collaboratively processed academic literature. Furthermore, this association may describe why students in the experimental group learned more efficiently. Restated, online discussion message scores, task-oriented reading of instructional materials, and perceptions of learning may serve to mediate the relationship between software system and learning efficiency. The mediation analysis we report below was a post hoc test. Figure 3 depicts the mediation model.

Note: * indicates significance at the 0.05 level, ** indicates significance at the 0.01 level.

Figure 3. Mediation Diagram
To test the relationships and estimate all regression paths between variables in Figure 3, we used the PROCESS macro for SPSS (Hayes, 2012). To perform the mediation analyses, we followed the steps that Barron and Kenny (1986) recommend: 1) show that the independent variable influences the dependent variable, 2) show that the independent variable influences the mediator, 3) show that the mediator affects the dependent variable, 4) employ both the independent variable and mediator to influence the dependent variable. If the influence of the mediator is significant, but the influence of the independent variable is not, then the mediator fully mediates the influence of the independent variable on the dependent variable. However, if both the independent variable and mediator significantly affect the dependent variable, then this mediator partially mediates the influence of the independent variable on the dependent variable.

We performed multiple regression analyses to assess each component in Figure 3. For step one, we found that the attention-guidance system was positively associated with learning efficiency (B = 0.61, t(62) = 2.51, p = 0.01). For step two, we found that the attention-guidance system (as opposed to the control system) was positively related to posting exploring dissonance messages (B = 0.69, t(62) = 2.15, p = 0.04), negotiating meaning messages (B = 0.86, t(62) = 2.35, p = 0.02), task-oriented reading of instructional materials (B = 0.72, t(62) = 2.23, p = 0.03), and perceptions of learning (B = 0.44, t(62) = 2.03, p = 0.05). However, the attention-guidance system did not have a significant influence on posting sharing information messages (B = 0.15, t(62) = 1.07, p = 0.29). We had insufficient data to assess message scores for testing proposed synthesis and agreeing on new knowledge scores. Thus, we combined the messages scores for these two categories for the overall mediation model. The attention-guidance system did not have a significant influence on posting testing proposed synthesis and agreeing on new knowledge messages (B = 0.13, t(62) = 1.02, p = 0.31). As for step three, we found that posting negotiating meaning messages (B = 0.73, t(62) = 2.05, p = 0.04), task-oriented reading of instructional materials (B = 0.68, t(62) = 2.70, p = 0.01), and perceptions of learning (B = 0.37, t(62) = 2.29, p = 0.03) were positively associated with learning efficiency. However, posting sharing information messages did not have a significant effect on learning efficiency (B = 0.11, t(62) = 1.30, p = 0.20). Moreover, posting exploring dissonance messages did not have a significant effect on learning efficiency (B = 0.56, t(62) = 1.62, p = 0.11). Lastly, posting testing proposed synthesis and agreeing on new knowledge did not have a positive effect on learning efficiency (B = 0.06, t(62) = 0.95, p = 0.35). Based on these results, we tested mediation analyses using the bootstrapping method with bias-corrected confidence estimates (Preacher & Hayes, 2008; Hayes, 2009). In the present study, we obtained the 95 percent confidence interval of the indirect effects with 20,000 bootstrap resamples (Preacher & Hayes, 2008). As for step four, the results of the mediation analysis show that posting negotiating meaning messages (B = 0.63; CI = 0.22 to 0.31), task-oriented reading of instructional materials (B = 0.49; CI = 0.18 to 0.35), and perceptions of learning (B = 0.16; CI = 0.08 to 0.13) had a mediating role in the relationship between condition and learning efficiency. In addition, we found that the direct effect of the attention-guidance system on learning efficiency became non-significant (B = 0.25, t(62) = 0.96, p = 0.34) when controlling for the mediators, which suggests full mediation.

### 6.6 Control Variables

#### 6.6.1 Demographic Data

The experimental group had 14 females (i.e., 44%) and 18 males (i.e., 56%) and the control group had 15 females (i.e., 47%) and 17 males (i.e., 53%). The distribution of males and females between the groups did not differ significantly ($\chi^2(1, N = 64) = 0.06, p = 0.80$). The average GPA of the control group was 3.15 (SD = 0.43), while the experimental group had an average GPA of 3.12 (SD = 0.37). These average GPA values are close to the national average of 3.11 at American colleges and universities as Rojstaczer (2009) has estimated. An independent-samples t-test indicated no statistically significant difference between the control and experimental groups with regards to GPA ($t(62) = 0.30, p = 0.77, d = -0.07$). Moreover, we found no significant difference in prior experiences with guidance systems in the context of CSCL for the control group ($M = 1.41, SD = 0.50$) and the treatment group ($M = 1.31, SD = 0.47$); $t(62) = 0.44, p = 0.22, d = -0.20$. The Cronbach’s alpha coefficient for internal consistency was 0.80 for the entire computer self-efficacy scale. As Table 13 shows, computer self-efficacy did not differ between the two groups. Therefore, we can assume homogeneity of pre-experiment skills.
### Table 11. Perceived Learning Results

<table>
<thead>
<tr>
<th>Item</th>
<th>Control group (n = 32)</th>
<th>Experimental group (n = 32)</th>
<th>Test statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>I could complete the job using a software package…</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If there was no one around to tell me what to do as I go.</td>
<td>4.25 0.57</td>
<td>4.34 0.48</td>
<td>0.48 -0.17</td>
</tr>
<tr>
<td>If I had never used a package like it before.</td>
<td>4.50 0.51</td>
<td>4.44 0.50</td>
<td>0.62 0.12</td>
</tr>
<tr>
<td>If I had only the software manuals for reference.</td>
<td>4.41 0.50</td>
<td>4.38 0.49</td>
<td>0.80 0.06</td>
</tr>
<tr>
<td>If I had seen someone else using it before trying it myself.</td>
<td>4.28 0.68</td>
<td>4.41 0.56</td>
<td>0.42 -0.23</td>
</tr>
<tr>
<td>If I could call someone for help if I got stuck.</td>
<td>4.40 0.50</td>
<td>4.31 0.47</td>
<td>0.44 0.19</td>
</tr>
<tr>
<td>If someone else had helped me get started.</td>
<td>4.31 0.59</td>
<td>4.38 0.49</td>
<td>0.65 -0.11</td>
</tr>
<tr>
<td>If I had a lot of time to complete the job for which the software was provided.</td>
<td>4.41 0.50</td>
<td>4.38 0.55</td>
<td>0.81 0.06</td>
</tr>
<tr>
<td>If I had just the built-in help facility for assistance.</td>
<td>4.40 0.49</td>
<td>4.47 0.51</td>
<td>0.62 -0.13</td>
</tr>
<tr>
<td>If someone showed me how to do it first.</td>
<td>4.53 0.51</td>
<td>4.41 0.56</td>
<td>0.35 0.22</td>
</tr>
<tr>
<td>If I had used similar packages before this one to do the same job.</td>
<td>4.47 0.57</td>
<td>4.40 0.50</td>
<td>0.64 0.12</td>
</tr>
</tbody>
</table>

#### 6.6.2 Perceived Access

The Cronbach’s alpha coefficient for the two items was 0.86, which suggests that the items had adequate internal consistency. Table 13 presents descriptive statistics and the results of independent samples t-tests. As Table 13 shows, the perceived access control variable did not differ between the two groups.

### Table 12. Perceived Learning Results

<table>
<thead>
<tr>
<th>Item</th>
<th>Control group (n = 32)</th>
<th>Experimental group (n = 32)</th>
<th>Test Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>The anchored discussion system quickly loads all the text and graphics</td>
<td>5.38 0.94</td>
<td>5.15 0.72</td>
<td>0.33 -0.25</td>
</tr>
<tr>
<td>The anchored discussion system provides good access</td>
<td>5.50 0.76</td>
<td>5.34 0.83</td>
<td>0.43 -0.20</td>
</tr>
</tbody>
</table>

#### 6.6.3 Perceived Ease of Use

The Cronbach’s alpha coefficient for the four items was 0.75, which suggests that the items had adequate internal consistency. Table 14 presents descriptive statistics and the results of independent samples t-tests. As Table 14 shows, the perceived ease of use control variable did not differ between the two groups.

### Table 13. Perceived Ease of Use

<table>
<thead>
<tr>
<th>Item</th>
<th>Control group (n = 32)</th>
<th>Experimental group (n = 32)</th>
<th>Test statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>My interaction with the anchored discussion is clear and understandable</td>
<td>5.56 0.88</td>
<td>5.41 0.71</td>
<td>0.44 -0.20</td>
</tr>
<tr>
<td>Interacting with the anchored discussion system does not require a lot of mental effort</td>
<td>5.60 0.64</td>
<td>5.44 0.76</td>
<td>0.37 -0.23</td>
</tr>
<tr>
<td>I find the anchored discussion system to be easy to use</td>
<td>5.34 0.74</td>
<td>5.22 0.63</td>
<td>0.52 -0.17</td>
</tr>
<tr>
<td>I find it easy to get the anchored discussion system to do what I want to do</td>
<td>5.19 1.01</td>
<td>5.12 0.96</td>
<td>0.78 -0.07</td>
</tr>
</tbody>
</table>
6.6.4 Perceived Reliability

The Cronbach’s alpha coefficient for the two items was 0.83, which suggests that the items had adequate internal consistency. Table 15 presents descriptive statistics and the results of independent samples t-tests. As Table 15 shows, the perceived reliability control variable did not differ between the two groups.

<table>
<thead>
<tr>
<th>Item</th>
<th>Control group (n = 32)</th>
<th>Experimental group (n = 32)</th>
<th>Test Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>The anchored discussion system is stable</td>
<td>M: 5.31, SD: 0.93</td>
<td>M: 5.28, SD: 0.81</td>
<td>p value 0.89</td>
</tr>
<tr>
<td>The anchored discussion system operates reliably</td>
<td>M: 5.34, SD: 0.82</td>
<td>M: 5.31, SD: 0.83</td>
<td>Cohen’s d -0.04</td>
</tr>
</tbody>
</table>

Taken together, Tables 13, 14, and 15 indicate that users’ general perception of anchored discussion system’s quality did not differ between the groups.

7 Discussion

In this research, we examine the effectiveness of an attention-guidance system. We designed our attention-guidance system to attract, retain, and, if necessary, reacquire students’ attention on instructional materials’ central principles in document-based AODs. We now interpret our findings in light of the theoretical background and discuss their implications.

As for RQ1a, the results show that the attention-guidance system improved experimental group students’ scores for each scale item with the exception of the second item (i.e., “I try to get back on track when I lose concentration”). Given that academic research papers do not offer a visual aid that makes central ideas prominent, the experimental group’s online discussion genuinely knowledge management may explain this difference. Perhaps the key insight these exploring dissonance and negotiating meaning message scores offer to prior prescriptive knowledge is that experimental group students appropriated the attention-guidance system to recognize and revise one another’s misconceptions in order to address problems of understanding from instructional materials. Thus, in line with Peters and Hewitt (2010), we can consider the experimental group’s online discussion genuinely knowledge advancing. Two complementary explanations may explain this difference. First, as experimental group students read and re-read task-relevant information in text, they could think and act more like knowledge workers who can contribute and work innovatively with ideas. This interpretation coincides with prior research that shows task-oriented reading of instructional materials and online discussion message scores as theoretically interrelated.
constructs in the knowledge-creation metaphor of learning (Baker, 1999; Paavola & Hakkarainen, 2005; Wise et al., 2014). Based on this interpretation, Table 6 clearly indicates that difficulties that originated from task-oriented reading of instructional materials hindered the control group students from generating deep inquiries. While producing new diversified ideas is essential to collaborative literature processing just as biodiversity is essential to an ecosystem’s success, the lack of control group students’ elaborated responses to each other’s diversified ideas made it difficult for them to have a genuinely knowledge-advancing discussion. Stated succinctly, the control group students’ online discussion message scores reported in Table 6 support Scardamalia and Bereiter’s (2003) remark that, if a community is unaware of important information, then it cannot realize higher phases of knowledge construction. Second, the experimental group students’ mutually decided shared focus on trouble spots from text possibly prevented them from losing face as they discussed their own incomplete or erroneous ideas. Given that many studies demonstrate the fear of losing face constitutes one reason why students do not post online discussion messages coded as exploring dissonance and negotiating meaning (e.g., Golanics & Nussbaum, 2008; Jeong, 2013), this finding expands our understanding of how to improve the depth of knowledge building in Gunawardena et al.’s (1997) content-analysis instrument. However, an important caveat in this interpretation is that we did not measure students’ fear of losing face. Thus, this behavior may not generalize to other discussions. Future research clearly needs to further investigate this area.

Since learning, as Kirschner et al. (2004) note, is a complex, multidimensional construct that cannot adequately be measured with a single scale, we measured it in three different ways to portray a nuanced picture. As for RQ1c, we found that experimental group students reported significantly higher perceptions of learning than control group students.

Drawing on above-mentioned online discussion message scores, a possible explanation for this finding is that knowledge-advancing discourse satisfied the experimental group students’ need to understand instructional materials and feel accomplished. This finding contributes to existing research that shows a close relationship between learning and knowledge building (e.g., Baker, 1999; Jordan et al., 2014; Paavola & Hakkarainen, 2005; Wise et al., 2014) but also extends it to suggest that, if students have limited time to devote to online discussion, they would be better focusing on depth than breadth. However, as for RQ1d, we found that the difference in knowledge gain scores between the two groups was marginally significant and represented a medium effect size. Taken together, these learning outcomes contradict Lowe’s (2004) finding that attention guidance constrains students to process information in isolated ways without addressing the overall aspects of a learning task. A possible explanation for this contradiction is that our attention-guidance system provided students with the opportunity to adjust the font size of any text (i.e., paragraph, phrase, word, heading, subheading, and figure and table captions) in HTML-formatted instructional materials. We consider this opportunity as our instantiation artifact’s contribution to prior prescriptive knowledge because the experimental group students appropriated the attention-guidance system not only to pinpoint specific information they deemed important from text but also to process the text as a whole. From this perspective, our research adds to a small but growing body of empirical design science research that addresses issues related to designing CSCL systems.

The divergence of the results between RQ1c and RQ1d 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, we covered each instructional material 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’ awareness of their own misconceptions increased, they gradually allocated their attention in more favorable ways to fine-tune their understandings. This explanation supports Eryilmaz et al.’s (2015) findings that show how the quality of students’ online discussion message scores change across time when they recognize their own misconceptions. Hence, students in both groups reached the same level of gain in knowledge scores. Moreover, as for RQ1e, we found that the attention-guidance system improved experimental group students’ learning efficiency based on a moderate to high practical significance. Turning back to our theoretical background, this finding sheds light on the discrepancy in the learning effects of attention guidance. A potential explanation of this finding is that, while the control group students disengaged and re-engaged their attention to instructional materials’ central principles, experimental group students’ mutually decided shared focus reduced potential distractions and prevented irrelevant information from intruding into the learning task. We precisely sought to reduce this reduction in potential distractions with our attention-guidance system because students may miss crucial information as their attention ebbs and flows. In this vein, our instantiation artifact can serve as a model for others when developing similar systems that introduce assistance to students without destroying the exploratory and creative potential of
their collaborative literature processing. Thus, we consider our instantiation artifact’s relatively unobtrusive assistance to students as another contribution to prior prescriptive knowledge because inhibiting the exploratory and creative potential of students’ collaborative literature processing can easily result in students’ doing what they are told without learning anything important (for an overview, see Kim & Hannafin, 2011).

Lastly, as for RQ2, we found some evidence that suggests that task-oriented reading of instructional materials, negotiating meaning message posts, and perceptions of learning mediated the relationship between software system and learning efficiency. To explain this relationship, we refer back to Figure 3. First, the association between task-oriented reading of instructional materials and learning efficiency supports Gil et al.’s (2015) remark that the essence of task-oriented reading is the ability to read between the lines while making connections not explicitly stated in a text. This association theoretically makes sense because it could be more efficient for students who care about resolving their misconceptions about trouble spots to re-read selected paragraphs multiple times than re-reading text from the beginning. Second, the association between negotiating meaning message posts and learning efficiency advances our understanding of Gunawardena et al.’s (1997) content-analysis instrument by demonstrating that the act of posting negotiating meaning messages to resolve misconceptions benefits learning more than posting messages in other categories (i.e., sharing information, exploring dissonance, testing proposed synthesis, and agreeing on new knowledge). We consider this association as an important contribution to the current body of descriptive knowledge because, as Wise et al. (2014) stress, it is not always clear which student behaviors are most productive and should be encouraged in online discussions. Third, the association between students’ perceptions of learning and learning efficiency indicates that social constructivism can be an efficient practice in IS education when students have a positive perception of CSCL. This association supports Jordan et al.’s (2014) remark that positive attitude is favorable for learning because of its influence on learning efficiency, motives, and knowledge application.

Overall, our findings can help instructors to improve students’ collaboration skills as emphasized by not only the IS model curriculum (Topi et al., 2010) but also the curriculum recommendations for information technology (Lunt et al., 2009), computer science (Joint Task Force on Computing Curricula Association for Computing Machinery and IEEE Computer Society, 2013), computer engineering (Joint Task Group on Computer Engineering Curricula Association for Computing Machinery and IEEE Computer Society, 2016), and software engineering (Joint Task Force on Computing Curricula IEEE Computer Society Association for Computing Machinery, 2014). For example, instructors can emphasize to their students that, if they have limited time to devote to online discussion, they would be better focusing on depth than breadth. Furthermore, teachers can refer to our findings in order to determine which student behaviors are most productive and should be encouraged in online discussions. Students may then apply those behaviors to computer-supported collaborative work settings to perform virtual team projects successfully and as efficiently as possible. Furthermore, given our results, others can extend existing learning management systems with tools that help students not to overlook important information from instructional materials due to inattentive reading. Perhaps most importantly, in designing such tools, one should not destroy the exploratory and creative potential of collaborative literature processing that wikis, blogs, or social media facilitate. Based on this understanding, CSCL design science researchers can look at our attention-guidance system’s design characteristics to set up opportunities for instructors and students to share a role as co-constructors of knowledge instead of students who perceive instructors as the authoritative source that could restrict or foreclose a discussion thread.

As with any research, our study has several limitations, and readers should view our conclusions with them in mind. First, we did not use any process measures such as eye tracking during task-oriented reading of instructional materials. Consequently, we cannot comment, for instance, on how attention ebbs and flows throughout a learning task. The use of eye-tracking methodology could have prompted additional details of the processes that the students engaged in while completing the learning task. Second, 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. Thus, future research with a larger sample size could validate the results. However, an important problem with larger group sizes is information overload because the amount of time they have available limits the amount information students can absorb, organize, and comment. In fact, some research has reported students to skip reading 39 percent of all messages in an asynchronous online discussion (Qiu & McDougall, 2015). Hence, information overload can have deleterious influence on successful collaborative learning as students miss important information or in-depth discussions. In order to alleviate this problem, we are currently designing a recommender system that suggests to students the messages that their
peers have found most insightful from a range of perspectives. Third, given discrepancy in the existing literature concerning the learning effects of attention guidance, we designed a simple experiment to search for a link between attention guidance and learning. Now that we have found such a link indeed exists, future studies can further investigate the possible remediating effects of personal characteristics such as learning style, fear of losing face, and number of posts that a student reads in an online discussion when using the attention-guidance system for online collaborative literature processing.

8 Conclusion

Despite the addressed limitations, we take an important step forward in rigorously designing a CSCL system and evaluating its effectiveness for students’ online literature processing. The uniqueness of our findings follows from the fact that, to the best of our knowledge, this study is the only one that examines the effectiveness of an attention-guidance system in CSCL in the context of students’ online literature processing. In conclusion, we lay the groundwork for theorizing how to manage efficiency in learning from online conversations, which is particularly important for not only the IS model curriculum (Topi et al., 2010) but also the curriculum recommendations for information technology (Lunt et al., 2009), computer science (Joint Task Force on Computing Curricula Association for Computing Machinery and IEEE Computer Society, 2013), computer engineering (Joint Task Group on Computer Engineering Curricula Association for Computing Machinery and IEEE Computer Society, 2016), and software engineering (Joint Task Force on Computing Curricula IEEE Computer Society Association for Computing Machinery, 2014) because online communities facilitated by forums, blogs, and wikis have a wide-ranging impact on knowledge-intensive software development projects. We hope the conceptualization and empirical findings that we present in this paper stimulate researchers to expand and build on our line of reasoning.
References


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