Improving the quality of online discussion: the effects of strategies designed based on cognitive load theory principles

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This article focuses on heavy cognitive load as the reason for the lack of quality associated with conventional online discussion. Using the principles of cognitive load theory, four online discussion strategies were designed specifically aiming at reducing the discussants’ cognitive load and thus enhancing the quality of their online discussion. The results indicate that, compared to a conventional discussion strategy, the discussion quality was significantly enhanced for participants using example-posting strategy and limited-number-of-posting strategy. Cognitive load was significantly reduced for participants using filtered-posting and combination strategies. Instructional efficiency of all proposed strategies was found to be significantly better than conventional discussion strategy. The results are discussed and implications of the findings on instructional design application and future research are also presented.

Keywords: online discussion; discussion quality; cognitive load; instructional efficiency; online instructional design

Introduction

Online discussion, already a major instructional component of online instruction, has also become an important part of face-to-face courses complemented with online support. This pervasive use of online discussion has created a context for research on its effectiveness and contribution to online learning. Many studies have reported the lack of higher level cognitive processing in online discussion (e.g., Garrison, Anderson, & Archer, 2001; Gunawardena, Lowe, & Anderson, 1997; Schellens & Valcke, 2005; Sing & Khine, 2006). Higher level learning processes first identified and categorized in Bloom’s (1956) taxonomy were listed and reclassified by Krathwohl (2002) as the “statements of what we expect or intend students to learn” (p. 212). Krathwohl refers to higher level cognitive processing when learners demonstrate analysis, evaluation, and creation. The higher ranking of these categories are relative to the other three categories he listed as remembering, understanding, and applying. In this hierarchy, each level of learning is built upon and makes use of the preceding learning behaviors. According to this classification, discussants’ demonstration of analysis, evaluation, and creation in online discussion can be construed as an indication of their higher level cognitive processing.

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Conversely, discussants who do not break their ideas into units (analysis), do not make judgment about values and merits of their statement (evaluation), or do not put together elements to form a new whole (creation) are not demonstrating much of a higher level cognition.

Researchers have found that in unstructured conventional online discussion, where learners are prompted with discussion tasks, learners post messages mostly indicating their understanding of the topic and sharing and comparing information, all within the lower level learning categories according to Krathwohl’s (2002) taxonomy. For example, in the Garrison et al. (2001) study, where graduate students were engaged in online discussions intended to foster critical thinking, only approximately 13% of student postings exhibited construction of possible solutions (creation) and only 4% showed critical assessment of concepts and solutions (evaluation). In another study conducted by Gunawardena et al. (1997), practicing specialists and advanced students in the field of distance education discussed controversial issues of the role and importance of interaction in effective education. Although the goal of the discussion was to cocreate knowledge, about 93% (191 out of 206) of the posted messages exhibited only sharing and comparing of knowledge. Sing and Khine (2006) also reported an online discussion task where preservice teachers were assigned to discuss how to develop lesson plans; they were prompted to provide feedback on each other’s ideas and to suggest improvements of the discussed lesson plans. The authors found that 80% of discussants’ postings did not go beyond sharing and comparing information and verifying or identifying disagreements. In a study of undergraduate students working on solutions to real-life authentic cases and commenting on peers’ work on an online discussion board, Schellens and Valcke (2005) found that less than 3% of students’ postings exhibited high-level efforts of constructing or testing of new knowledge.

These studies reveal that lack of higher level learning was a frequently observed problem when the online discussants were prompted and were expected to demonstrate better quality online discussion indicating higher level learning. These findings elicit a concern about the ineffective use of online discussion and call for innovative discussion strategies that can improve learners’ cognition of the subject matter. Recognizing this need, we speculated that the problem may originate from the heavy extraneous cognitive load imposed on learners by the lack of structure and instructional strategies in conventional use of online discussion. We argue that in an online course where the instructor assigns an ill-structured discussion task by providing just a discussion prompt and expecting learners to participate in the discussion, a great amount of extraneous cognitive load is imposed on the learners. To perform this task, the learners spend a great amount of their cognitive resources just to figure out the context, requirements, strategies, and participation rules. As a result, they only post a simple response and do not engage in a higher level cognitive process required for a meaningful discussion.

Following this line of argument, we developed four discussion strategies according to the principles of cognitive load theory (CLT) (Chandler & Sweller, 1991; Paas, Renkl, & Sweller, 2003, 2004; Sweller, 1988; Sweller, van Merrienboer, & Paas, 1998), to address the issue and test the effectiveness of these strategies in an online course. Specifically, the study aimed to examine the effects of the CLT-based strategies on the quality of online discussion, learner’s cognitive load invested in the discussion tasks, and the instructional efficiency of the strategies.
Cognitive load in online discussion

When applied to instructional systems, CLT is concerned with techniques for managing the cognitive load of the learning task to an appropriate level to facilitate schema construction and automation in long-term memory. Simply stated, CLT assumes a cognitive architecture consisting of a working memory of limited capacity and a long-term memory of comparatively more or less unlimited capacity storing many schemas that vary in their degree of automation (Sweller et al., 1998).

In the early days of cognitive psychology, Miller (1956) documented that the amount of new information memorized and recalled by a person was more or less limited to seven items. Since then, the discussion of cognitive processing of new information and the function of working memory have evolved into a more complex discussion. Baddeley (1992) defined working memory as “a brain system that provides temporary storage and manipulation of the information necessary for performance of complex cognitive tasks” (p. 556). Ricker, AuBuchon, and Cowan (2010) argued that the term working memory has seen a variety of uses including being described as temporarily maintained information for the purpose of performing mental work or a “multi-component system” that maintains information temporarily and uses it for performing cognitive tasks. However, in their discussion of working memory, they refer to both the available information in mind at any given time and the process for maintaining that information.

Given these definitions about the function and processes of working memory, Melby-Lervåg and Hulme (2012) argued that performing working memory tasks involves not only maintaining the information in active memory but, at the same time, dealing with distracting activities which can be seen as limiting the person’s capability to access the stored information that is no longer the focus of attention. It is because of this limiting feature of distracting activities in instruction that CLT argues for a sound design and delivery of instruction so that the load does not exceed the limited cognitive ability of learners. According to CLT, performing a particular learning task imposes a cognitive load on the learner’s cognitive system (Paas & van Merrienboer, 1994a). This load originates from the complexity of the learning task (intrinsic load), inefficient instructional design (extraneous load), and the learner’s cognitive effort devoted to schema construction and automation (germane load). Following this framework and according to the documented function of working memory and its limitation in maintaining and manipulating new information, CLT argues that effective instruction should keep the extraneous load as low as possible, provide sufficient capacity for maximum germane load, and foster the learner’s schema constructions.

From this perspective, it seems worthwhile to examine the heavy cognitive load associated with conventional online discussion due to the inefficient presentation of discussion tasks (intrinsic load) and its weak structure, which imposes heavy extraneous load. As it is currently practiced, in many online educational settings, a conventional online discussion design provides learners with a discussion topic, some participation rubrics, and a discussion board that displays all the postings in threaded or timely formats. Learners are expected to understand the discussion topic, read others’ postings, process related information, and apply participation rules to contribute to the discussions. Other than processing the new elements in the information (e.g., new concepts or theoretical framework, new ideas, or opinions from peers) and the interactions among these new elements throughout the discussion (high intrinsic
load), learners have to spend a great amount of cognitive effort dealing with isolated postings displayed in different places on the discussion board while searching for appropriate processes to accomplish the complex discussion task (extraneous load). This loaded process is complicated by the fact that online discussion encourages increased participation (Ruberg, Moore, & Taylor, 1996), which generates a large number of student postings that a discussant is expected to read. The cognitive task in this situation, we argue, far exceeds the capacity of working memory according to the discussions we cited before. As a result, rather than using their cognitive capacity for handling the germane load of the learning task, the learners have to deal with extraneous activities (such as analysing and evaluating) to create the structure that has not been provided to them.

**CLT-based strategies**

To address these problems with conventional online discussion, we propose four discussion strategies based on CLT principles.

**Example-posting strategy**

The first strategy was designed to provide learners with proper examples of postings. The design of this strategy was inspired by the effectiveness of worked examples demonstrated in the CLT research literature. Worked examples have been reported to reduce extraneous load by directing the learner’s attention to learning material rather than spending cognitive resources on searching for appropriate steps (Cooper & Sweller, 1987; Darabi, Nelson, & Palanki, 2007; Sweller & Cooper, 1985). Similar to worked examples, example postings were meant to reduce extraneous load by demonstrating appropriate ways to perform the discussion tasks. Acknowledging the difference between the operational definition of example posting used in this study and of the worked examples examined in CLT literature, our rationale was that example postings might reduce intrinsic load by illustrating abstract relationships among concepts and the way new concepts relate to existing knowledge (schemas). Furthermore, example postings might direct learners to appropriate processes that are likely to lead to better learning by engaging them in imitating the structures of the example postings, situating their statements in their own contexts, and finding their own solutions.

**Filtered-posting strategy**

This strategy aimed at allowing the learners to see only the relevant postings. The purpose was to reduce the amount of extraneous load imposed on the discussants for cognition of information irrelevant to the topic. We managed to filter the postings so that the discussion board only displayed relevant and meaningful postings. The strategy was intended to reduce the extraneous load the learners invest on mentally holding relevant messages that are usually displayed in different pages or under different threads. The messages were temporarily placed on one page to reduce the interference of irrelevant information.

**Limited-number-of-posting strategy**

Considering the discussion of limited capacity and function of working memory presented above, this strategy was designed to limit the number of postings
displayed on each page of a discussion board. We presented the participants with no more than nine items on a page, the amount of new information seemingly sufficient for the limited capacity of human working memory. Here, the purpose was to enable learners to process the information on each page and not search multiple postings of a thread on multiple pages. We hypothesized that the strategy facilitates learners’ construction of new schemas, based on limited number of pieces of information before they move on to the next page of postings.

**Combined-discussion strategy**

As our last strategy, we combined the above three strategies into one. Including the two example postings, there were no more than nine messages on each page, and all the messages were filtered to be relevant to the current topic. Our rationale was that if each of the three strategies could reduce the learners’ cognitive load, the combination of all three would likely be more effective.

**Purpose and research questions**

The purpose of this study was to examine the effectiveness of the four proposed online discussion strategies on the learners’ quality of discussion and cognitive load. Two outcome variables were measured and compared to determine the strategies’ effectiveness: (1) the quality of discussion represented by learners’ demonstration of higher level cognitive processing of the issues and (2) the strategies’ instructional efficiency. Specifically, discussion quality was measured by the percentage of the statements indicating higher level processes in discussion postings. This was the proportion of the participants’ analysis, evaluation, and creation statements over their statements in all of Krathwohl (2002) categories. In other words, the higher the percentage of those statements, the better the learners’ ratings for the quality of their discussions.

Instructional efficiency represented an overall evaluation of the proposed discussion strategies. It was calculated based on both the discussion quality and the use of cognitive effort invested in the process. Discussants’ mental effort invested in the discussion task was used as an indication of their cognitive load as measured by the self-reported 9-point scale proposed by Paas, Tuovinen, Tabbers, and van Gerven (2003) and Paas, van Merrienboer, and Adam (1994). According to this measure, a well-designed instructional strategy, compared to an ill-designed one, should either produce higher quality discussion with a similar level of cognitive investment or retain the similar level quality with less cognitive effort.

The study was designed based on the following assumptions: heavy cognitive load associated with conventional discussion strategy hinders higher level online discussion, and; CLT-based strategies can reduce learners’ cognitive load and thus contribute to the quality of online discussion. Based on these assumptions the following research questions were investigated:

1. Compared to the conventional discussion strategy, does each of the CLT-based online discussion strategies enhance the quality of online discussion?
2. Compared to the conventional strategy, are any of the CLT-based discussion strategies more efficient instructionally as measured in terms of invested mental effort and exhibited quality of discussion?
We hypothesized that compared to the conventional discussion strategy, the CLT-based online discussion strategies would improve discussants’ quality of discussion because they reduce the cognitive load associated with the discussion tasks. Consequently, all the CLT-based discussion strategies would be more efficient than the conventional discussion strategy in terms of required mental effort and the quality of discussion.

Method

**Online learning environment and discussion task**

An undergraduate online course, Stress and Resilience in Families and Children, was used in this experimental study. The course offered a topic for online discussion each week of the semester and students received credits for participation. The course was delivered on the Blackboard learning management system (LMS). However, this LMS would not allow independent enrolment of the groups and execution of the discussion strategies as designed in this study. To overcome these limitations, the discussion task of the topic of interest was performed on a different system (described in the Procedures section).

The online discussion topic for the 13th week of the semester was selected for this study because of its complexity. It required participants to use the Family Distress Model (FDM) (Cornille & Boroto, 1992) and the Family Outreach Model (FOM) (Cornille, Meyer, Mullis, Mullis, & Boroto, 2008) to develop effective helping relationships with children and their families based on selected career paths. The discussion task was described as follows:

> When you think about your profession after you complete your education, what phase of the Family Distress Model best describes what the families you will encounter will be experiencing? What are the similarities or differences between your expectations and others in this discussion? Using the framework provided by the Family Outreach Model, describe how you might work most effectively with families in that phase.

> In reading the other participants’ thoughts, share with one another how your and their expectations are similar and different, and comment on how well other participants handled or interpreted their situations. Pay attention to some participants’ thoughts that might be wrong.

In the context of applying the prescribed models, this discussion task demanded lower level cognitive skills of remembering, understanding, and applying of the concepts as well as the higher level skills of analyzing the application situations, comparing, contrasting, evaluating the effectiveness of suggested processes (evaluation), and developing processes and solutions for new environments (creation).

**Participants**

A total of 59 undergraduate students who enrolled in this online class consented to participate in the study. All of the participants were in the third year or above in their program. A majority of the participants were in majors related to family studies. Only 2 of them were from outside of the Department of Family and Child Sciences, but both had taken classes in the field of Family and Child Studies. Thus, all the participants were considered to have similar prior knowledge of the subject.
As for experience on using online discussion tools, considering that all the participants had participated in online discussions in the 12 weeks before this study, we expected them to be equally experienced in using the online discussion board.

**Procedures**

Students were randomly assigned to one of five discussion groups according to the assigned discussion strategy: example-posting, filtered-posting, limited-number-of-postings, combination, and conventional group. As mentioned above, due to the limitations of Blackboard, week 13 discussion, the topic of interest in this study, was implemented on Moodle operated by Albert Ingram, a colleague at Kent State University. With permission, the authors created discussion forums for each of the five strategy groups on this Moodle site. As was required by the design of this study, discussants had access to only the group to which they were randomly assigned and the investigators were able to simulate presentation of the filtered and limited number of postings on each page. We had also the flexibility of access control for each participant, which was not offered by Blackboard in this procedural scheme.

Following this design, participants in each group had access only to their assigned discussion strategy and could not see other groups’ discussions. Students were required to (1) complete a survey to report their prior knowledge of the discussion topic and prior skills of using online discussion boards; (2) contribute to the discussion at least once during week 13; and (3) fill out the mental effort instrument right after they posted their discussion postings.

**Independent variable (discussion strategy)**

The independent variable was the type of instructional strategy used for the online discussion. Including the conventional way to conduct an online discussion, there were five strategies, each associated with one discussion group.

**Example-posting group**

For this group we provided two example postings along with the discussion topic. Drawn from the discussion task, the first example presented a profession and described a family with which this profession might work. The example analyzed the situation of the family using the FDM model and listed possible operations for working with this family. The second example (shown in the Appendix) referred to the characteristics of the family described in the first example and described another family that a different profession might encounter. It highlighted the differences between the conditions of the two families and evaluated how well the first posting handled the situation. Both example postings demonstrated how the discussion task might be conducted.

**Filtered-posting group**

Participants in this group used a discussion strategy that displayed only information relevant to the discussion topic. The irrelevant postings, such as a new thread in current thread or postings that did not contribute new ideas or new information to the discussion, were eliminated. Because none of the discussion boards in use
allowed users to filter messages (i.e., to choose which messages to display on the current screen and which not to), we simulated the discussion session for this group. First, we ran a pilot discussion on the same discussion task for some volunteer students other than the participants. Then we selected 10 messages from the pilot discussion and posted on the discussion board for the participants. As a result, each group member saw the 10 messages that seemed to be posted by other members of the group. Participants were then directed to join the discussion.

Limited-posting group
For this group we displayed a limited number of postings on each page of the discussion board. In order to provide the same condition for individual participants in this group, a simulated discussion forum containing preconstructed postings by students in a pilot discussion was created. A total of 14 discussion postings were displayed on two pages (seven postings and the discussion topic on page one, and seven postings and a reminder message on page two). This simulated a discussion that presented participants with a limited number of messages on each page. Participants were directed to read and process the messages on page one before they moved onto the next page.

Combination group
For this group we used a combination of these strategies. Example postings were provided in the form of two messages and a limited number of seven other postings were filtered for irrelevant information and then displayed for participants in this group. The total of nine postings were carefully constructed by the researchers (including the instructor of the course) to discuss aspects of the discussion topic; each brought in some new ideas, and none of them were irrelevant to the topic.

Conventional group
As the control group for this experiment, discussants were presented with the discussion topic and participation rubrics at the beginning of the week. As regularly practiced in online discussion, participants’ postings were displayed by threads and sequenced by the time they were posted under each thread. Participants could see postings under a certain thread or display all the postings (under all the threads) in one page in the discussion board. They could also scroll the screen up or down to view the postings.

Dependent variable
Discussion quality
Content analysis of discussion postings was used to measure the quality of the discussions. Krathwohl’s (2002) six categories of cognitive processes were used as indicators of discussion quality and coding guidelines. Table 1 illustrates the description and examples of each of the six categories.

To conduct the content analysis, each posting was segmented into meaningful units so that each unit could be assigned to only one of the Krathwohl’s (2002) six categories. A meaningful unit consists of a sentence or a group of sentences that
Table 1. Description and examples of quality of discussion categories.

<table>
<thead>
<tr>
<th>Learning</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember</td>
<td>Recall of specifics and universals, methods, processes, or a pattern, structure, or setting.</td>
<td>I want to be a news anchor, which would have me interacting families in four stages of the Family Distress Model: Predictable Patterns, Coping with Problems, Acute Crisis, and Crisis with Support.</td>
</tr>
<tr>
<td>Understand</td>
<td>The understanding of the materials or ideas being communicated.</td>
<td>I feel I will be a support system fighting for these children’s lives. Someone who can suggest the best possible result that is beneficial for the children coping from certain circumstances.</td>
</tr>
<tr>
<td>Apply</td>
<td>The use of abstractions in particular concrete situations.</td>
<td>However, dealing with the FOM, my situation would best be described in Phase Five. I will solve the issue through positive social support.</td>
</tr>
<tr>
<td>Analyze</td>
<td>The breakdown of an idea into its elements, to make clear their relative hierarchy, and make their relations explicit.</td>
<td>Phase Four in the FDM would best describe the situation because at this point they have been withdrawn from any potential social support, and the family has become preoccupied, I will be the resource speaking on the child’s behalf and well being.</td>
</tr>
<tr>
<td>Evaluate</td>
<td>Judgments about the merits of material and methods for given purposes.</td>
<td>I disagree with Student H, but agree with Student C. I feel that the family is dealing with the crisis in their own way at this point and do not need the help of others quite yet. Maybe eventually they will but you can’t assume that they are going to end up in phase 4.</td>
</tr>
<tr>
<td>Create</td>
<td>The process of working with pieces, parts, elements, etc., and arranging and combining them into new patterns or structures.</td>
<td>For instance, a husband and wife may be on the brink of divorce, after having tried to isolate themselves, and decided to seek social support as a last resort. At which point, it would be my job to give them directive advices as the sessions begin and once I noticed improvements on the part of the couple, I can collaborate on what does and does not work well for them as a couple, try and increase those desired behaviors and decrease the undesirable behavior that will lead to reconciliation.</td>
</tr>
</tbody>
</table>

indicate a demonstration of a learning behavior stated in Krathwohl’s taxonomy. The coauthor segmented the discussion postings into units and assigned them to the taxonomy categories. The classification was not a complex task due to the exclusivity of the categories. However, to validate this process, a portion of the discussion postings (10%) was randomly selected to be categorized by a second coder. Following a training session about categorization and segmentation of the postings, the second coder categorized the selected portion with a close to total agreement with
the first coder. The disagreements over a few items were resolved through discussion and consensus of the coders. The following formula was then used to measure the discussion quality (DQ) for each student. This percentage was the ratio of sum of the units coded into the three higher level categories of the Krathwohl’s taxonomy over the total number of units for all of six categories.

\[
DQ = \frac{N(\text{analysis}) + N(\text{evaluation}) + N(\text{creation})}{N(\text{units})}
\]

Based on this formula, the higher the DQ value, the higher the proportion of a posting exhibiting better quality. This calculation discounted longer postings that might contain more low level activities, such as reviewing the theory or explaining the terms. On the other hand, postings focusing on analyzing expected situations, evaluating peers’ work, and synthesizing ideas received higher scores.

**Instructional efficiency (E)**

In order to identify which one of the instructional strategies imposed less cognitive load in producing better quality postings, we applied the instructional efficiency calculation introduced by Paas and van Merrienboer (1993). As a component of this formula, we measured participants’ mental effort (ME) using the 9-point scale developed by Paas et al. (1994). Participants were requested to report level of mental effort they invested in composing a discussion message right after they posted that message. The internal consistency of this measure has been reported by several studies (de Croock & van Merrienboer, 2007; de Croock, van Merrienboer, & Paas, 1998; Paas & van Merrienboer, 1994b). Based on participants’ ratings on multiple tasks, the Cronbach’s coefficient alpha estimated ranged from .82 to .98 in these studies. The other component of the efficiency measure was the participant performance, which in this case was the quality of discussion posting. Here we used the DQ as it was described before. Both ME and DQ were standardized \((M = 0, SD = 1)\) and denoted as \(Z_i(ME)\) and \(Z_i(P)\). Instructional efficiency for each condition was calculated using the following formula:

\[
E = \frac{1}{n} \sum_{i=1}^{n} \frac{Z_i(P) - Z_i(ME)}{\sqrt{2}}
\]

Where:
- \(n\) is the number of participants in each group,
- \(Z_i(ME)\) is the standardized score of ME for student \(i\)
- \(Z_i(P)\) is the standardized score of DQ for student \(i\).

According to this calculation, for each instructional strategy, a higher \(E\) value indicates a more efficient instructional condition. A negative value of \(E\) associated with the situation that \(Z_i(P)\) was less than \(Z_i(ME)\), but it was not interpreted as negative outcome of the instructional condition.
Results

Of the 59 students, six were excluded from the analysis because five of them did not have any postings and one missed the mental effort survey. A further investigation of the exclusion did not reveal any pattern that might have affected the results of the study. The means and standard deviations of outcome variables across groups are reported in Table 2.

Following are the findings outlined by the research questions.

Research question 1: Compared to the conventional discussion strategy, does each of the CLT-based online discussion strategies enhance the quality of online discussion?

In comparison to the conventional group, participants in example-posting and limited-posting strategies exhibited significantly better quality postings indicated by showing higher level cognition processes in their statements: $t(18) = 1.73$ and $t(15) = 2.67$ respectively; $p = <.05$ (one-tailed) for both. However, this outcome was not observed for those who used filtered-posting strategy: $t(17) = 1.28$, $p = .11$ (one tailed); and combination strategy: $t(16) = .55$, $p = .29$ (one tailed).

Research question 2: Compared to the conventional strategy, are any of the CLT-based discussion strategies more efficient instructionally as measured in terms of invested mental effort and exhibited quality of discussion?

The analysis of the instructional efficiency for each strategy indicates that the conventional discussion strategy was the least efficient. All other four discussion strategies were found to be significantly more efficient than conventional discussion. In comparison to the conventional group, participants in example-posting and limited-posting strategies exhibited significantly better quality postings indicated by showing higher level cognition processes in their statements: $t(18) = 1.73$ and $t(15) = 2.67$ respectively; $p = < .05$ (one-tailed) for both. However, this outcome was not observed for those who used filtered-posting strategy: $t(17) = 1.28$, $p = .11$ (one tailed); and combination strategy: $t(16) = .55$, $p = .29$ (one tailed).

Discussion and conclusion

In this study, four CLT-based online discussion strategies were implemented in a 1-week-long online discussion. The underlining assumption was that cognitive overload, originating from unstructured and poorly designed strategies, hinders the conduct of a sound online discussion. We suggested that the CLT-based strategies would reduce cognitive load placed on the learners and thus facilitate their use of higher cognition processes and enhance their online discussion quality. The participants’ quality of discussion and the instructional efficiency of the strategies were compared with those of the discussion strategy that is commonly used in online instruction.

The results of the study partially confirm the hypothesis that the CLT-based online discussion strategies reduce the cognitive load of the discussion task and consequently enhance student discussion quality. Compared to the control group, example-posting users and limited-number-of-posting users exhibited better performance. This seems to confirm that the availability of the example posting facilitated the discussants’ engagement in the in the process and understanding the content. By
Table 2. Means and standard deviations of outcome variables across groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Filtered-posting ( (n = 13) )</th>
<th>Limited-number-of-posting ( (n = 12) )</th>
<th>Combination ( (n = 11) )</th>
<th>Conventional ( (n = 7) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>DQ</td>
<td>.64</td>
<td>(.33)</td>
<td>.58*</td>
<td>(.34)</td>
</tr>
<tr>
<td>E</td>
<td>.00*</td>
<td>(.47)</td>
<td>.35*</td>
<td>(1.07)</td>
</tr>
<tr>
<td>ME</td>
<td>6.54</td>
<td>(1.05)</td>
<td>5.75*</td>
<td>(1.42)</td>
</tr>
</tbody>
</table>

*Significantly different compared to conventional discussion group at .05 (one-tailed).
showing the learners an example of the appropriate steps and a flow of the process for a more focused discussion, the strategy seemed to have freed the cognitive resource the learners might have otherwise invested in searching for those steps to complete the discussion task. Using the example posting, the discussants had more cognitive capacity available for processing the content and contributing to a better quality discussion.

Similarly, limiting the number of postings on each page seems to have provided the right amount of new information to facilitate the construction of new schemas based on that information. This might have led to the reduction of the cognitive resources required for the discussants to hold the information that were spatially separated. Consequently, more cognitive capacity was available for processing the content and achieving better discussion quality.

The unexpected finding of this study is related to the use of filtered-posting and combination strategies. Discussants who used these two strategies did not exhibit better performance than their counterparts in the conventional group. In a post hoc analysis of the discussants’ mental effort invested in completing the discussion task, we found that the users of these two strategies reported significantly less mental effort than the users in the conventional group: $t(17) = 2.32$, $p < .05$ (one-tailed) and $t(16) = 2.25$, $p < .05$ (one-tailed), respectively. The users in the other two CLT-based strategies, example postings and limited postings, also reported a similar level of mental effort compared to conventional discussion strategy users: $t(18) = 1.28$, $p = .10$ (one-tailed) and $t(15) = 1.44$, $p = .09$. This indicates that the strategies for these groups also were effective in reducing cognitive load even though they did surpass the conventional discussion strategy in terms of discussion quality. These findings seem to be directly supporting our hypothesis that the CLT-based online discussion strategies would reduce the cognitive load of the discussion task.

Overall, the findings of this study indicate that the participants who used the CLT-based strategies reported lower mental effort and at least for the two strategies, example postings and limited postings, they also exhibited better quality of discussion. We found the results to be in accordance with the notion of cognitive load research. Cognitive load researchers point out that effective instructional design may reduce cognitive load while keeping the performance level constant, or, as a result of the cognitive load reduction, learners may achieve better performance without additional investment of cognitive resources (Chandler and Sweller, 1991; Sweller et al., 1998). The results of using these four strategies reflect this point. However, only two of the strategies, example-posting and limited-number-of-posting, seem to contribute to the discussion quality. It is worth the effort to replicate this study and further investigate the reasons for this occurrence.

Our investigation of the strategies’ instructional efficiency turned up similar results. All discussion strategies show better instructional efficiency than the conventional condition. Instructional efficiency describes the gain (quality of discussion) in terms of the cognitive load imposed on the learner. Our study shows that learners achieved better discussion quality with less cognitive load when they used CLT-based discussion strategies. The contribution of these strategies could be explained as follows. Example postings could reduce cognitive load by demonstrating appropriate ways to fulfill the discussion task and illustrating abstract relationships in contexts that are familiar to learners. Regarding the filtered-posting strategy, displaying relevant messages on one page might have been the key because learners therefore did not need to mentally hold relevant information while looking for other
pieces that were spatially separated. We think that the limited-number-of-posting strategy offered the information on each page at once and directed the learners’ attention to that information only so they could avoid the potentially overwhelming irrelevant information. The combination strategy also may have successfully eliminated irrelevant information and directed learners’ limited cognitive resources to the points that are important for learning.

We expected that the combination strategy would be more effective than the other three but this was not supported by the results. A possible explanation to this may be that example-posting strategy and filtered-posting strategy actually improve learning by increasing germane load and limited-number-of-posting strategy improves learning by reducing extraneous load. All four strategies may enhance discussion when they are used separately but do not do so when they are combined for they exceed the cognitive capacity of the learners by increasing germane load. This explanation needs to be tested in future studies.

The findings of this study have noteworthy implications for the design and use of online discussion. It is evident that learners will participate and contribute to online discussions when they are provided with well-designed structures that comply with principles of learning and instructional design theories. Based on our findings, the conventional discussion design fails to address learners’ limited working memory capacity, thus imposing a heavy cognitive load on learners. Providing learners with example postings or controlling what messages and how many messages are displayed on one screen will enable them to make better use of their cognitive resources. We suggest that instructors consider using the CLT-based strategies we tested in this study or develop other strategies for online discussions by referring to relevant theories and research findings.

Furthermore, instructors should pay attention to the context when they apply these CLT-based strategies in online discussions. Based on our findings, we have reason to hypothesize that example-posting strategy and limited-number-of-posting strategy are more likely to engage learners in the discussion process because learners in these two groups showed better quality of discussion and lower cognitive load. On the other hand, we think the filtered-posting and combination strategies are more likely to reduce the difficulty of the discussion task because the participants in these two groups reported less cognitive load even though they did not surpass others in terms of the quality of discussion. As a result, we suggest that instructors may consider providing example postings or limiting the number of postings on each page when the purpose is to ease the participants into a discussion session.

Few studies have applied CLT principles to online learning. Thus, we believe this investigation contributes to the research in this field. Our findings have implications for the design and development of online discussion tools. Functions of turning message on/off (which enables users to filter postings) and setting number of postings to be displayed on each page should be embedded in online discussion boards. Other functions that give users control of discussion board functions and accommodate users’ diverse needs will also be useful for instructional designers of online courses.

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References


Appendix. Example posting: My Goal.

By student B

My goal is to become an OB/GYN ultrasound technologist, so I will deal with families that will be experiencing a variety of different phases in the FDM. Typically I think that the new parents to be will experience a slight disruption in their predictable patterns and then they will be able to develop new predictable patterns for dealing with the pregnancy. I will provide these families with suggestions on what they should do, and provide them with resources that can facilitate their coping strategies, like some books, websites, and professional consultants. If the family is experiencing an unplanned pregnancy and they are overwhelmed by the disruption for a long time, then I will adjust my role to be more directive rather than collaborative because the family senses their inability to cope with the crisis.

The situations I will deal with are different from Student A. The family she talks about is in different phase as the situations I talked, and the outreach strategies we use are to be different too. The family in her case is doing well in dealing with the problem. We can provide supportive views of their family goals, but we do not provide them advice on how they should or need to act differently.