Using CTL-based Online Discussion Strategies to facilitate Higher Level Learning

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Background

Online discussion has become a major instructional component of face-to-face, online and blended instruction. It has been found to enhance students' learning by supporting social learning (Wells, 1992), mindfulness and reflection (Hiltz, 1994; Poole, 2000), and idea sharing and collaborative thinking (Ruberg, Moore, & Taylor, 1996). Scholars have reported student perceived learning to be correlated with the use of online discussion (Picciano, 1998, Jiang & Ting, 2000). Yet, lack of higher level learning (Bloom, 1956) in online discussion has been a drawback reported in many studies focusing on the effectiveness of this strategy (Garrison, Anderson, & Archer, 2001, Gunawardena, Lowe, & Anderson, 1997; Schellens & Vackle, 2005; Sing & Khine, 2006). Given the complexity of today's instructional and training tasks, the latest strategies used in face-to-face or online instruction should be designed to bring about all levels of learning.

Participating meaningfully in an online discussion is a complex cognitive task. In the conventional online discussion format currently used in higher education, learners are provided with a discussion topic and some participation rubrics before they are immersed in the assigned discussion task. They are then expected to apply the participation rules, read and respond to other participants' postings, figure out the interrelationships of materials being posted, deal with different styles in which the materials are presented, and finally cope with the technological problems that may arise during the discussion. Learners experience great amount of extraneous load within these activities, as well as germane and intrinsic cognitive load (Chandler & Seweller, 1991; Sweller, van Merrienboer, & Paas, 1998) presented by the instructional content of the discussion. Learners not only face new elements of information (e.g., the concepts, their theoretical framework, and identified information from other resources) that they need to learn, they also have to deal with the interactions among these new elements throughout the enumerated activities. Furthermore, as a result of encouraging participation in online discussion (Ruberg, Moore, & Taylor, 1996), a large number of postings are created by students in the same class. Ideally, individuals should read each other's posting, comment or reflect on them, and provide each other with responses. The cognitive resources needed in the process is far beyond the capacity of human working memory (Miller, 1956).

In the present study we investigated the effectiveness of several cognitive load theory (CLT)-based strategies in facilitating higher level learning in online discussion. These strategies have been designed to reduce learners' cognitive load in order to improve their learning performance. We applied these strategies in an online discussion and contrasted the outcomes with a conventional online discussion strategy. Following is a description of the online learning environment and the discussion tasks.

Online Learning Environment

An online course on Stress and Resilience in Families and Children was used in this experimental study. The course provided undergraduate majors in Family & Child Sciences with an introduction to family-based theories about the responses of children, adults, and families to stress. It examined ways of applying those theories to understanding the process of coping with stress and ways for professionals to intervene to help families in distress. The course objective was for the students to learn the techniques of working with families and children dealing with distress and supporting them in resolving the disruptions they were experiencing.

The Family Distress Model (FDM) was grounded in research on social support and family problem solving (Cornille & Boroto, 1992). Families, based on this model, will cope with distress, depending on whether the stressor is a crisis or "just a problem", following a predictable set of steps. The Family Outreach Model (FOM) was developed to identify specific strategies that persons can use to be supportive and effective when they form working relationships with families during times of distress (Cornille, Meyer, Mullis, Mullis, & Boroto 2008; Nalls, Mullis, Cornille, Mullis, & Jeter, 2009). This model grew out of the Family Distress Model and research about common factors of helping relationships (Hubble, Duncan, & Miller, 2002). In particular, the FOM links the stages of coping of families with the various styles and quality of helping relationships, suggesting the most effective style of helping relationship for each of the five stages, and strategies for using those specific styles.

For this experiment, we selected the topic of Working Professionally with Families in Distress. This topic was on the course agenda for the week of 13 of a 16 week semester and focused on students understanding how persons who work with families in a professional capacity, such as teachers or health care providers, can develop effective helping relationships with children and their families. During this week, the participants learned how the Family Outreach Model and Family Distress Model could be used to help both the child and their family deal with

problems if the students selected career paths such as teaching, counseling, or social work. The discussion topic used for this week was designed based on the content and purposes of the discussion:

> *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 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 other participants' thoughts, share with one another how your expectations are similar and different from theirs?*

Students participated in group discussions that were organized around one of four strategies.

Discussion Strategies

Strategy 1. Example-based postings

The use of example posting aims at reducing the intrinsic cognitive load of the discussion task and the mental effort required for searching of appropriate steps to fulfill the task. In a complex learning situation, the learners need to understand abstract relationships of the concepts and how the abstract concepts fit with the schemas they already have. They need to process the relationships among the elements and be able to process multiple elements as one (Sweller & Chandler, 1994). Based on the findings of numerous research conducted on the effectiveness of worked-out examples (i.e. Van Gog, 2006; Darabi, Nelson, and Palanki, 2007; Darabi, Sikorski, Nelson, and Palanki, 2006), we argue that an example-based posting that demonstrates what the learner is expected to do, reduces the intrinsic cognitive load involved in performing the task and frees the working memory capacity for higher cognitive activities, such as extracting new relations (analysis) and constructing new ideas (synthesis) (Bloom, 1956).

Generally, an example posting helps students to understand the abstract concepts and relationships embedded in complex learning tasks by illustrating what those concepts and relationships mean in a specific situation. It also demonstrates the processes of how the learning task could be fulfilled, including how to analyze the elements of a situation, form new ideas, and how to make judgment base on certain criteria. Consequently, the learners' attention is directed to the relations between relevant materials and relevant steps, which is similar to what a worked example (Sweller & Cooper, 1985, van Merrienboer & Sweller, 2005) would do. We contend that example postings reduce cognitive load by reducing irrelevant tasks, thus make the working memory available for activities fostering higher level learning.

Strategy 2. Filtering messages

Filtering message is a strategy that allows posting relevant messages together rather than scattering them around in a discussion board. Most of the discussion boards currently in use display messages under threads. It is very common that not all the messages contribute to the discussion threads. Often time a student will find only several of classmates' postings make sense and he or she would not need all the information to form a good understanding of what is being discussed. In fact the non-relevant postings, we argue, may be distractive and thus causing extraneous mental load learners. By using filtering messages strategy, a user will be able to choose only the relevant messages to be displayed on his current screen. The messages irrelevant to current task will not be deleted and can be retrieved later for other tasks. By doing so, learner's cognitive resource is concentrating on holding and processing relevant elements rather than irrelevant ones.

Strategy 3. Limited number of postings on each page

This strategy limits the number of postings on each page of discussion board to 7 ± 2 (Miller (1956). The popular online discussion boards nowadays (e.g., BlackBorad, WebCT Vista, and Moodle) display more than 20 messages on each page by default. If all of the 20 messages provide new information, they will obviously exceed learner's working-memory capacity and thus leave no extra cognitive capacity for processing abstract relationships of the 20 messages. Facing this cognitive overload, we argue, learners are not likely to achieve higher level learning. The design of limiting number of postings on each page of the discussion board is to break the new information into smaller chunks that hold no more than 7 ± 2 elements. So that students are able to preprocess the limited pieces of information before they move on to next chunk.

Strategy 4. Combination Strategy

This strategy combines the above three strategies of example posting, filtering messages, and limiting number of posting on each page. The messages are related to the current topic and include new ideas (no irrelevant messages) and there are no more than 7 ± 2 messages on each page. Using this strategy, the users should presumably be able to reduce the cognitive capacity needed for understanding the discussion task and save the cognitive resource for searching of appropriate problem solving processes. The users' attention should be focused on relevant elements because irrelevant messages are filtered out and the number of message is limited to less than 9 including example posting.

Research Questions and Hypotheses

Our research questions are: (1) Does each of the CLT-based online discussion strategies reduce cognitive load placed on learners compared to conventional discussion board? Which is the most effective? (2) Does each of the CLT-based online discussion strategies enhance higher level learning compared to conventional discussion board? Which is the most effective? (3) Does each of the CLT-based online discussion strategies enhance students' performance on quiz? (4) Which discussion strategy is the most efficient in terms of mental effort invested and learning outcome?

Assuming that cognitive overload is one reason for lack of higher level learning in online discussion, these strategies were designed to reduce cognitive load and therefore assist them with processing discussion content more efficiently for achieving higher level learning. Given the principles of CLT, We hypothesized that compared to the conventional method of online discussion, each of the proposed discussion strategies will result in: (1) a decrease in learners' cognitive load; and (2) an increase in the amount of higher level learning.

Method

Participants

Fifty nine undergraduate students enrolled in an online class in a large university in southeastern United States participated in the study. Six were eliminated from the study (reasons stated in the next session). The course offered an online discussion topic each week and students received credits for participation in online discussions. The majority of the participants were in majors related to family studies. Only two were from outside of the College of Human Sciences. All the participants were considered to have the similar pre-knowledge level of the subject. All of the participants were in at least the 3rd year in their program. As to experience of online discussion tools, nine out of 53 had not taken any online class before. Considering that all the participants had used online discussion for the 12 weeks before this study was conducted, we expected them to be equally experienced in using online discussion board.

Procedures of the study

The students were randomly assigned to one of five discussion groups: Example posting group, Filtered postings group, Limited number of postings group, Combination group, or Conventional group. All groups used the same discussion topic but different discussion strategies. Participants had access only to their assigned discussion group and were not able to see other groups' discussion.

Before the project began, it was approved by the Institutional Review Board for human subjects. Students gave their consent to participate in this study. They were asked to: (1) participate in the discussion at least once during week 13; (2) report their mental effort level right after they posted their postings for that week's discussion; and (3) take a quiz at the end of the week. Six of the 59 students were excluded from the analysis because each of them had missed at least one of the tasks. Other than completion of a course assignment, no additional incentives were provided.

Five groups

Example postings group: This group used a discussion forum with example postings. Two postings were presented to the group together with the discussion topic. The first example posting presented a profession and described a family with which this profession might work. It analyzed the situation of the family using the FDM model and listed possible operations suggested by FOM model for working with the same family. The second posting, described another family that a different profession might encounter and referred to the characteristics of family described in posting 1. It derives the abstract relationships between the conditions of the two families, and evaluated how posting 1 handled the situation. The participants in this group could construct their postings by referring to the scenarios provided in the two example postings and other participants' postings.

Filtered postings group: Participants in this group used a discussion strategy that only allows displaying information relevant to the discussion topic. The irrelevant postings were eliminated. Because none of the currently in use discussion boards has the function that allows the users to filter messages, we used a simulation for this group. We filtered and posted 10 messages in a simulated discussion board. Each actual participant saw 10 messages that seemed posted by 7 other students. Each participant saw the filtered content, but they could not see each other's postings. This ensured that the information each participant saw was identical.

Limited number of postings group: For this group we used a discussion forum that had limited number of postings on each page. In order to provide the same condition for participants in this group, a simulated discussion forum that contained pre-constructed postings by "fake" students were used. There were 14 discussion postings displayed in two pages (7 postings and the discussion topic on page 1 and 7 postings and a reminder messages on page 2). A note on Page 2 instructed participants how to go back to page 1 and how to link to the mental effort

measure. This simulated a discussion board that contained no more than 9 messages on each page. Participants were expected to read the messages on page 1 and process them before they move onto page 2.

Combination group: For this group a combination of the three strategies (example posting + filtered message + limited number of message) was used. In addition to the discussion topic, 9 messages were displayed for these participants. The messages were carefully constructed by the researchers (including the instructor of the course) to discuss a new aspect of the discussion topic. Two of the 9 messages were example postings.

Conventional group: As our control group, participants used a conventional discussion board strategy. They were presented with the discussion topic at the beginning of the week. Participants could see each other's posting and were expected to read other's messages to find the similarities and differences and develop their own reflection on the topic.

Measures

Higher Level Learning

Content analysis of the discussion postings was used to measure levels of learning. Bloom's (1956) six levels of learning were used as coding categories. They are knowledge, comprehension, application, analysis, synthesis, and evaluation, from low level to high level. To conduct content analysis, each posting was divided into meaning units so that each unit was coded into only one category. The primary author coded all the units according to the categories. A second coder was trained and asked to code a sample of postings (three postings) randomly selected from the data. There was 100% agreement between the coders.

The following formula was used to calculate the percentage of higher level learning (PHL) for each posting. This percentage is the ratio of sum of the units coded as three higher levels of learning over the total number of units for all of six levels of learning. The higher the PHL value, the more percentage of higher level learning presented in a posting.

$$\text{PHL}=\frac{N(analysis)+N(synthesis)+N(evaluation)}{N(all)}$$

Mental effort level

Participants were requested to report the level of mental effort they invested in composing a discussion message. Mental effort is measured using 9-scale instrument developed by Paas, Van Merrienboer, and Adam (1994). 9 is the highest level of mental effort, 1 is the lowest level of mental effort.

Quiz score

All the participants took an online quiz at the end of Week 13. The quiz was designed to test the students' knowledge and understanding of the content discussed during this week. It consisted of 10 multiple choice questions. The participants' score on this quiz was calculated as part of their final scores of the course.

Instructional efficiency

In order to identify which instructional condition is the most efficient in terms of less demand on mental effort and greater learning outcome, instructional efficiency (E) is calculated based on the formula suggested by Paas and van Merrienboer (1993). Mental effort level is standardized and denoted as Z(ME). Standardized score of higher level learning (Z(P)) was derived at by using the learners percentage of higher level learning as their performance scores and then instructional efficiency for each strategy was calculated using the following formula:

$$E=\frac{Z(P)-Z(ME)}{\sqrt{2}}$$

Results

Strategies and mental effort

A calculation of mean mental effort reported by participants in each group revealed that the participants using the conventional strategy reported the highest mental effort level (M=7.14, SD=0.900). Compared to the conventional strategy group, the lowest mental effort exerted on the discussion of the topic was reported by the participants using the filtered posting strategy (M=5.75, SD=1.422). This was 19.5% lower mental effort than that of the conventional group. This was followed by the group using combination of the three strategies that reported 13.45% lower mental effort (M=6.18, SD=0.87). The group provided with limited number of postings on each page experienced medium level of mental effort (M=6.30, SD=1.337) and the participants in example posting strategy reported the least decrease in their mental effort (M=6.54, SD=1.05)

Higher level learning

The results of content analysis of the discussion postings with regard to higher level learning shows that participants in control group using the conventional strategy of discussion posting indicated the smallest proportion of higher level learning (38.1%). Learners in limited number of posting strategy indicated the highest proportion of higher level learning (72.5%). Participants in example, filtered, and combination strategy groups displayed better percentages (64%, 58.0%, and 48.3%, respectively) of higher level learning compared to the participants using the conventional strategy.

A One-way ANOVA test of group differences indicated significant difference between limited and conventional groups at .05 level ($t=2.50$, $p=0.03$). A significant difference was also found between example and conventional group at .10 level ($t=1.78$, $p=0.10$). According to the results of this examination, although participants in filtered and combination strategies outperformed conventional group, the differences were not significant.

The analysis of learners' performance on the quiz showed no difference across strategies. The quiz scores were found to be are positively skewed, with the range between 0 and 100 (100 is the highest possible score), mean of 74.3. The mean scores for participants in different strategies were as follows: Example group ($M=65.4$, $SD=25.0$), filtered group ($M=77.5$, $SD=12.2$), limited group ($M=76.0$, $SD=12.7$), combination group ($M=77.3$, $SD=28.0$), and finally the conventional group ($M=74.3$, $SD=15.7$).

Instructional efficiency

The analysis of the instructional efficiency data for each strategy, calculated according to the formula discussed earlier, indicated that the conventional discussion board was the least efficient ($E=-.89$). The filtered messages strategy was found to have the highest efficiency score ($E=0.35$) followed by the limited number of postings strategy ($E=0.32$). No instructional efficiency for example postings strategy was indicated ($E=0.00$). The combination strategy showed the lowest instructional efficiency (-.1094) among interventions right next to the conventional discussion strategy. A one-way ANOVA test of differences indicates that all of the four experimental conditions had significantly higher instructional efficiency comparing to conventional condition at .05 level.

Discussion

The results of this study clearly indicated that learners in conventional discussion group faced a heavy cognitive load placed by discussion task. Presumably the learners in online discussion processed part of the task and failed to perceive the latent relations and constructs of the materials which we contend was the reason for not achieving a higher level learning. Compared to the conventional group, participants in experimental groups reported lower level of mental effort indicating the success of our discussion strategies in reducing learners' cognitive load. The example postings strategy provided users with connections between their existing schema produced by their prior knowledge and new abstract concepts and relations. Moreover, example postings, we contend demonstrated processes for performing the task which directed the learners' attention to latent relations and relevant solutions. Similarly, filtered message strategy saved the cognitive resources needed to integrate relevant elements usually scattered around in discussion board. Limited number of posting strategy on each page broke the learning materials into several chunks of smaller size limited to working memory capacity to avoid overload.

We expected that the strategy of combining the three experimental strategies would reduce cognitive load at least as much of the most successful individual discussion strategy. The results showed the combination condition reduced cognitive load by 13.45%, second to our more successful strategy, filtered message strategy (19.5%). Then the question became why the filtered messages strategy, when combined with other strategies, lost some of its impact in reducing the cognitive load while we expected more than when it was offered individually. One can argue that the fact that this successful strategy was combined with two others (example and filtered strategies) might have created a redundancy effect of strategies which lead to their combined lower effectiveness. They seemingly placed heavier cognitive load because (1) each of the two example postings, and each of the seven filtered messages contributed new information which participants might have perceived important for the task and (2) example postings were different from other messages in nature since they included instructor comments requiring more cognitive capacity. Compared example postings group, combination group had more elements to handle and compared to groups using filtered messages and limited number of messages, the combination group needed to handle messages different in nature.

Another area of examination in this study was the impact of these strategies on the learners' acquisition of higher level learning. Our content analysis results indicated higher scores for our discussion strategies in terms of this acquisition when compared with the conventional discussion method. Learners using the example postings and limited number of postings strategies demonstrated significant gains over their counterparts in conventional group. The filtered messages group had smaller gain. The group using the combination of the three strategies produced the least improvement in acquisition of higher level learning.

Test scores have been regarded as measurements of performance. But no difference has been found in quiz score across groups in this study. Quiz score was not a good measurement in this situation because the online

multiple-choice quiz tested students' lower level learning skills: recall of facts, understanding and ability to apply learned theory in given scenarios. Higher level learning was not the outcome for measure in the quiz, also higher level learning was not easy to be measured in multiple-choice quiz.

We also examined the instructional efficiency for the experimental strategies used in this investigation. According to the results of our analysis, we found our experimental conditions to be significantly more efficient than conventional discussion board at .05 level. These findings indicated that the discussion boards embedded with each of the four strategies will enhance students' learning with a lower level of mental effort.

To sum up the findings of this study, we propose that the experimental strategies used in this study, compared to the more conventional method of online discussion, are more effective in terms of enhancing students' gain in higher level learning. Because they were purposefully designed according to the CLT principles, they require less mental effort in part of learners using these strategies in their discussion of the online topics. Consequently, the strategies were found to be instructionally efficient in this learning environment.

These findings have some implications for designing and developing instruction and training materials. Designers should make an effort to reduce learners' cognitive load through the use of innovative strategies so that provide the learners with the opportunities for better performance. It seems that freeing some of the learner's mental capacity from extraneous load, usually imposed by not desirable instruction, will result in higher achievements of learning. It also appears that as a result of this cognitive capacity that is freed by appropriate instructional strategy, the learners will have a chance for integrating, synthesizing, and evaluating the new information which lead to the higher level learning.

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