Using CLT-Based Online Discussion Strategies to Facilitate and Higher Level Learning

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Abstract

Because the limitation of human cognitive capacity, cognitive overload is assumed to be a reason for lack of higher level learning in online discussion. Three online discussion strategies -- providing example postings, filtering messages, and limiting number of postings on each page -- are designed to reduce cognitive load placed on learner so as to enhance learning. The groups use each of the experimental strategies and the group use combination of the three strategies reported reduced cognitive load in composing discussion postings compared to a control group using conventional discussion board. The four experimental groups showed higher percentage of higher level learning in their discussion postings than control group. Instructional efficiency of each of the four experimental groups is significantly higher than control group. Quiz scores did not show any correlation with any of the treatment conditions. The combination of the three strategies is the least effective in enhancing higher level learning.

1. Background

1.1. Lack of high level learning in online discussion

Online discussion has been used in face-to-face, online and blended classes. On one hand, online discussion has been found useful in enhancing students' learning by supporting social learning (Wells, 1992), mindfulness and reflection (Hiltz, 1994; Poole, 2000), and idea sharing and collaborative thinking (Ruberg, Moore, and Taylor, 1996). Student perceived learning has been reported to be correlated with the use of online discussion (Picciano, 1998, Jiang & Ting, 2000). On the other hand, lack of higher level learning presented in online discussion has been a problem reported in many studies (Garrison, Anderson, & Archer, 2001, Gunawardena, Lowe, & Anderson, 1997; Schellens & Vackle, 2005; Sing & Khine, 2006).

Higher level learning, as defined in Bloom (1956), is behaviors demonstrating analysis (breaking down into elements), synthesis (putting together elements to form a new whole), and evaluation (making judgment about the value) of materials. In contrast to higher level learning, lower level learning is showing knowledge (recall of methods, processes, patterns, structures or settings), comprehension (knowing what is being communicated), and application (use of abstractions).The six levels of learning are hierarchically ordered, each level of learning is built upon and making use of the learning behaviors found in the levels lower than it. According to the "Committee of College and University Examiners" (Bloom, 1956), "all educational objectives" (all of the six levels of learning objectives) should be included in American education (p.30).

Although anticipated as results of educational activities, higher level learning has not been achieved satisfactorily. Content analysis of online discussion postings (Garrison, et al., 2001, Gunawardena, et al.,1997; Schellens, et al., 2005; Sing, et al., 2006) has

revealed that most of student postings are showing understanding, sharing and comparing information, which are lower levels of learning in Bloom's (1956) terminology of cognition. In a study conducted by Gunawardena, Lowe and Anderson (1997), about 93% (191 out of 206) of the messages in an online discussion were sharing and comparing of knowledge. Sing and Khine (2006) also reported that 80% of the online discussion they studied were sharing and comparing information, seeking verification and identifying disagreement. Romeo (2001) found that among the 930 online discussion messages she analyzed, only 17 showed summarizing efforts (less than 2%), but the students were merely summarizing the information they read (analysis), there did not appear to be much reflective thinking (evaluation).

1.2. Heavy cognitive load in online discussion

Participants in online discussion face heavy cognitive load from multiple sources: the discussion task, the participation criteria (such as restraints), other participants' postings, interactions between materials, and the formats how these materials are presented. Some of the cognitive loads are intrinsic because of the nature of the materials; some are extraneous because of the manners the materials being presented (Sweller, van Merrienboer, & Paas, 1998).

1.2.1. Cognitive load placed by discussion task

For a common design of online discussion used in higher education, a discussion topic and some participation rubrics (such as what types of message should be posted) are used to direct the learners' activities. These materials can expose heavy intrinsic cognitive load on learners, especially when they are associated with complex tasks intending to trigger high level learning. In order to construct a discussion posting that achieves higher level cognition (for example, synthesis), a student should be able to hold several elements, including the concepts and theory framework mentioned or related to the discussion topic and identified information from other resources, in working memory at a time. Also, the interactions among these elements (e.g., similarities and differences between these elements) should be realized and held in the learner's working memory as well. When the student's working memory can't handle the heavy cognitive load, the learning procedure reduces the cognitive load but at the expense of higher level learning.

1.2.2. Cognitive load placed by searching for appropriate solutions for fulfilling the task

According to CLT (Sweller & Cooper,1985; Cooper & Sweller, 1987; and Sweller, van Merrienboer, & Paas, 1998), the searching for appropriate processes to solve the problem requests large capacity of working memory. When learners invest much of their working memory in searching for appropriate steps to fulfill the task, they might end up with less learning of the content because that reduces the working memory available for the learning task and they will learn only part of the materials (Chandler & Sweller, 1991). Leaving the novice learners alone in searching for appropriate solutions is less effective in comparing with alternative approaches such as providing learners with worked examples illustrating solutions to problems (van Gerven, Paas, Merrienboer, & Schmidt, 2002; Paas, 1992).

1.2.3. Cognitive load place by large number of materials

Online discussion encourages increased participation (Ruberg, Moore, & Taylor, 1996). As a result, which is also anticipated, 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, provide each other with responses. Researchers (Shea, Swan, Fredericksen, & Pickett) also found correlation between frequency of participation in online discussion and students' perceived interaction, and students perceived higher level of interaction also reported higher levels of learning. Imagining a class of 20 students, each post 2 messages each week, each student will have at least 10-20 messages to read. Plus the discussion topic, and the participation rubrics, the number of materials need processing is in far more excess of the limitation of human working memory, which is suggested as 7+-2 (Miller, 1956).

1.2.4. Cognitive load placed by integrating materials distributed in space

In order for high level learning to occur, students should process information from multiple resources to analyze them, find the abstract relationships, combine them into a new whole, or make judgment about their value. According to Chandler and Sweller (1991), the structure of learning materials could direct learners' cognitive resources toward activities irrelevant to learning when the interactive learning materials are separately displayed. Extra mental effort should be invested in integrating the materials to make learning (especially high level learning) occur. When the capacity of working memory cannot handle the heavy cognitive load of integrating learning materials in addition to understanding the learning materials, the learners will not be able to learn the interaction among separated information, or fail to understand the learning materials, both will end up with lack of higher level learning.

1.3. CLT-based strategies facilitating higher level learning in online discussion

A variety of strategies have been utilized to facilitate higher level learning in online discussion. The use of small groups (Schellens & Vackle, 2006), questioning techniques(Gerber, Scott, Clements, & Sarama, 2005; Chen, Wei, Wu, & Uden, 2009;), and constrained debates all have been reported being effective in enhancing student learning (Jeong & Joung, 2007, Kobbe, Weinberger, Dillenbourg, Harrer, Hamalainen, & Fischer, 2007). This study investigates the strategies facilitating higher level learning in online discussion from a different approach—to reduce cognitive load placed on learners. The following strategies are designed to reduce the intrinsic and extraneous load: providing example postings, limiting number of postings on each page, filtering messages, and combination of these three strategies.

1.3.1. Providing example postings

The use of example posting aims to reduce the intrinsic cognitive load in understanding the discussion task and the mental effort for searching of appropriate steps to fulfill the task. Successful understanding of the task is essential for achieving high level learning. When the learning task is complex, the learners need to understand abstract relationships and concepts. If the learners understand the task very well before conducting the task,

they will have ideas about how the abstract concepts are interpreted by materials they already familiar with, and how the relationships among the elements can be processed, as well as how multiple elements can be processed as one (Sweller & Chandler, 1994). The intrinsic cognitive load of conducting the task will be lower for these learners because their understanding of the task frees the working memory capacity for higher cognitive activities, such as extracting new relations (synthesis) or referring to outside criteria (evaluation).

The example posting in this study demonstrates how to use the models learned in this class to analyze the families a specific profession will encounter, how to identify the characteristics of these family, how to derive similarity/difference relations among the families encountered in several professions, how to propose a set of operations based on the models learned and a specific profession expectation, and how to evaluate peers' responses. An example posting helps students to understand the abstract concepts and relationships embedded in complex learning tasks by illustrating what they mean in a specific phenomenon. Secondly, an example posting demonstrates the processes how the learning task could be fulfilled, including how to identify the elements of a specific phenomenon in terms of the new knowledge (analysis), how to put together elements from multiple sources to form a new whole (synthesis), such as a new abstract relation or a implementation plan, and how to make judgment base on the criteria (evaluation). The learners' attention is shifted to the relations between relevant materials and relevant solution steps (Sweller & Cooper, 1985, van Merrienboer & Sweller, 2005), which is similar to what a worked example would do. Example postings reduce cognitive load by reducing irrelevant tasks, thus make the working memory available for activities fostering higher level learning.

1.3.2. Filtering messages

Filtering message is a strategy that allows placing relevant messages together to save the mental effort otherwise needed in integrating relevant messages scattered around in discussion board. Most of the currently in use discussion board display all the messages under each thread, either the full message or the subject line. It is very common that not all the messages contribute to the learning task the learner is fulfilling. Often time a student will find only several of his classmates' postings make sense to him, and he would not need all the information to construct a very good reflection. By using filtering message function, a user will be able to choose specific messages to be displayed on his current screen. The messages irrelevant to current task will not be deleted and may be retrieved later for other tasks. By doing so, his cognitive resource is concentrating on holding and processing relevant elements rather than irrelevant ones.

1.3.3. Limiting number of postings on each page

The third strategy designed in this study is limiting the number of postings on each page of discussion board to 7+-2. The mostly used online discussion boards nowadays (BlackBorad, WebCT Vista, and Moodle) display more than 20 messages in each page by default. If all of the 20 messages provide new information, they will obviously exceed learner's working-memory capacity, not to say extra cognitive capacity is needed to

process the abstract relationships of the 20 messages. In facing the cognitive overload, learners are not likely to achieve higher level learning.

Miller (1956) suggests 7 +-2 elements to be the human judgment limitation when there is only one dimension of stimuli, like text-based online discussion. When the learners face new elements their working memory cannot handle at one time, they either fail to learn or learn part of the task by ignoring some of the elements. The design of limiting number of postings on each page in discussion board is to break the discussion into chunks of 7+-2 pieces of information. Students are expected to process the 7+-2 pieces of information in one page before they move on to the information on next page.

1.3.4. Combination of example posting, filtering message, and limiting number of posting on each page

The combination of the three strategies is a discussion board that has example postings, all the messages are related to the current topic and brings new ideas, (no irrelevant messages), and there are no more than 9 messages on each page. In practice, the first page of the discussion will contain example postings and no more than 7 postings by other participants, the second page contains no more than 9 postings by others.

If all of the three strategies can reduce cognitive load as expected, then the combination of the three strategies should work better in reducing cognitive load. The users of the combination group should 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 also be focused on relevant elements because irrelevant messages are not displayed. The number of message, including the example posting and others' postings, is limited to less than 9 (7+2) to avoid overload.

1.4. Hypotheses and research questions

Based on the assumption that cognitive overload is one reason for lack of higher level learning in online discussion, this study examines the effects of using experimental discussion boards embedded with the following strategies: (1) example postings, (2) filtered messages, (3) limited number of posting in each page, and (4) a combination of these three strategies, on learning outcome, specifically on the higher levels of learning presented in online discussion postings. These strategies are designed to reduce the cognitive load placed on learners, which are expected to increase the cognitive capacity available to processing materials in achieving higher level learning.

If the assumed cognitive overload is true, the learners should report less mental effort being invested in discussions using these strategies comparing to conventional discussion. If the assumption that cognitive overload is a reason for lack of higher level learning in online discussion is true, the learners should achieve better learning in experimental discussion boards. When learning is assessed by percentage of higher level learning presented in discussion postings, learners using experimental discussion boards should achieve higher percentage of higher level learning compared to conventional discussion

board. When learning is assessed by test scores, learners in experimental discussion boards should perform better than conventional discussion board users.

Given the principles of CLT, We hypothesize that (1) inclusion of each of the three discussion strategies reduces cognitive load placed on learners; (2) inclusion of each of the three discussion strategies enhance learning; (3) inclusion of the three structures in one discussion condition will produce a better result in reducing cognitive load and enhancing learning.

Our research questions are:

(1) Will these strategies reduce cognitive load placed on learners compared to conventional discussion board? Which condition is the most effective?

(2) Will these strategies enhance learning compared to conventional discussion board? Which condition is the most effective?

(3) Which condition is the most efficient in terms of mental effort invested and learning outcome?

2. Method

2.1. Participants and discussion topic

The participants are 59 undergraduate students in a large university in southeastern United States. They enrolled in an online class in Spring, 2009. The class has an online discussion topic on BlackBoard each week during the 15 weeks of the semester. Participants receive credits for participation in each week's online discussion. Participants are directed to participate in an online discussion for the week of 13 in a set of different discussion forums hosted in Moodle which applied different strategies in each of the forums. All the students in this class gave their consent to participate in this study. They are asked to (1) fill up a survey of prior knowledge level; (2) participate in the discussion at least once during week of 13; (3) report their mental effort level right after they post their postings for week 13 discussion; and (4) take a quiz at the end of week 13 on the same content as this week's discussion. Six of the 59 students are excluded from the study because each of them has missed at least one of the four tasks.

Associated with the application of Cognitive Load Theory, learners' level of expertise has been reported to be a factor that influences cognitive demands on working memory. Learners' levels of expertise are the distinctions between novice and expert learners in their knowledge of the subject matter and the processes to fulfill the learning task. The same learning task may post less cognitive load on expert learners than on novice learners (Tuovinen & Sweller, 1999, Sweller, et al., 1985). Learners' level of expertise in online discussion relates to aspects other than the learning content-- the learners' expertise level of using online discussion tool (the technology). Clarke, Ayres, and Sweller (2005) suggested that learners' prior knowledge level of the technology had impacts on the intrinsic cognitive load because the technology would have interactivity with the subject matter content. In this study, we survey students' prior knowledge of the content as well

as experience of using online discussion tool prior to this class. See Appendix A for prior knowledge survey.

The results showed that majority of the participants were in majors related to family studies. Only 2 were from outside of the College of human science. All of the participants were in at least the 3rd year in their program. These indicate that majority of the participants have good prior knowledge of the discussion topic. As to experience of online discussion tools, 9 out of 53 have not taken any online class before. But they all reported having good skills of using computer and internet. Considering the fact that all the participants have used online discussion for the 12 weeks before the experimental study conducted, we do not expect any difference the prior experience and skills of using the technology (online discussion board) will make any difference on cognitive load and their learning outcomes. As a result, level of expertise is not considered as a factor influencing learning outcomes in this study.

The discussion topic was the same for all the groups:

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

2.2. Design of the study

The students were randomly assigned to five discussion groups. They used the same discussion topic but different discussion boards. A participant can see his/her assigned discussion board but cannot see other groups' discussion board.

2.2.1. Group 1 – Provided with example postings

Group 1 uses a discussion forum that has example postings. Two postings are presented to the group together with the discussion topic. The first posting presents a profession and describes a family this profession might work with. It analyzes the situation of the family with the FDM model and lists possible operations to work with this family suggested by FOM model. The second posting is an example posting. It analyzes an expected family her profession might encounter with the framework of FDM and FOM models. It also refers to the characteristics of family described in posting 1, derivates abstract relationships between the two families, and comments on how good posting 1 handles the situation with supporting reasons. The participants in this group can construct their posting based on the scenarios provided in the two sample postings, as well as other participants' postings. See Figure 1 for the screen shot of discussion board with example postings used in Group 1.

2.2.2. Group 2 – Provided with filtered postings

Participants in group 2 use a discussion forum that displays only relevant information to the discussion task. The postings that are not relevant to the discussion topic, such as a new thread posted in current thread, and postings not contributing to current discussion task, such as agree or not agree postings, have been eliminated. Because the current features of the either BlackBoard nor Moodle would allow the users to filter messages, i.e., choose what to display on current screen and what not to, the discussion forum used for this group is set up by the researchers as a simulation of the filtering function. The discussion topic and 10 messages posted by 7 students are presented to each participant in this group. (See Appendix B for the layout of this forum). These 7 students are not real participants of this study; their postings are constructed by the researchers including the instructor of this class. Each of the 10 postings contains some new points or ideas to the discussion topic. This simulates the situation that the participant is a member of a group of more than 8 people (which is the case for our study, each group has 8-12 people), and by the time he participate in the discussion, 7 of the group members have posted their messages, some of them are having a discussion about a point they don't agree upon. Each participant in group 2 see the same content, but they can't see each other's posting. This is to make sure all the information each participant see is identical and is "filtered". Each participant is expected to read all of the 10 postings, and refer to his professional expectations and the two models to find the similarities and differences compared with others' profession expectations, and come up with a suggestions what he would do to help his customers or evaluate how good other participants' comments and suggestions are. The number of postings is set to 10 in order to exceed 7+-2 limitation.

2.2.3. Group 3 – Provided with limited number of postings on each page

Participants in group 3 use a discussion forum that has limited number of postings in each page. In order to control the condition to be the same for every participant in this group, fake students and pre-constructed postings are used to set the discussion forum (Appendix C). There are 14 discussion postings displayed in two pages. There are 7 postings and the discussion topic on page 1. On page 2, there are 7 postings and a reminder message explaining how to go back to page 1 and a link to the mental effort survey. This simulates a discussion board of which each page contains no more than 7+2 messages. Participants are expected to read the messages on page 1 and process them before they move onto page 2. Each participant in this group see the same contents but can't see each other's posting.

2.2.4. Group 4 – Provided with combination of three strategies

For group 4, a combination of the three strategies (example posting + filtered message + limited number of message on each page) is used. 9 messages are displayed for group 4, other than the discussion topic. All of the 9 messages are carefully constructed by the researchers (including the instructor of the class). Each of the messages brings in a new aspect of the discussion topic. 1 of the 9 messages is an example posting with researchers' comments on why this is a good posting. In contrast, another message is commented by the researchers as a not-good posting but contributes new points to the discussion.

2.2.5. Group 5 – Control group

Participants in group 5 use a conventional discussion board design. They are presented with the discussion topic at the beginning of the week. Each of the participants in group 5 can see each other's posting and is expected to read other's messages to find the similarities and differences and develop own reflection on the topic.

2.3. Measurements

2.3.1. Levels of learning

Content analysis of the discussion postings is used to measure levels of learning. Bloom's (1956) six levels of learning are used as coding categories. Table 1 illustrates the explanations of each of the six categories. The Postings are split into units so that each unit is coded into only one category.

Table 1

Six Levels of Learning

Level of learning	Description	Example
Knowledge	The recall of specifics and universals, the recall of methods and processes, or the recall of a pattern, structure, or setting.	They will either in stage 5, in which they will be seeking for social support, or stage 4, in which they will withdraw from potential social support.
Comprehension	The understanding of the materials or ideas being communicated.	I will include scenes of how the family communicate with others in their social network…anything that disturbs the routings and patterns of the family to cause major distress.
Application	The use of abstractions in particular and concrete situations.	I believe I have a calm disposition to help implement a health plan and return the patient back to a better stage of the distress model than they were at before.
Analysis	The breakdown of a communication into its constituent elements or parts such that the relative hierarchy of ideas is made clear and/or the relations between the ideas expressed are made explicit.	I feel that the students will be in stage 2 of the FDM because they are struggling with what they want to do in the future so they are trying to find out what's right for them.
Synthesis	The process of working with pieces, parts, elements, etcl, and arranging and combining them in such a way as to	The situations I will deal with are similar to that of Student A's in that we will both be dealing with families dealing

	constitute a pattern or structures not clearly there before.	with crises and helping them to work through the crisis.
Evaluation	Judgments about the value of material and methods for given purposes.	One thing is that the student did not take into account that they will be dealing with a much broader range of families. For instance, the student who wants to be physician assistant will not always be assisting families that are experiencing a crisis, so he may not need to provide directive assistance.

Inter-rater reliability

A second rater is invited to code the postings to check the inter-rater reliability of the instrument. The underlining rationale is that if a rater without any knowledge of the content of discussion and without any experience of coding starts to learn the coding protocol and code the data, the higher the second rater can reach agreement with the primary coder, the better reliability is the analysis instrument.

In this study, the second rater is a second year college student (major in engineering) who has no knowledge about family studies. This rater has no experience of content analysis studies. The primary coder trained the second coder for 30 minutes. The second coder then was asked to code three postings randomly selected from the data. The results of the second rater reach 100% agreement with the primary coders. This is a sign of good reliability of the coding protocol.

Percentage of higher level learning (P) is the rate between sum of units of three higher level learning and the number of units for all of six levels of learning.

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

The higher the P value, the more percentage of higher level learning presented in a posting. Although it is reasonable to use the number of units of higher level learning instead of percentage of higher level learning, we decided to use the percentage because the intention of the online discussion was to encourage higher level learning rather than longer posting. Especially, long posting contains more low level learning activities, such as reviewing the theory or explaining the terms, is not encouraged. On the contrary, postings focusing on analyzing expected situations, deriving operational procedures, and commenting on peers' work get higher scores.

2.3.2. Mental effort level

Participants are requested to report the level of mental effort they invested in composing a discussion message after they post that 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.

2.3.3. 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 consists of 10 multiple choice questions. The participants' score on this quiz will be calculated as part of their final scores of the course.

2.3.4. 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 is calculated based on the formula suggested by Paas and van Merrienboer (1993). Mental effort level is standardized and denoted as Z(ME). Standardized percentage of higher level learning (Z(P)) is used as performance score for each participant. Instructional efficiency (E) is calculated as:

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

Among the instructional conditions P and ME are standardized, the higher the E value, the more efficient the instructional condition is. A negative value of E associated with the situation that P is less than ME, but it is not interpreted as negative outcome of the instructional condition.

3. Results

3.1. Experimental conditions reduced cognitive load placed on learners

Mental effort level reported by participants in each group were averaged and summarized in Table 2. The control group reported the highest mental effort level (M=7.14, SD=0.900). The group using discussion board with filtered message reported the lowest mental effort level (M=5.75, SD=1.422), which is almost 20% lower than control group. The other three group reported mental effort levels lower than control group but higher than filtered message group. Group 1 (provided with example postings) reported the lease decrease in mental effort level (M=6.54, SD=1.050) compared to control group. Group 3 (provided with limited number of postings on each page) experienced medium level of mental effort (M=6.30, SD=1.337) relative to other groups. Group 4, which used the combination of the three strategies, reported 13.45% lower on mental effort compared to control group, but 4% higher than the group using filtered messages.

Table 2
Mental Effort Level by Group

Group	No. of Participant	Mental Effort Level[a]	SD	% of Reduction[b]
1	13	6.54	1.050	8.4
2	12	5.75	1.422	19.5

3	10	6.30	1.337	11.8
4	11	6.18	0.874	13.45
5	7	7.14	0.900	-

Note. The higher the score, the greater the mental effort level.
[a]Mean of mental effort levels of each group.
[b]Compared to Group 5.

3.2. Experimental conditions enhanced higher level learning but did not make any difference on quiz score

Content analysis results of the percentage of higher level learning presented in discussion postings are summarized in Table 3. Control group indicated the smallest proportion of higher level learning (38.1%), and Group 3 indicated the highest proportion of higher level learning (72.5%). Group 1, Group 2 and Group 4 presented better percentage (64%, 58.0%, and 48.3%, respectively) of higher level learning compared to control group, but less improvement than Group 3.

Table 3
Contrast of Higher Level Learning across Groups

		Levene's Test for Equality of Variances		ANOVA Test[a]			
Group	% of Higher Level Learning	F	Sig.	t	df	Sig. (2-tailed)	Std. Error
1	64.0	0.108	.746	1.772	18	0.100	.149
2	58.0	0.071	.793	1.321	17	0.218	.156
3	72.5	1.294	.273	2.503	15	0.019	.131
4	48.3	1.168	.296	0.594	16	0.590	.186
5	38.1	-	-	-	-	-	-

[a]Compared to Group 5.

One-way ANOVA test of group difference indicated significant difference between Group 3 and Group 5 at .05 level (t=2.503, p=0.029). Significant difference also found between Group 1 and Group 5 at .10 level (t=1.772, p=0.099). Although Group 2 and Group 4 over performed conventional group, the differences are not significant.
No difference was found in quiz score across groups. The quiz scores are positively skewed, with the range between 0 and 100, mean of 74.3. Mean of quiz score for Group 1 is 65.4, SD=25.0, Group2 is 77.5, SD=12.2, Group 3 is 76.0, SD=12.7, Group 4 is 77.3, SD=28.0, Group 5 is 74.3, SD=15.7.

3.3. Experimental conditions are more efficient than conventional group

Conventional discussion board has the lowest instructional efficiency value (-.8926) compared to other groups. Instructional efficiency is the highest in discussion boards with filtered message (0.3494) and limited number of postings (0.3217). Instructional efficiency for discussion board with example postings is close to 0 (0.0032). The combination of the three strategies ends up with least improvement on instructional efficiency (-.1094) comparing to conventional discussion condition.

Table 4

Contrast of Instructional Efficiency across Groups

Group	Instructional Efficiency	ANOVA Test[a,b]	
		t	Sig. (2-tailed)
1	0.0032	4.067	0.001
2	0.3494	3.474	0.003
3	0.3217	3.322	0.005
4	-.1094	2.567	0.020
5	-.8926	-	-

aDon't assume equal variances.
[b]Compared to Group 5.

One-way ANOVA test of group differences indicates that all of the four experimental conditions significantly improved instructional efficiency comparing to conventional condition at .05 level.

4. Discussions

In this study, four experimental conditions have been used in online discussion board to reduce cognitive load placed on learners and thus enhance higher level learning. A conventional condition has been used as control group. Five groups of students discussed the same topic in five different online discussion boards: one was provided with example postings, the second was presented with filtered messages, the third had limited number of postings on each page, the fourth used the combination of the three strategies, and the fifth used a conventional discussion board. Perceived cognitive load, learning outcome (percentage of higher level learning), and instruction efficiency of the four experimental conditions were compared to conventional condition. Experimental conditions reduced cognitive load perceived by users and enhanced higher level learning. The results supported our assumption that cognitive overload in online discussion inhibited higher level learning. The instruction efficiency has been significantly improved by using the strategies.

4.1. Conventional discussion board posts heavy cognitive load on learners, the experimental conditions reduced perceived cognitive load.

The results clearly support the assumption that cognitive overload is a reason for lack of higher level learning in online discussion. Cognitive load measured as perceived mental effort level was higher in conventional discussion board than in experimental conditions. Learning outcome measured as percentage of higher level learning was the lowest in conventional condition. This confirms our assumption that cognitive overload in conventional discussion prevented learners from achieving higher level learning.

Learners in conventional discussion board face the heavy cognitive load placed by discussion task, large number of elements (such as other participants' postings), interactions between materials, and the distractions caused by layout of the materials. In dealing with the heavy cognitive load, learners in online discussion may process part of

the task, or fail to perceive the latent relations and constructs of the materials. In neither case will they achieve higher level learning.

Participants in experimental groups reported lower level of mental effort compared to conventional group. This indicates that the three strategies reduced the cognitive load in each condition. The example postings provided users with connections between their prior knowledge and new abstract concepts and relations. Less cognitive capacity was needed in understanding the task. Other than that, example postings also demonstrate processes to fulfill the task, which will direct the learners' attention to latent relations and relevant solutions to the task. Filtered message saved the cognitive resource needed to integrate relevant elements scattered around in discussion board. Limited number of posting on each page broke the learning materials into several chunks of smaller size. The size of each chunk was limited to working memory capacity to avoid overload.

Filtered message strategy is the most effective condition which reduced cognitive load by 19.5% compared to conventional discussion board. This indicates that placing relevant materials together can reduce cognitive load effectively. Most of the currently in use discussion boards display all the postings published. Same contents are displayed to every user. Individual user can not "switch off" the messages that are not necessary for current task. The filtering message function is very useful in making efficient use of limited cognitive resource. We recommend program designers to include this option in new versions of discussion board.

Providing of example postings reduced cognitive load by 8.4% compared to conventional discussion board. Example postings were designed to reduce the intrinsic cognitive load of the discussion task and the cognitive capacity needed for searching of appropriate processes to fulfill the task. The result shows that example postings can reduce cognitive load, but not as much as filtered message can. A possible explanation for this is that the discussion task is not very hard for the participants in this study, thus the cognitive load needed is not very high, the possible reduction is also not much.

Limiting the number of postings on each page reduced cognitive load by 11.8% compared to conventional discussion board. This improvement is appealing in magnitude. But one problem observed in this condition is that almost no participant in this group reviewed contents on the second page. The reduction of cognitive load is at the cost of skipping some the elements.

We were expecting the combination of the three strategies would reduce cognitive load the greatest, but the results showed the combination condition reduced cognitive load by 13.45%, second to filtered message condition. Why did the filtered message strategy function less effective when it was combined with other strategies? One reason we found was that the inclusion of example postings and the seven filtered messages in this discussion board actually placed heavier cognitive load than the conditions of using each of them. This is because (1) each of the two example postings, and each of the seven filtered messages contributed new information, participants might have perceived all the messages to be important for the task so that they would not skip any of them; (2) example postings were different from other messages in nature since they included instructor comments, more cognitive capacity may be needed to handle elements different

in nature than handle one type of messages. Compared to group using example postings, combination group needed to handle more elements. Compared to groups using filtered messages and limited number of messages, combination group needed to handle messages different in nature. Considering all these factors, the combination of the three strategies did not reduce cognitive load as effective as expected.

4.2. The experimental conditions enhanced higher level learning, but had no effect on quiz score.

Content analysis results showed that percentage of higher level learning in experimental conditions were higher than that of conventional condition. The group used example postings and the group used limited number of postings on each page indicated significant improvement. The group presented with filtered messages gained less improvement on learning compared to groups used other two strategies. The results of mental effort level survey indicated that the filtered-message group made less effort in constructing their postings since this group reported greatest decrease (19.5% less than the conventional group). Self-reported mental effort level reflects not only the cognitive load the instructional condition placed on the learners, but also the efforts invested by learners in the learning process.

The group used combination of the three strategies unexpectedly produced the least improvement in enhancing higher level learning. The other three experimental conditions supported our hypotheses that each of them could reduce cognitive load, and less cognitive load could improve learning. Theoretically, the combination of the three strategies should reduce cognitive load more effectively than each of them, and improve learning more than each of the strategies could. One reason is that, as we analyzed earlier in 4.2, the combination condition might have placed heavier cognitive load on learners than other experimental conditions. The other reason is, combination group put less effort in constructing their postings because they reported great reduction on mental effort level, only second to filter-message group.

According to Paas, et al. (1993), the higher the mental effort invested, the better the performance. This is consistent with our result when the when the cognitive load does not exceed the learner's cognitive capacity. The two experimental groups reported higher perceived cognitive load over-performed the two experimental groups reported less cognitive load. The conventional group performed the worst while they reported the highest cognitive load because they faced cognitive overload.

Test scores have been regarded as measurements of performance. But no difference has been found in quiz score across groups in this study. This is the same results as … Quiz score is not a good measurement in this situation because the online multiple-choice quiz tests students' lower level learning skills: recall of facts, understanding and ability to apply learned theory in given scenarios. Higher level learning is not the outcome for measure in the quiz, also higher level learning is not easy to be measured in multiple-choice quiz.

4.3. Conventional discussion board is the lowest in instructional efficiency

The results of instruction efficiency indicated how learners' mental effort had been efficiently used in performance (Paas, et al., 1993). With the same level of mental effort, a learner performs better in an efficient instructional condition than he does in a less efficient condition. The instruction efficiency of four experimental conditions were significantly higher than conventional discussion board at .05 level.

The instructional efficiency in this study is a measurement of how much better a user can perform in one instructional condition (discussion board) than he can in other conditions if he uses the same mental effort. Since instructional efficiency is calculated based on the mental effort in constructing the posting and the quality of the posting, this performance difference is the difference of the quality of his posting. In other words, discussion boards embedded with each of the three strategies will enhance students' learning when they use the same level of mental effort. Higher instructional efficiency can also be interpreted as for the same level of learning outcome, less mental effort is needed compared to a condition with lower instructional efficiency. A student will invest less mental effort for the same level of learning in the experimental conditions than he will in a conventional condition.

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