Effect of using peer tutoring to support knowledge sharing in Learning Networks: A cognitive load perspective

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Abstract

In Learning Networks, learners need to acquire knowledge through knowledge sharing with other participants. However, without support, learners have to self-organize knowledge sharing by finding a relevant knowledge sharer, structuring the interaction and maintaining the communication process. According to cognitive load theory, these activities could induce extraneous load because they are not directly relevant to learning itself but to the learning environment. When working on complex tasks, extraneous load becomes detrimental to learning effectiveness and efficiency because learners have to simultaneously deal with the high intrinsic load of the complex tasks and the extraneous load of knowledge sharing activities. For such tasks, it is considered imperative to reduce extraneous load and we used a peer tutoring system to support knowledge sharing by matching learners together, providing role specifications and an interactional tool of wiki. This study investigated the effect of using this peer tutoring system to support knowledge sharing on different levels of task complexity in the Learning Network of Internet Basics. Based upon cognitive load theory, an interaction effect was expected that peer tutoring would reduce extraneous load and result in better learning effectiveness and efficiency only on complex tasks. In addition, we expected that using peer tutoring would result in better knowledge sharing on complex tasks. However, these hypotheses were not confirmed because of the limited number of knowledge sharing inquiries: this indicated that the peer tutoring support was not used sufficiently to have effects on cognitive load, learning effectiveness and efficiency. The major contributions of this study were i) we explored the effect of using different supports of knowledge sharing on humans' cognitive system in a non-formal Learning Network by applying cognitive load theory, ii) we showed the challenges of data collection, especially for measuring cognitive load in such learning environments.

Introduction

Learning Networks (LNs) are a particular kind of online social network designed to support self-directed lifelong learners in a particular domain. They comprise groups of people who use learning resources to learn at the place, time and pace that suits them best (Koper et al., 2005; Sloep, 2009). Within our notion of a LN, learners have to take responsibilities to organize their own learning activities to acquire knowledge from others to achieve their personalised learning goals (Kester et al., 2007). During the learning process, it is likely that learners in LNs have the same needs of formal learners: they need to share and construct knowledge through interaction with others. In formal learning settings, this is usually done by either consulting the teacher or sharing knowledge with other students within the social structure of a class. In LNs, learners have to self-organize knowledge sharing and this might have consequences on learning effectiveness and efficiency according to cognitive load theory (CLT) (J. Sweller, 1988).

CLT distinguishes among the three types of cognitive load: intrinsic, extraneous and germane load[1]. When learners have to organize knowledge sharing by themselves, they first have to find out who the relevant knowledge sharers are, figure out how to interact with the others and then maintain the communication during knowledge sharing. Without support, these activities increase extraneous load because they are not directly related to learning itself but to the learning environment and they detract from learning rather than facilitate it. According to CLT, extraneous load is ineffective or detrimental for learning and it has a significant negative impact on learning complex tasks that are high in intrinsic load (Van Gog & Paas, 2008). It is thus considered imperative to reduce extraneous load for complex tasks (Van Merriënboer & Sweller,

[1] For more extensive introduction of CLT, please refer to the articles by Paas, Renkl et al.(2003), Van Merriënboer and Sweller (2005) and Van Gog and Paas (2008).

2005).Within the last three decades, CLT has been extensively applied to inform the design of instruction and instructional materials to achieve effective knowledge construction and skill acquisition (Beckmann, 2010; De Jong, 2010; F. Paas, Renkl et al., 2003; J. Sweller, 1988). Numerous studies have applied CLT for teacher-lead instruction, particularly to solve problems of a high extraneous load. To the best of our knowledge, none addresses the cognitive aspects of learners in non-formal learning environments such as LNs where no teachers' guidance is available. Thus, we apply CLT to gauge whether a support reduces extraneous during knowledge sharing.

In formal learning settings, peer tutoring (PT) is one frequently used method to structure student-student interaction (King, 1997, 1998, 2002). PT is defined as "people from similar social groupings who are not professional teachers, helping each other to learn, and learning themselves by teaching"(Topping, 1996, p.322). This method has been applied in diverse educational disciplines to stimulate learners to *discuss their learning* and *negotiate meaning* with each other: learners clarify their understanding of a topic and uncover gaps in or misunderstandings of the material (King, 1997, 1998, 2002). Various studies report that the students who learned with a PT intervention achieved higher learning outcomes (Fantuzzo, Riggio, Connelly, & Dimeff, 1989; Gyanani & Premlata, 1995; King, Staffieri, & Adelgais, 1998). When applying PT, students were more engaged in learning activities and knowledge sharing and less engaged in structuring these activities (Fantuzzo et al., 1989; Greenwood, Delquadri, & Hall, 1989).

In traditional PT, the teacher usually relies on instructional considerations to assign peer tutors. In LNs, learners have to find peer tutors by themselves and, as argued, this imposes extraneous load because they do not know what peers are suitable as tutors for sharing knowledge with about a specific topic. To avoid this, Van Rosmalen and colleagues (2008; 2008) developed a technology-enhanced PT system to replace the teachers' arrangements. When knowledge sharing was inquired by learners (tutees), this system automatically assigned suitable peer tutors based on a set of selection criteria such as availability, content competency, tutor competency and eligibility (Van Rosmalen, Sloep, Brouns et al., 2008; Van Rosmalen, Sloep, Kester et al., 2008). Additionally, this PT system included role specifications that specified what tutors and tutees should do as well as an editable website of *wiki* that allowed learners to work collaboratively. The main purpose of this study is to investigate whether such a PT system can support knowledge sharing by reducing extraneous load as argued, especially when working on complex tasks.

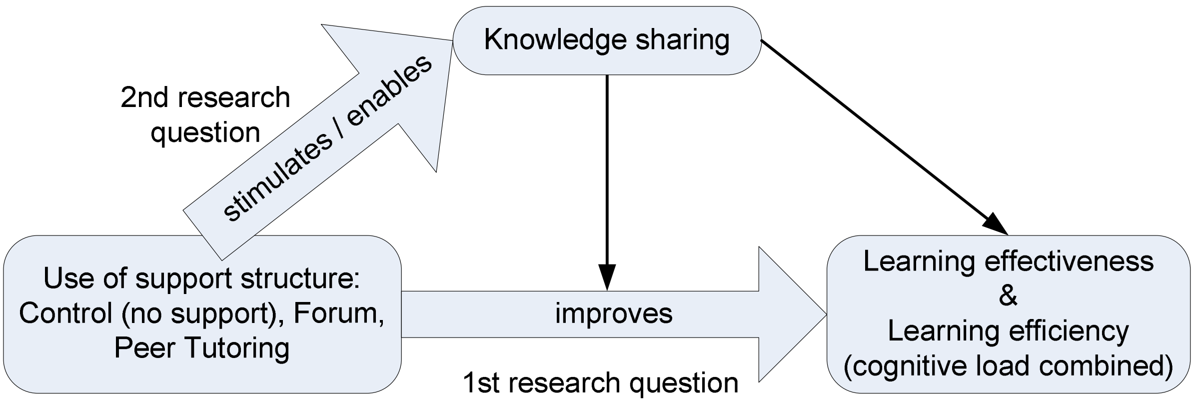

Figure 1. The research questions of this study.

To know whether a support is effective in reducing extraneous load during knowledge sharing, we calculate *learning efficiency* based on the formula by Van Gog and Paas (2008). Learning efficiency is determined by combining cognitive load measures with performance measures (F. Paas & Van Merriënboer, 1993; Van Gog & Paas, 2008). The most commonly used cognitive load measure is based on the learner's subjective judgment on a unidimensional rating scale (Van Gog & Paas, 2008). What learners report on this rating scale is called *mental* *effort,* which refers to how much cognitive capacity actually has been allocated to accomplishing a learning task (F. Paas, 1992; F. Paas, Tuovinen, Tabbers, & Van Gerven, 2003). However, this mental effort measure does not distinguish between the three types of cognitive load (Beckmann, 2010; De Jong, 2010). Thus, a high learning efficiency can be inferred from a high performance score with a low mental effort investment whereas a low learning efficiency is a low performance score with a high mental effort investment. If an instructional design aims to reduce extraneous load, the efficiency measure should take into account the perceived mental effort during the learning phase (i.e. the *adapted* efficiency formula) (Van Gog & Paas, 2008).

Research questions

We aimed to investigate whether using supports reduces extraneous load when working on complex tasks. We focused on three levels of supports for knowledge sharing: no support (as control groups), forums that only support communication, and PT that supports finding relevant knowledge sharers, interacting and maintaining the communication process. Accordingly, this study responded to the following research questions (see Figure 1):

1. What is the effect of using different supports on learning effectiveness and efficiency when working on complex tasks?
   - Does the use of PT result in better learning effectiveness (i.e. post-test scores and difference scores between prior knowledge tests and post-tests) than forum and control groups when working on complex tasks?
   - Does the use of PT result in better learning efficiency (i.e. efficiency measures that combine mental effort measures in the learning phase and post-test scores) than forum and control groups when working on complex tasks?

2. What is the effect of using different supports on knowledge sharing when working on complex tasks?
   - Does the use of peer tutoring help solve more inquiries than forums on complex tasks?
   - Are learners who use peer tutoring for complex tasks more satisfied with the knowledge sharing process than those who use forums and control groups?

Hypothesis

1. There is a significant interaction effect on learning effectiveness and efficiency between using different supports and task complexity. No differences of learning effectiveness and efficiency between PT, forum and control groups will be found for simple tasks while the PT group has better learning effectiveness and efficiency than forum and control groups for complex tasks and forum better than control.
2. There is a significant interaction effect on knowledge sharing between using different supports and task complexity. No differences of knowledge sharing results between PT and forum groups will be found for simple tasks while the PT group has better knowledge sharing results than forum group for complex tasks.

Method

Participants

We announced a course *Internet Basics* on different websites to recruit participants. In total, 534 volunteers sent us an e-mail expressing their interests in this course. When recruiting participants, we announced that they would get a certificate after they finished all requirements of this course.

Materials

The course

We implemented the course Internet Basics in a Moodle learning environment as LNs. This course consisted of ten *modules* dealing with different subjects related to Internet. The estimated number of study hours was 20 hours. The course was available online for eight weeks from 19th May to 13th July 2010. This course was not part of any formal program of the Open University, which means participants *did not* get any European Credits after they finished the course. In addition, this course was designed fully for self-study and there was no staff teacher available during the learning process.

Modules and module complexity

Each module started with a brief introduction and followed with several topics. These ten modules differed in complexity, which was determined by levels of topic interactivity in a module (J. Sweller, 2006; John Sweller & Chandler, 1994). For modules with high complexity, there were topics interacting with each other and they could not be learned and understood in isolation; for modules with low complexity, there were non-interacting topics that could be learned and understood independently of each other. Two experts in the field of cognitive load theory judged the *relative* complexity of each module. Based on their rankings, all modules were classified as either simple (n=5) or complex ones (n=5). The simple modules were: *getting more out of your internet browsers*, *paying safely on the internet*, *making use of useful websites*, *Web 2.0 a new internet* as well as *using internet as a recreation place*. The complex modules were: *getting access to internet*, *searching the web*, *virus and spyware*, *spam and inappropriate content*, as well as *how to build a personal webpage*.

Knowledge sharing tasks and task complexity

We designed twenty *knowledge sharing tasks* to determine whether there is an interaction effect between task complexity and using different support structures. Again, we used Sweller and Chandler's method to define task complexity (John Sweller & Chandler, 1994). A simple task required content knowledge of non-interacting topics whereas a complex task required synthesized/integrated knowledge of multiple interacting topics. The same two experts in the field of cognitive load theory checked the *relative* complexity of these twenty tasks to ensure that task complexity was as designed. We added a simple task to each module for groups of simple tasks and a complex task to each module for groups of complex tasks (see *Design and procedure*).

Measures

Cognitive load measure

For CL measures, participants reported how much mental effort they invested by rating on a 9-point cognitive load rating scale for learning the modules, doing the knowledge sharing tasks and taking the post-tests (F. Paas, 1992; F. Paas & Van Merriënboer, 1994). This rating scale ranged from *very very low effort* (1) to *very very high effort* (9).

Prior knowledge tests and post-tests

For every module, there were a prior knowledge test and a post-test. Both tests were identical and they consisted of a few content-related multiple choice questions or matching questions. Additionally, each of the post-tests included one CL measure. The order of questions and answer options was randomized.

Learning effectiveness

We used two types of scores to represent learning effectiveness: post-test scores as well as difference scores (gains) between prior knowledge tests and post-tests.

Learning efficiency

For adapted efficiency measures, we combined mental effort invested in the learning phase with performance in the test phase. zP_{test} is z-score for post-test scores and $zE_{learning}$ is z-score for mental effort ratings on knowledge sharing tasks or learning modules:

$$Efficiency = \frac{zP_{test} - zE_{learning}}{\sqrt{2}}$$

Knowledge sharing

Each of the modules contained a knowledge sharing task we anticipated the participants to carry out, but they did not have to submit evidence of it. We hoped that they would use the provided support structure during the process. The support structure could also have been used to submit inquiries unrelated to the specific knowledge sharing task, but still related to the module. Thus, we took the use of the supports, either forums or PT, as indication of knowledge sharing. We collected these data: number of inquiries submitted for each of the modules, names of persons who submitted inquiries, names of persons who responded to the inquiries as well as the text of the inquiries and responses. In addition, for the PT groups we traced for which topic the PT support was activated, who was invited, how many people were invited, whether the invitation was accepted or not, and finally the outcome, as rated by the learner submitting the inquiry.

To investigate how participants thought of using forums or PTs for sharing knowledge, we modified the course evaluation questionnaire developed by Van Rosmalen et al. (2008). After the course was finished, we sent out the invitation to participants to fill in this questionnaire. The questionnaire included three sections: general questions (i.e. which were the same for Control, Forum and PT groups), use of forums or PT as being inquirers, respondents and overall evaluation (only for Forum and PT groups), as well as the closure (i.e. whether they wanted to apply for the certificate and research results).

Design and procedure

We used two experimental designs in this study. Table 1 shows the factorial design with two between-group variables: supports (Control vs Forum vs PT) and task complexity (simple vs complex). There were thus six groups: Control Simple (CS), Control Complex (CC), Forum Simple (FS), Forum Complex (FC), PT Simple (PTS) and PT Complex (PTC). All groups had access to the same module content, but each group had either simple or complex knowledge sharing tasks or a different support of knowledge sharing. Before the course started, we randomly assigned participants to each group and there were 89 to 90 participants per group.

Table 1. *Factorial design*

Task	Supports		
complexity	Control	Forum	PT
Simple	CS (n=88)	FS (n=88)	PTS (n=89)
Complex	CC (n=90)	FC (n=89)	PTC (n=90)

Table 2 shows the mixed design with two between-group measures (supports & task complexity) and one within-group measure (module complexity). This is because all participants were supposed to finish the measures on all ten modules and modules also varied in complexity (see Modules and module complexity).

Table 2. *Mixed design*

Task complexity	Supports Control	Forum	PT
Simple tasks	5 Simple modules 5 Complex modules	5 Simple modules 5 Complex modules	5 Simple modules 5 Complex modules
Complex tasks	5 Simple modules 5 Complex modules	5 Simple modules 5 Complex modules	5 Simple modules 5 Complex modules

For Control groups, there was no support at all, which means they had to acquire knowledge or organize knowledge sharing by themselves. For both Forum and PT groups, the support that participants could submit their inquiries for knowledge sharing was called *Pose your question* (see Figure 2.). For Forum groups, they could post their inquiries and wait until others responded to their posts. For PT groups, when inquiries were submitted to the system, *available* peer tutors were automatically selected for the inquirers. Availability was based on participants' past workload, i.e. the number of inquiries responded to previously (Van Rosmalen, Sloep, Brouns et al., 2008). Table 3 shows the main steps of how PT supported the knowledge sharing process and stored the data.

Table 3. *The main steps of the PT support*

Context	A Learning Network of Internet Basics with ten modules and learners with information of their (past) working load.
Main steps	Anne submits an inquiry to *Pose your question* concerning a specific module or knowledge sharing task. The system determines the available learners and selects the most suitable ones.

	The selected learners receive an invitation to act as a peer tutor. The system sets up a *wiki* containing the inquiry text and role specifications as guidelines. Anne and the peer tutor discuss and formulate results in the wiki. When they finish the discussion, Anne closes the discussion, rates the results.
Data	The system stores results, discussion log, and ratings of the answer.

Note. This table is modified from Van Rosmalen et al. (2008)

To start with the course, we sent out an e-mail to provide the participants with the URL of the course site as well as their usernames and passwords. We strongly advised participants to read *General information* first after they logged in the course sites. General information consisted of welcome words, four questions of personal information, expectations of this course, user manuals, links to internet vocabulary dictionaries, FAQ, prior knowledge tests as well as general conditions. The user manual included the instruction to log in the course site, course overview, navigation to the course or module page, how to access a new module, what consisted of each module and frequently asked questions (*FAQ*). FAQ consisted of three types of questions: general questions, questions about the course and questions related to computers. For Forum and PT groups, there was an extra manual of using Forum and PT to share knowledge with others. We added *Pose your question* to the right-hand side of each module homepage (see Figure 2). To pose an inquiry, participants simply clicked on *Pose your question* and the system navigated them to the Forum or PT pages.

Figure 2. Pose your question.

To start with a module, participants first had to take the prior knowledge test of that module and get an enrollment key. There were separate enrollment keys for each of the modules. Participants could access the module by entering the enrollment key. For each module, they were supposed to learn the content, finish the knowledge sharing task, take the post-test and fill in three mental effort measures. At the learning phase, we asked participants to rate mental effort invested on performing the knowledge sharing task and learning module. At the testing phase, we asked them to rate mental effort invested on taking the post-test.

Results

Though 534 volunteers registered for this course, only 415 participants have actually logged onto the course sites and only 329 of them have started at least one module. Therefore, the final number of participants for the dataset was 329. Overall, there were more women (55%), people over 45 years old (75%) and people with a high educational level (higher professional education or university level, 68%). Finally, 43% said their computer skills were poor or very poor.

Although 89-90 people were assigned to each of the treatment groups, on average only 24.1 learners enrolled for the modules, 13.6 learners answered the mental effort measures of knowledge sharing tasks, 16.5 learners answered the mental effort measures of learning modules and 21 learners finished post-tests. This showed there were many missing values in our dataset: not all participants completed the measures on all ten modules. In addition, we lost mental effort measures on eight modules in Control Complex (CC) group because of a technical error. Thus, we could only calculate adapted efficiency scores by combining mental effort measures on knowledge sharing tasks with post-test scores (Efficiency1) or difference scores (Efficiency2) (i.e. between prior knowledge tests and post-tests).

Because of the incomplete data, we ignored personal differences on different modules and regarded the results of the whole course as one unit for dependent variables. Before analyzing the data for the factorial design, we considered results of ten individual modules for each dependent variable as *a variable group* and used the restructure function in SPSS to organize the data into six variable groups for all dependent variables: prior knowledge test scores, mental effort results of knowledge sharing tasks, post-test scores, difference scores between prior knowledge tests and post-tests, Efficiency1 and Efficiency2 scores. For the mixed design, results of each dependent variable were further grouped into simple and complex modules. A significance level of .05 was used for all analyses.

As for the first hypothesis, the data were analyzed with 3 (supports: Control vs. Forum vs. PT) × 2 (task complexity: simple vs. complex) analyses of variances (ANOVA) with between-group measures on both factors. The cell sizes, means and standard deviations for this 3

× 2 factorial design are reported in Table 4. With regards to scores of prior knowledge tests, post-tests and difference scores between prior knowledge tests and post-tests, no effects were statistically significant at the .05 significance level.

As for mental effort measures on knowledge sharing tasks, the main effect of using different supports was non-significant, $F(2, 808) = 2.67$, $p > .05$. However, there was a significant main effect for task complexity, $F(1, 808) = 12.54$, $p < .05$, such that the average mental effort was higher for complex tasks ($M = 4.72$, $SD = 1.34$) than for simple tasks ($M = 4.39$, $SD = 1.48$). The interaction effect was significant. $F(2, 808) = 13.84$, $p < .05$, indicating that the task complexity effect was greater in Control than Forum and PT groups.

As for Efficiency1, the main effect of using different supports was non-significant, $F(2, 797) = 2.77$, $p > .05$. However, there was a significant main effect for task complexity, $F(1, 797) = 18.30$, $p < .05$, such that the average Efficiency1 was higher for simple tasks ($M = .21$, $SD = .90$) than for complex tasks ($M = -.06$, $SD = .96$). The interaction effect was significant. $F(2, 797) = 8.82$, $p < .05$, indicating that the task complexity effect was greater in Control than Forum and PT groups.

As for Efficiency2, the main effect of using different supports was non-significant, $F(2, 797) = 2.34$, $p > .05$. However, there was a significant main effect for task complexity, $F(1, 797) = 7.81$, $p < .05$, such that the average Efficiency2 was higher for simple tasks ($M = .12$, $SD = .91$) than for complex tasks ($M = -.06$, $SD = .95$). The interaction effect was significant. $F(2, 797) = 5.60$, $p < .05$, indicating that the task complexity effect was greater in Control than Forum and PT groups.

Table 4. *Means and standard deviations of the dependent variables in the factorial design*

	Support structure

Dependent variable	Control M	Control SD	Control N	Forum M	Forum SD	Forum N	PT M	PT SD	PT N
Prior knowledge tests grade (1-10)									
Simple tasks	6.11	2.38	328	6.38	2.26	251	6.39	2.05	266
Complex tasks	6.25	2.24	269	6.41	2.16	295	6.24	2.35	307
Mental effort on knowledge sharing tasks (1-9)									
Simple tasks	4.73	1.20	168	3.98	1.76	131	4.36	1.39	123
Complex tasks	4.36	1.34	119	4.78	1.25	133	4.96	1.37	140
Post-tests grade (1-10)									
Simple tasks	8.60	1.66	245	8.71	1.52	199	8.72	1.74	198
Complex tasks	8.47	1.75	195	8.59	1.70	184	8.22	1.91	238
Differences between prior knowledge tests and post-tests									
Simple tasks	2.08	2.16	245	2.12	2.07	199	1.91	2.04	198
Complex tasks	1.94	2.12	195	2.04	2.29	184	2.02	2.26	238
Efficiency1									
Simple tasks	-0.01	0.85	165	0.42	1.00	130	0.28	0.80	123
Complex tasks	0.10	0.96	115	-0.02	0.87	131	-0.23	1.02	139
Efficiency2									
Simple tasks	-0.03	0.89	165	0.31	0.96	130	0.12	0.85	123
Complex tasks	0.09	0.88	115	-0.05	0.89	131	-0.21	1.04	139

As for the second hypothesis, Table 5 shows that there were only a limited number of inquiries submitted by both Forum and PT groups. Therefore, we cannot test this hypothesis since the support of Forums and PT were not used sufficiently to have effects on knowledge sharing. In addition, Table 5 shows that only half of the inquiries were responded for the Forum groups and less than the half of the inquiries were responded for the PT groups. Among these responses, only a small proportion of responses provided valid answers to the inquiries.

Table 5. *Frequencies of use of Pose your question*

	Forum simple	Forum complex	PT simple	PT complex
Total inquiries submitted	16	13	16	9
Invitations sent	n/a	n/a	58	34
Responses provided/invitations accepted	9	9	7	3
Percentage responses/inquiries	56,25%	69,23%	43,75%	33,33%
Valid answers	5	6	3	1
Percentage valid answers/inquiries	31,25%	46,15%	18,75%	11,11%

Table 5 displays that groups with simple knowledge sharing tasks submitted more inquiries than complex ones and Table 6 shows that more inquiries are related to simple than complex modules. This trend was contrary to our prediction that complex tasks would induce more knowledge sharing inquiries than simple ones.

Table 6. Frequencies *of use of Pose your question related to simple or complex modules*

	Forum simple	Forum complex	PT simple	PT complex
Total inquiries submitted	16	13	16	9
About simple modules	11	6	9	7
About complex modules	5	7	6	2

When the course was due, we asked all participants to fill in a course evaluation questionnaire but only 121 participants responded (see Table 7).

Table 7. *Number of learners per group who finished all 10 modules and filled in the course evaluation*

	CS[a]	CC[b]	FS[c]	FC[d]	PTS[e]	PTC[f]
Course evaluation filled	21	18	19	20	18	25

[a]Control simple. [b]Control complex. [c]Forum simple. [d]Forum complex. [e]PT simple. [f]PT complex.

Discussion

In addition to 3 × 2 ANOVAs, we planned to analyze data in a mixed design ANOVA with using different supports (Control vs. Forum vs. PT) and task complexity (simple vs. complex) as between-group factors and module complexity (simple vs. complex) as a within-group factor (see Appendix for the descriptive statistics of this mixed design). However, the limited number of inquiries submitted by Forum and PT groups revealed that the supports of Forums and PT were not sufficiently used to have effects on knowledge sharing, learning effectiveness and efficiency. That is why we did not include the analyses of this mixed design in Results.

The study was designed to investigate whether CL can be reduced by introducing a PT support structure. As it turned out for some reason or other, the participants did not use the instruments (supports of Forum and PT) as devised. Therefore we can not draw any conclusions with regard to learning effectiveness and efficiency. Nevertheless, control groups showed significant lower cognitive load on knowledge sharing tasks and higher efficiency scores (Efficiency1 and 2) on complex tasks. These significant differences might result from other confounding variables or bias beyond the control of our experimental design. The evaluation questionnaire provides some insights. Half (53%) of the respondents thought that the course was *very easy* or *easy* for self-study. More than three-fourth (77%) said they were *not* in need of finding someone to share knowledge. These results might explain why the supports of Forum and PT were not used sufficiently because participants did not need to share knowledge for learning this course. In the same way, they might explain why 70% of the respondents were still satisfied with the course though knowledge sharing did not occur very often. Furthermore, respondents of the Control groups (85%) were more satisfied with the course than those of the Forum and PT groups (63%). When there is no need for knowledge sharing, those who did not share knowledge at all (Control groups) might be easily satisfied with only learning the course than those who did more than that such as knowledge sharing (Forum and PT groups), especially when knowledge sharing was not supported properly.

For the Forum and PT groups, we did find that complex knowledge sharing tasks imposed significantly more cognitive load than simple ones. More cognitive load might be imposed on those who did knowledge sharing in the Forum and PT groups than those who did not have any chance to share knowledge in the Control groups. In addition, the PT support in this study randomly assigned other available participants as peer tutors to those who submitted inquiries. According to e-mails we received at the Helpdesk, some participants were irritated when they got invitations because they have not yet studied the modules related to the inquiries submitted. Thus, this random matching might impose extraneous load instead of reducing it.

It is interesting to note that complex knowledge sharing tasks did not induce more knowledge sharing inquiries than the simplex ones though they did impose more cognitive load than the simple ones. One possible explanation may be that the intrinsic load imposed by complex knowledge sharing tasks was so high that participants had very little cognitive capacity left for knowledge sharing. Thus, they might be overloaded by further using the supports for knowledge sharing: they might have tried to use supports of Forums or PT such as formulating their inquiries about complex tasks but eventually they did not submit knowledge sharing inquiries to the supports.

To sum up, there were four main limitations in this study. First, the incomplete dataset with many missing values is a threat to the study's validity. We could not force participants to fulfill all course requirements because this was against their self-directness, personalized learning goals and defining features of LNs that are to cater for these both needs. Second, the data was biased by the choices made by participants. It was likely that participants chose the topics that interested them to do or skipped the topics they already knew to do. When calculating difference scores between prior knowledge tests and post-tests as well as efficiency scores, we could only use cases that completed both related dependent variables. These cases might bias the results compared to the dataset without missing values. The third limitation was the lost of cognitive load measures. Our aim was to know whether the PT support would reduce extraneous load imposed by knowledge sharing on complex tasks and we could only validate this with calculating adapted efficiency scores (Van Gog & Paas, 2008): if the extraneous load is reduced, then there should be a higher efficiency score that combines low mental effort in the learning phase and high test performance in the test phase. Because of the mistakes we made, no complete data of mental effort in the learning phase (learning modules) can be used. The only cognitive load measure we had is the mental effort invested on knowledge sharing tasks. However, there was no significance correlation between mental effort scores on knowledge sharing tasks and post-test scores (r_s = .01, p > .01) and we cannot draw conclusions based on the limited number of participants (M = 13.57) who answered it. Finally, as for measuring cognitive load we followed the conventional way to ask participants report how much mental effort they invested on knowledge sharing tasks, learning modules and taking post-tests. For the most CLT studies, cognitive load is measured within the limited time for every participant. This method became problematic when measuring in non-formal LNs because we could not limit time on doing each knowledge sharing task, learning each module and taking each post-test. Thus, we cannot compare the cognitive load perceived differently by online distance participants.

This study displayed the challenges of applying CLT in non-formal LNs where it is extra difficult to measure cognitive load and control all possible confounding variables and bias that naturally occurred for non-formal learning. It is inevitable that we need to find an approach that considers the characteristics of non-formal LNs and how to collect valid data to test the hypotheses of this study.

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Appendix

Table 8. *The means and standard deviations of the dependent variables in mixed designs*

			Prior knowledge tests			Mental effort on knowledge sharing tasks		
Module complexity	Supports	Task complexity	Mean	SD	N	Mean	SD	N
Simple	Control	Simple	6,12	2,41	142	4,86	0,93	66
		Complex	6,41	2,16	109	4,31	1,28	39
	Forum	Simple	6,70	2,35	107	4,17	1,55	48
		Complex	6,45	2,27	124	4,80	0,92	51
	PT	Simple	6,57	2,14	112	4,47	0,97	45
		Complex	6,21	2,41	134	4,83	1,04	46
Complex	Control	Simple	6,36	2,25	142	4,58	1,49	66
		Complex	6,56	2,23	109	4,64	1,25	39
	Forum	Simple	6,48	2,22	107	3,83	1,77	48
		Complex	6,55	2,07	124	4,76	1,46	51
	PT	Simple	6,46	2,03	112	4,24	1,55	45
		Complex	6,28	2,28	134	5,35	1,43	46

Table 8. *The means and standard deviations of the dependent variables in mixed designs (Continued).*

			End-quizzes			Difference scores		
Module	Supports	Task	Mean	SD	N	Mean	SD	N

complexity		complexity						
Simple	Control	Simple	9,03	1,34	106	2,63	2,27	106
		Complex	8,75	1,40	84	2,01	2,02	84
	Forum	Simple	9,11	1,28	92	2,37	2,18	92
		Complex	8,76	1,54	81	2,24	2,24	81
	PT	Simple	8,91	1,69	88	1,86	2,15	88
		Complex	8,33	1,98	108	1,94	2,22	108
Complex	Control	Simple	8,60	1,58	106	1,77	1,80	106
		Complex	8,74	1,63	84	1,95	2,09	84
	Forum	Simple	8,59	1,41	92	1,90	1,97	92
		Complex	8,63	1,62	81	2,00	2,25	81
	PT	Simple	8,88	1,40	88	2,10	1,92	88
		Complex	8,43	1,54	108	2,30	2,13	108

Table 8. *The means and standard deviations of the dependent variables in mixed designs (Continued).*

			Efficiency1			Efficiency2		
Module complexity	Supports	Task complexity	Mean	SD	N	Mean	SD	N
Simple	Control	Simple	0,13	0,75	65	0,14	1,07	65
		Complex	0,45	1,03	38	0,16	1,07	38
	Forum	Simple	0,60	0,96	48	0,26	1,18	48
		Complex	0,01	0,95	51	-0,09	1,02	51

	PT	Simple	0,31	0,84	45	0,09	1,04	45
		Complex	-0,10	1,11	46	-0,27	1,18	46
Complex	Control	Simple	0,23	1,03	65	-0,02	1,08	65
		Complex	0,18	1,07	38	0,14	1,20	38
	Forum	Simple	0,33	1,16	48	0,21	1,20	48
		Complex	0,04	0,99	51	0,01	1,15	51
	PT	Simple	0,54	0,98	45	0,25	0,87	45
		Complex	-0,31	1,16	46	-0,14	1,07	46