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Use of Scaffolds to Manage the Cognitive Load Experienced By Student Teachers in an Online Training Package on Problem Based Learning Strategy (PBLS)

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ABSTRACT

Cognitive load refers to load imposed on the working memory while performing a particular task. The basic premise of cognitive load theory is that learners have a limited capacity when dealing with new information. Moreover cognitive load theory assumes that learners have "an effectively unlimited long term memory holding cognitive schemas that vary in their degree of complexity and automation". Furthermore, when handling new information, working memory is severely limited in both capacity and duration. The educational implication of cognitive load theory hence focuses on reduction of work load on working memory so as to increase learning effectiveness. Because novices lack the schemas necessary to process complex material in working memory, scaffolding for these missing schemas, thereby promotes schema construction. In this study on 41 Student teachers undergoing the online training on Scaffolded Problem Based Learning (PBLS), Cognitive load is measured in terms of mental efforts and mental load experienced by the learners while working towards solutions to the problems. Findings indicate significant difference between the cognitive load felt before and after the training which is also supported by the qualitative data indicating reduction in the cognitive load as the students move from Problem one to Problem ten.

Keywords: *Scaffolds, student, teachers, online training, Learning Strategy (PBLS)*

Cognitive load refers to load imposed on the working memory while performing a particular task. The basic premise of cognitive load theory is that learners have a limited capacity when dealing with new information, working memory is severely limited in both capacity and duration. Moreover cognitive load theory assumes that learners have "an effectively unlimited

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long term memory holding cognitive schemas that vary in their degree of complexity and automation" (Sweller, van Merrienboer & Paas, 1998). Working Memory processes information either prior to it being stored in Long Term Memory or after it has been stored. It can be equated with consciousness, in the sense that we are only conscious of the information currently being processed in Working Memory and are oblivious of the far larger amount of information stored in Long Term Memory.

The information held in long term memory is organized and stored in the form of domain specific structures known as schemas. As indicated by Sweller (2004), the relationship between working memory and schemas stored in the long term memory may be even more important than the processing limitations of working memory. However before incoming information is stored in the long term memory, it must be processed through working memory first. According to the principle of cognitive load theory, there is a limit to the amount of information that can be used, processed, and stored by the working memory. Overloading working memory impedes this information processing operation and leads to ineffective learning.

Working memory can also be overloaded by the entertainment or activity before the learner ever gets to the concept or skill to be learned.

Types of Cognitive Load

Current developments of Cognitive Load Theory considers two sources of load when learners have to process instructional material in order to achieve a learning task (Sweller 2004):

- **Intrinsic load** refers to the load required to process the instructional task. It is related to the complexity of the content itself and particularly to the degree of interactivity between elements, which impacts the number of elements that must be held in working memory simultaneously. Element interactivity is dependent on both the complexity of the material to be learnt and learner expertise (their schema availability and automation). The only way to foster understanding and to reduce intrinsic cognitive load is to develop schemas that incorporate the interacting elements.
- **Extrinsic load** refers to two sub-categories of load:

➢ **Extraneous load** refers to the additional load that is influenced by the format of instruction (material presentation or structure of the learning task) and that does not contribute to learning. It is also known as ineffective cognitive load – result of instructional techniques that require learners to engage in working memory activities that are not directly related to schema construction and automation (e.g., searching for information on the web). Extraneous cognitive load may be caused by using weak problem-solving methods (e.g., working backward from a goal using means-ends analysis), integrating information sources that are distributed in place or time, searching for information that is needed to complete a learning task in instructional materials, and so forth. The end result maybe fewer cognitive resources left in working memory to devote to schema construction and automation during learning. Consequently learning may suffer (Sweller, 1994).

- **Germane load** promotes the construction of the cognitive schema, which is the ultimate goal of deep learning. It is also known as effective cognitive load which is the result of beneficial cognitive processes such as abstractions and elaboration that are promoted by the instructional presentations (Gerjets and Schieter, 2003).

The notion of germane load, recently taken into consideration by the cognitive load model, acknowledges that cognitive load can be beneficial to learning, provided that this load is allocated to the construction of cognitive schemata rather than to the processing of extraneous information. Working memory processing capacity depends on the level of expertise (Ericsson & Kintsch, 1995), individual abilities (Gyselinck, Jamet & Dubois, 2008), metacognitive processes (Valcke, 2002) and level of involvement in the task. It is therefore difficult to discriminate between a cognitive load level that is manageable and beneficial to learning and the overload level that is detrimental to learning.

Intrinsic, Extrinsic and Germane cognitive load are additive. When summed total load cannot exceed the total working memory capacity that is available to student if learning is to occur.

Learning tasks and practices that engage learners in rich and complex interactions with the learning environment, such as inquiry learning or discovery learning, have been shown to be situations in which deep learning can occur (Schnotz, Vosniadou, & Carretero, 1999). According to the Cognitive Load Theory, deep learning is described as the acquisition of cognitive schemata that enables categorizing the problem, choosing the correct procedures to apply and regulating problem solving. The construction of such schemata is cognitively demanding.

Additionally, Jonassen & Driscoll (2003) asserts that with the increase in use of computer based instructions and hypermedia environments, the greater cognitive demands of navigating these multiple paths, multiple option environments may increase the chance of learner cognitive overload.

E-learning tasks often use 2D and 3D graphics, audio narration, animations, background colors and/or interactions of these possibilities. Additionally, the information might not be linearly organized, because most e-learning environments allow learners to navigate freely through the available information, with or without the aid of hyperlinks and graphical organizers. As a result, the cognitive load imposed by e-learning environments may be too high for novices, and could seriously hamper learning.

Ways to reduce different types of cognitive load

Research has shown that instructions designed to decrease extraneous load has negligible effects on learning simple tasks (i.e. involving low element-interactive materials). There simply is no need to decrease extraneous load because there are sufficient cognitive resources available to deal with the low intrinsic cognitive load. However, for teaching complex tasks (i.e. involving high element-interactive materials), the sum of the intrinsic and extraneous loads may easily surpass working memory capacity and yield overload. Then, extraneous load and, if the reduction of extraneous load is still insufficient, intrinsic load must be lowered to free up processing resources necessary for learning. The more extraneous cognitive load is reduced, the more working memory resources can be devoted to intrinsic cognitive load and so the easier it becomes to induce a germane cognitive load for learning. Also, the ideal collaborative learning situation would minimize extraneous load (by load reduction mechanisms) and generate germane load by rich social interactions.

Scaffolding strategies to reduce various types of cognitive load

Scaffolding strategies in complex learning situations can facilitate consolidation of new knowledge in schemata.

Strategies to reduce or manage various types of loads are as follows:

- Extraneous load can be reduced by the use of question prompts, hints, worked examples and completion tasks, by integrating different sources of information and using multiple modalities.
- Intrinsic load can be managed by simple-to- complex ordering of learning tasks and working from low- to high-fidelity environments.
- Germane load can be optimised by increasing variability over tasks, applying, question prompts and problem definition templates.

Many conceptual papers on use of various scaffolds to reduce different types of cognitive load are available but the researcher came across very few studies where the different types of scaffolds have been actually used and studied in Problem Based Learning context.

This is reflected in studies conducted by Renkl, Stark, Gruber & Mandl, 1998, Bunch & Chase, 2003; Renkl, Hillbert, & Schworm, 2009; Danilenko, 2010, Yen-Ting Lina & Yi-Chun Linb, 2015 and Thomas, Bennett, & Lockyer, 2016, wherein scaffolds were found to be useful to reduce cognitive load.

Cognitive load measurements

Cognitive load measurements can be done using following measures:

- Objective measures: Eye tracking, heart rate measurements, skin conductance measurements are physiological measures and are objective in nature. Also to use the physiological measures, the researcher needs to be proficient in use of physiological measures.

- Subjective measures (self reports). Cognitive Load is a multidimensional construct and can be assessed by measuring :

➢ Mental Load which is a task based dimension i.e it is the load imposed by the task itself including content complexity.

➢ Mental Effort which is a learner based dimension i.e amount of cognitive capacity a learner allocates to accommodate task demands. Effort is a measure of the intentional load a learner applies to understand the content and concepts and develop new schemas.

➢ Performance which depends on both mental efforts and mental load.

Cognitive load research has made far less use of dual task methodology than of subjective measures as an indicator of cognitive load. Ease of use probably provides the major reason for this differential use of two measures. Subjective measures can be obtained easily and quickly. They can be used when testing learners individually or in groups without specialised equipment.

Online Training Package on Scaffolded Problem Based Learning Strategy (PBLS)

Problem based learning, based on the premise of constructivist epistemology, represents a major development in higher education practice that continues to have a large impact across subjects and disciplines around the world. It is the need of today's society that people are able to solve complex problems efficiently. Being able to successfully solve problems is more than just accumulating knowledge- it involves development of flexible, cognitive strategies that help analyse different problem situations to produce meaningful learning outcomes. Online training package on Scaffolded Problem Based Learning Strategy is intended to guide student teachers to become experts in the field of study, capable of identifying the problems based on the domain knowledge of the discipline and analyzing and contributing to the solutions in a completely online mode.

Since Problem Based Learning is a novel and complex task for the student teachers who are novices in area of constructivism, they need to be provided with scaffolds for Problem Based Learning Strategy (PBLS). The scaffolds provided help in reducing the cognitive load of learners as they encounter the problems to be resolved leading to effective learning. Also the various online resources available for interaction and collaborative work act as scaffolds which is possible only in an online mode.

The online training package is assigned four credits and student teachers need to put in 120 hours of study for completion of the training.

The salient features of the Online Training Package on Scaffolded PBLS are as follows:

- It is designed on the lines of ADDIE model,
- It incorporates Problem Based Learning Strategy
- It is based on constructivist approach,
- It has provision of variety of Scaffolds,
- It is available 24*7,
- It makes good use of Activity features of MOODLE and
- It has provision for collaborative learning.

Operational Definition

Cognitive Load

Cognitive load refers to load imposed on the working memory while performing a particular task. Cognitive load is measured in terms of mental efforts and mental load felt by the learners.

Research Question

To what extent are scaffolds effective in managing the cognitive load experienced by student teachers in an Online training Package on Problem Based Learning Strategy (PBLS)?

Hypothesis

- *There will be no significant difference in the pre test and post test mean scores of cognitive load experienced by student teachers.*

METHOD

Participants

The study was conducted on 41 student teachers of Hansraj Jivandas College of Education. The student teachers were selected on the basis of their competence in the use of computer and internet. None of the student teachers were exposed to online training earlier and most of them were not aware of Problem based learning as well the scaffolding. The student teachers undertook the online training in Scaffolded Problem Based Learning strategy (PBLS) wherein the student teachers had to solve ten problems related to difficulties faced by school teachers and administrators in the implementation of various aspects of PBLS.

Materials and instrumentation

The Online training package on Scaffolded Problem Based Learning Strategy (PBLS) used the technique of Scaffolded Problem Based Learning Strategy (PBLS) to sensitize the student teachers to the Problem Based Learning Strategy (PBLS).

Measures of Cognitive load

The cognitive load subjective rating scale developed by Paas, van Merriënboer, and Adam (1994) is a self report 9 point rating scale used to measure the overall cognitive load experienced by the student teachers before, during and after the training. The scale's Cronbach's alpha is more than 0.8, indicating a high level of internal consistency and the construct validity has been established.

The scale was also used to measure the cognitive load experienced by student teachers for every problem. The overall cognitive load comprises of three aspects which are as follows:

1) Mental efforts invested in solving the problem
2) Difficulty of experience for PBLS
3) Difficulty of understanding the instructions for PBLS

Cognitive load experienced by the student teachers was also assessed through daily reflections of the student teachers in the form of a diary.

Data collection Procedure

The student teachers were given an orientation for the online training on Scaffolded Problem Based Learning Strategy (PBLS) that they were expected to undergo. After the orientation the cognitive load subjective rating scale was administered to the student teachers. Also the student teachers were expected to note down in the form of reflections the cognitive load that they would experience during the training.

The student teachers were also expected to fill the cognitive load scale for each problem and write their reflections about the cognitive load experienced by them during that problem.

At the end of the training, the cognitive load scale was administered to the student teachers and they were also expected to reflect on the cognitive load experienced by them during the training.

Data Analysis

The data collected was both quantitative and qualitative in nature. The quantitative data was analyzed by finding the means of the pretest and posttest scores of the cognitive load experienced by the student teachers before and after the treatment. The dependent t test was used to test the null hypothesis that there would be no significant difference in the pretest and posttest mean scores of cognitive load experienced by the student teachers before and after the training,
The means of the cognitive load experienced for individual problems were compared.

The qualitative data was analyzed with respect to the cognitive load experienced by the student teachers.

RESULTS

The results are divided into two categories

I) Cognitive load experienced by student teachers before and after the training programme

II) Cognitive load experienced by student teachers as they move from Problem one to Problem ten

I) Cognitive load experienced by student teachers before and after the online training on Scaffolded PBLS

1) Overall cognitive load experienced by the student teachers for PBLS before and after the online training on scaffolded PBLS

Table 1. Dependent Samples Statistics

	Mean Score	N	Standard Deviation	Standard Error of Mean
Pretest	15.2439	41	3.1367	0.48987
Posttest	13.4878	41	3.29486	0.51457

Table 2**. **Dependent Samples t test

	Difference between Means	Standard Deviation	$\sigma_{\bar{x}}$	r	df	t ratio	LOS
Pretest Posttest	1.75610	4.27657	0.66789	0.116	40	2.629	0.05

Dependent sample t test was calculated to compare the mean scores of the Overall cognitive load experienced by student teachers for PBLS before and after the Online training on Scaffolded PBLS.

Table 2 reveals that for the df=40, calculated t is greater than the tabulated t i.e calculated t =2.629 and the tabulated t=2.02. Hence the null hypothesis is rejected and it can be concluded that there is significant difference between the mean scores of the Overall cognitive load experienced by student teachers for PBLS before and after the online training on Scaffolded PBLS.

The components of the overall cognitive load comprises of the following:

1. Mental efforts invested in solving the problem before and after the online training on scaffolded PBLS

Table 3. Dependent Samples Statistics

	Mean Score	N	Standard Deviation	Standard Error of Mean
Pretest	6.0488	41	0.89306	0.13947
Posttest	5.4146	41	1.43136	0.22354

Table 4. Dependent Samples t test

	Difference between Means	Standard Deviation	$\sigma_{\bar{x}}$	r	df	t ratio	LOS
Pretest Posttest	0.63415	1.77139	0.27664	0.11	40	2.292	0.05

Dependent sample t test was calculated to compare the mean scores of the mental efforts invested in solving the problem before and after the Online training on Scaffolded PBLS

Table 4 reveals that for the df=40, calculated t is greater than the tabulated t i.e calculated t=2.292 and the tabulated t=2.02. Hence the null hypothesis is rejected and it can be concluded that there is significant difference between the mean scores of the mental efforts invested in solving the problem before and after the Online training on Scaffolded PBLS.

2. Difficulty of experience for PBLS before and after the online training on scaffolded PBLS by Student teachers

Table 5. Dependent Samples Statistics

	Mean Score	N	Standard Deviation	Standard Error Mean
Pretest	4.8049	41	1.70616	0.26646
Posttest	4.5122	41	1.51858	0.23716

Table 6. Dependent Samples t test

	Difference between Means	Standard Deviation	$\sigma_{\bar{x}}$	r	df	t ratio
Pretest Posttest	0.29268	2.11239	0.32990	0.146	40	0.887

Dependent sample t test was calculated to compare the mean scores of the difficulty of experience for PBLS before and after the Online training on Scaffolded PBLS

Table 6 reveals that for the df=40, calculated t is smaller than the tabulated t i.e calculated t=0.887 and the tabulated t=2.02. Hence the null hypothesis is accepted and it can be concluded that there is no significant difference between the mean scores of the difficulty of experience for PBLS before and after the Online training on Scaffolded PBLS.

3. Difficulty of understanding the instructions for PBLS before and after the training by the student teachers

Table 7. Dependent Samples Statistics

	Mean	N	Standard Deviation	Standard Error of Mean
Pretest	4.3902	41	1.51456	0.23654
Posttest	3.5610	41	1.44998	0.22645

Table 8. Dependent Samples t test

	Difference between Means	Standard Deviation	$\sigma_{\overline{x}}$	r	df	t ratio	LOS
Pretest Posttest	0.82927	1.84259	0.28776	0.228	40	2.882	0.05

Dependent sample t test was calculated to compare the mean scores of the difficulty of understanding the instructions for PBLS before and after the Online training on Scaffolded PBLS

Table 8 reveals that for the df=40, calculated t is greater than the tabulated t i.e calculated t =2.882 and the tabulated t= 2.02. Hence the null hypothesis is rejected and it can be concluded that there is significant difference between the mean scores of the difficulty of understanding the instructions for PBLS felt before and after the Online training on Scaffolded PBLS.

FINDINGS AND DISCUSSIONS

The findings reveal that the scaffolds provided are effective in reducing the Overall cognitive load experienced by student teachers prior to the online training package on Scafolded PBLS with respect to

- the mental efforts to be invested in solving the problem by student teachers prior to the training.
- the difficulty of understanding the instructions for PBLS experienced by student teachers prior to the training.

The effectiveness of the package in reducing the cognitive load may be attributed to the, provision of variety of scaffolds whenever required.

Findings also reveal that the scaffolds are not effective in reducing the difficulty of experience for PBLS felt by the student teachers prior to the online training on scaffolded PBLS. The reasons for the ineffectiveness of the package may be attributed to the load experienced for completion of tasks as part of the B.Ed programme that the student teachers were undergoing along with the Online training which made the student teachers experience the same difficulty for PBLS that they had perceived before undergoing the course.

Qualitative analysis of the reflections about cognitive load data collected before the online training on scaffolded PBLS revealed the following:

1) Student teachers who felt the cognitive load that they would experience while undergoing the online training would be high gave the following reasons:

- PBLS would involve solving problems which would involve lot of thinking.
- They would have to learn by solving problems which they have not experienced before
- There was fear of the unknown
- They had not experienced such online training before
- They also felt they would enjoy and explore new experience once they start the online training on scaffolded PBLS.

2) Student teachers who felt the cognitive load that they would experience while undergoing the online training on scaffolded PBLS would be moderate gave the following reasons:
   - It would require dedication and commitment
   - They felt the problems would be difficult
   - There was problem solving involved
   - There would be use of new technology

Qualitative analysis of the reflections about cognitive load data collected after the online training on scaffolded PBLS revealed the following:

1) Student teachers felt that the cognitive load they experienced while undergoing the online training on scaffolded PBLS was high initially but reduced later once they understood the problems and arrived at solutions.
2) Student teachers who felt the cognitive load that they experienced while undergoing the online training was moderate gave the following reasons:

- Load felt due to technology and learning new concepts but became a routine activity later
- Load felt was not for solving problems but meeting deadlines
- They took more time to understand and solve when loaded with other tasks

The other student teachers also expressed that they were excited about the new experience gained by them which was possible for them due to the instructions given, interesting problems and the resources provided and were looking forward to the more such training programmes. These student teachers did not mention about any cognitive load experienced by them.

II) Cognitive load experienced by student teachers for individual Problems

Table 9. Means of the cognitive load experienced by student teachers for individual problems during the training

Problem	1	2	3	4	5	6	7	8	9	10
Mental effort invested in solving the problem	6.5	5.05	4.75	5.05	5.2	5	4.95	4.55	4.7	4.1
Difficulty of the experience	5.3	4.1	4.1	4.25	4.55	4.1	4.1	3.5	4.1	3.25
Difficulty in understanding the instructions	4.75	4.2	3.8	4.15	4.65	4.15	4	3.85	3.9	3.65
Overall cognitive load	16.45	13.25	12.55	13.35	14.3	13.15	12.95	11.8	12.6	10.9

Fig 1. Graph representing regression of overall cognitive load

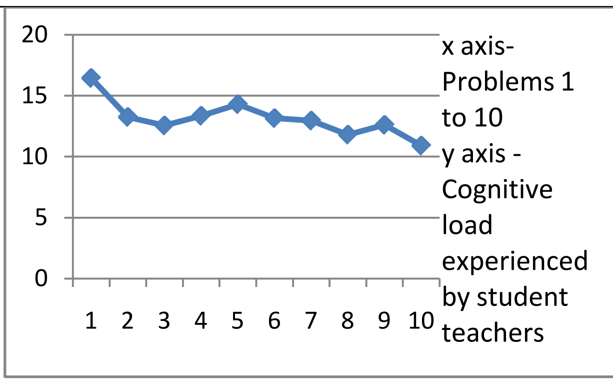


Fig 2. Graph representing regression of mental efforts invested in solving problems

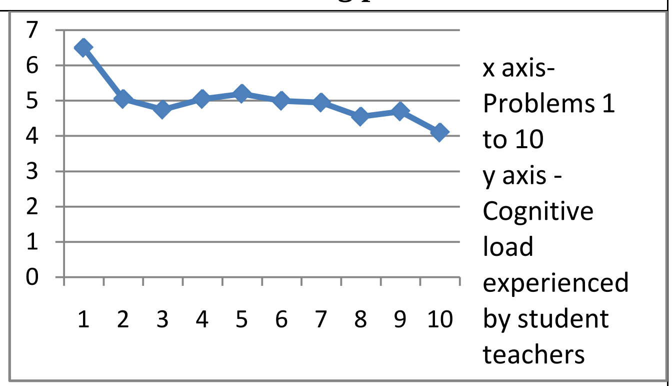
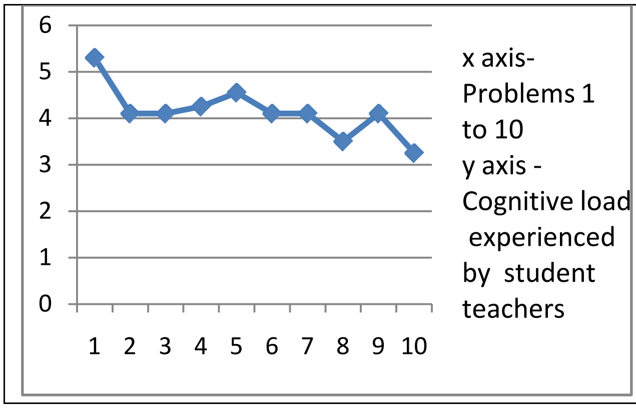
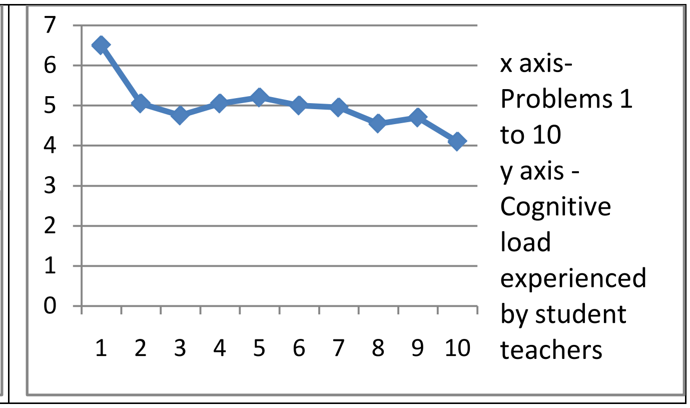


Fig 3. Graph representing regression of difficulty of the experience for PBLS

Fig 4. Graph representing regression of difficulty of the understanding of instructions during the course





Cognitive load experienced by student teachers while working on individual problems

Problem 1	High to moderate cognitive load as new to the activities and online delivery of the programme
Problem 2	Lesser cognitive load felt as student teachers became aware and confident of dealing with the problems
Problem 3	Experienced high cognitive load as learning issues were to be generated
Problem 4	Moderate to high cognitive load experienced as were busy with other activities of B.Ed programmes and were searching for more resources
Problem 5	Low to moderate cognitive load and had started to enjoy the process of problem
Problem 6	solving
Problem 7	No to low cognitive load experienced as had acquired the skills of dealing with
Problem 8	the problems
Problem 9	No to very low cognitive load experienced
Problem 10	

The graphs indicate that there is gradual reduction in the cognitive load experienced by student teachers as they proceed from problem one to ten. The increase in cognitive load experienced during problems four, five and six maybe attributed to the hectic schedule of the B.Ed programme while working on those problems.

SUMMARY AND CONCLUDING DISCUSSIONS

To sum up, there is significant difference between the mean scores of pre test and post test cognitive load experienced by student teachers. This is also supported by the regression of mean scores which indicates that there is a gradual reduction in the means scores of the cognitive load experienced by student teachers as they move from problem one to problem ten. Also qualitative findings indicate that the number of student teachers who experienced high cognitive load before the training is more as compared to students who experienced high cognitive load at the end of the training. Also the cognitive load was attributed to the time constraints and technical issues but the training was found to enjoyable, interesting and exciting by a majority of student teachers. Thus the findings are in line with the studies conducted by Jonassen (2003), Kischner (2002) that situations wherein deep learning occurs and the acquisition of cognitive schemata that enables categorizing the problem, choosing the correct procedures to apply and regulating problem solving are cognitively demanding. The findings are also in accordance with the findings of Renkl, et al. 1998, Bunch & Chase, 2003; Renkl et al. 2009; Danilenko, 2010, Yen-Ting Lina & Yi-Chun Linb, 2015 and Thomas et al. 2016, wherein scaffolds reduce the cognitive load of learners. Also the findings reflect the views put forth by Jonassen & Driscoll (2003) that the use of computer-based instruction and hypermedia environments may increase the chance of learner cognitive overload. Based on the above findings the researchers recommend incorporating clear instructions, multimedia resources, scaffolds, opportunities for collaborative learning in online training packages based on constructivist approach for development of 21st century skills in learners especially the pre service and in service teachers.

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Conflict of Interests

The author declared no conflict of interests.

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