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EFFECTIVENESS OF INSTRUCTIONAL DESIGN FRAMEWORK BASED ON COGNITIVE LOAD THEORY FOR CLINICAL SKILLS TRAINING

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Purpose: Cognitive load theory (CLT) is receiving increased recognition in medical education and it was cited as an important theoretical framework for simulation-based medical education. Simulated learning environments can place a high demand on the cognitive resources of the learners, hence, we aimed to design an instructional framework to optimise the total cognitive load imposed on the medical students during their clinical skills training in the clinical skills laboratory. **Method:** This study is a quasi-experimental post-test design. The sampling technique was purposive sampling, which included year 2 students at the Faculty of Medicine-Suez Canal University population. The study was conducted in the clinical skills and simulation laboratory. The intervention group received a developed instructional design framework based on CLT. The control group learned with the ordinary teaching method without any intervention. The cognitive load was measured using the Cognitive Load Inventory (CLI) immediately after the training session for both groups. Furthermore, students' achievement in the clinical skill laboratory was compared in both groups. **Findings:** The total cognitive load is lower in the group that received the developed instructional design than that of the control group, and this result was statistically significant. Also, the performance of the intervention group is higher than in the control group. **Implications for research and practice:** The developed instructional design framework is a potentially useful guide for managing students' cognitive load in the clinical skills training session.

Keywords: cognitive load theory; clinical skills training; instructional design; working memory' simulated environment.

Introduction

Simulated learning environments place a high demand on the cognitive resources of the learners' working memory. Emotions experienced by students in a simulated environment will affect what they learn Tremblay et al., (2017). Most studies in this area focused on measuring CLT, or testing contributors to this construct, however, little research worked on developing an instructional framework based on CLT especially in a clinical simulated environment.

CLT was first described by Sweller (1988). It represents an important learning theory. CLT is an example of a wide variety of theories adopted by medical education from other fields as originated in educational psychology Kalyuga (2011). This theory explains learning according to three important aspects: the types of memory (working and long-term memory), the learning process, and the forms of cognitive load that affect our learning Sweller (1988). The main assumption of CLT is that working memory and information processing is limited, which implicates that cognitive load exceeding the individual learner's cognitive capacities leads to cognitive overload Sweller (1988). Hence, CLT makes specific instructional design prescriptions for managing working memory load as a key issue for successful learning and performance Kalyuga (2011). Despite the increasing part of CLT research, most of the data, available to support the theory, comes from experiments in high school and college learners in traditional learning environments De Jong (2010). Recently, CLT is being increasingly cited as an important theoretical framework for simulation-based medical education, because simulated learning environments can place a high demand on the cognitive resources of the learners Reedy (2015).

Evolutionary psychology in CLT emphasises the distinction between primary source of knowledge and secondary source of knowledge which has an instructional impact. Primary knowledge is naturally, unconsciously, and easy to acquire like learning to communicate with others and learning a native language. On the other hand, secondary knowledge needs explicit instruction to be acquired Kirschner et al. (2018).

The recent researches in medical education focused either on cognitive load measurement and the development of measurement tools Naismith, et al., (2015); Sewell et al., (2016), or testing contributors to cognitive load. Other studies explored the relationships between CLT and other constructs such as emotions during simulation training. Some others studied the effect of adopting principles of working memory theory, such as integrating information from multiple sources, to adjust the distribution of attentional focus which in turn will explain, clarify, and support CLT Sepp et al., (2019). Nevertheless, there has been little research that worked on the development of an instructional design, based on CLT, specifically during clinical skills training particularly in health simulation education Fraser et al., (2012).

Numerous empirical studies have demonstrated that traditional instruction can and should be re-designed according to the principles of CLT, and this re-design results in better learning. Fraser et al., (2015); Van Merriënboer et al. (2003); Van Merriënboer and Sweller (2010). Since theory-based instructional design is a top priority in medical education Naismith et al., (2015), CLT can provide a useful conceptual framework for understanding learning processes and can be used as a guide for teaching clinical skills in a simulated setting. In addition, understanding and use of CLT can help to achieve a more positive learning outcome for learners, and make a more robust and educationally sound learning environment Paas et al. (2003).

CLT is relevant to complex learning settings such as health profession education. The main aim of instructional design is to match intrinsic load to the level of learners, minimise extraneous load, and optimise German load Sewell et al., (2019).

The main hypothesis in this study is that a framework based on CLT for teaching in a simulated environment will improve total cognitive load.

CLT was adopted in this study aiming at developing an instructional design framework to optimise the total cognitive load imposed on the medical students during their clinical training in the clinical skills laboratory.

Methods

Research Design: In this study a quasi-experimental post-test design was applied; in which the participants were divided into two groups (intervention and control groups). Abdominal examination was selected as the suitable skill for the study because it is a complex learning task and has a high cognitive demand. In addition, it is one of the most frequently performed physical examinations during medical studies and after graduation during clinical practice. The intervention group received the developed instructional design framework. The control group learned with the conventional teaching method without any intervention. In the conventional method, students are divided into groups consisting of eight to twelve students with one tutor from the same gender. The training is preceded by watching a video demonstrating the clinical skills performed by an expert. Then, the tutor begins to demonstrate the skill with one student as a patient. He demonstrates the skill with an explanation. Finally, students perform the skill on each other under the guidance of their tutor.

Sample/ participants. The sampling technique was a purposive sampling from year two students. The cognitive load and the performance of both intervention and control groups were measured after the end of a clinical skill training session.

Table 1 illustrates the steps of the instructional design framework that was developed in the study, concerning its role in managing the cognitive load imposed by the students' working memory during the clinical training session.

Table 1. Instructional design framework for abdominal examination

Stage of training	**Actual steps**	**Strategies for Managing Cognitive Load**	**The target cognitive load**
Pre-session (a day before the session)	• A clinical examination video was shared with the students. • A soft copy of the abdominal examination training guide was sent to the students.	Segmentation & pretraining	Intrinsic load
The session	• The tutor ensures that students are familiar with the setup of the simulated environment • The tutor ensures that students are familiar with the process of the training session. • The tutor ensures the absence of any distractors in the learning environment.	Manage emotions & Avoid split attention	Extraneous load
	Gagne's nine events: 1.Gaining attention by clinical case scenario (paper form)	Manage emotions & Pretraining	Extraneous load & Intrinsic load
	2.Informing the learner of the objectives they are expected to achieve by the end of the session.	Pretraining & segmenting	Intrinsic load

	3.Stimulating recall of prerequisite learning.	Activation of learners' prior knowledge	Germane load
	4.Presenting the stimulus material. (Demonstration)	Worked examples	Extraneous load
	5.Providing learning guidance. (Deconstruction & comprehension)	Worked examples - Dual modality	Extraneous load
	6.Eliciting the performance. (Performance & self-explanation)	Self-explanation	Germane load
	7.Providing feedback. (Pendleton model) 8.Assessing the performance 9.Enhancing retention and transfer.		Germane load

Preparation of The Scientific Materials

A paper form case was formulated to draw students' attention and promote their participation by engaging them. In addition, A guide for the skill (abdominal examination) was developed and sent to students before the clinical training session. It included a simplified illustration of anatomy and presented a structured sequence of abdominal physical examination. A video for abdominal examination was selected and reviewed by a subject matter expert to ensure its matching with the abdominal examination checklist. Photos for abnormal abdominal findings were selected and reviewed by a subject matter expert. They are printed for each class to be used in the session. A clinical skills training tutor guide was developed by the researcher and reviewed by medical educationists and subject matter experts. This guide aims to help each tutor to teach clinical skills and moderate the clinical skills training session in a way to optimise and improve the total cognitive load. A briefing session for ten clinical skills lab tutors was conducted to orient them with the newly developed instructional design framework. Furthermore, they were trained on using the Peyton model for teaching clinical skills Qutieshat (2018), and the Pendleton model for giving feedback Hosseinsabet (2017), aiming at standardising clinical skills teaching. By observation of the classes, the sessions ran as follows:

1. At the beginning of the session, the tutor ensured that students were familiar with the setup of the simulated environment and the process of the training session.
2. Then, the tutor asked the students to read the clinical scenario and think about the next step that they would do with the patient.
3. After that, the tutor guided them to discuss the importance of abdominal examination its indications, and its steps.
4. Then, the tutor informed the students of the objectives they are expected to achieve by the end of the session.
5. Ten minutes were allocated to interactive discussion through asking questions about relevant anatomy of the abdomen, and other questions.
6. Then, the tutor demonstrated each element of the abdominal examination without any explanation.
7. The demonstration video of the abdominal examination was played after that without interruption. Then the tutor repeated the steps of the abdominal examination, this time describing all necessary sub-steps.
8. Each student performed the abdominal examination under the tutor's supervision while describing the steps.
9. Then the tutor gave the students constructive feedback following the Pendleton model.

Gagne model (1992) was used as a framework for our instructional design during the session Buscombe (2013); Khadjooi et al., (2011). Gagne's nine events of instruction in combination with the Peyton model for teaching psychomotor skills Qutieshat (2018) and Pendleton model for giving constructive feedback were used in the planning of the teaching sessions to optimise the cognitive load that impacts students ' training in the clinical skill laboratory Hosseinsabet (2017).

Instruments and procedures. The cognitive load was measured using the Cognitive Load Inventory (CLI). It was modified from the Cognitive Load Inventory for Colonoscopy (CLIC) Sewell et al., (2016), which is a validated self-reported questionnaire. Written permission was obtained from its developer through e-mail before the study.

The Cognitive Load Inventory is a twenty-item validated self-reported questionnaire used for the measurement of intrinsic load, extraneous load, and germane load. It is a ten-point Likert scale ranging from 'strongly disagree' to 'strongly agree' which measures participant's subjective ratings of the listed items: items 1-9 measure the intrinsic load; items 10-15 measure the extraneous load; and the remaining items measure the students' germane load.

Two weeks after the intervention, an objective structured single assessment for abdominal examination was done. It was a low stake exam which does not affect the students' overall performance. Each student in the two groups (intervention and control) was assessed using a structured abdominal examination checklist.

*Statistical Analysis***.** Analysis of data was performed using the Statistical Package for Social Sciences (SPSS) version 20.0. Data are presented as mean ± SD. N= 104. T-Test was used to determine the intervention and control groups' difference among intrinsic cognitive load items, Germane load, and total cognitive load. Mann-Whitney test is a non-parametric test that was used to measure extraneous cognitive load., as the data here is not normally distributed. A 95% (CI) confidence interval was used to test significance.

*Ethical issues***.** Authors declare no conflict of interest to this work, and they declare that this is the first time to publish this work. An approval from the Research Ethics Committee (Tel No: +20 64 323 0539) was obtained.

Results

This study included two groups: 52 students in each group. The results showed that there was a significant difference between the intervention and control groups in intrinsic cognitive load, t (102) = -3.61, p< 0.05 (table 2). There was no significant difference between intervention and control groups in extraneous cognitive load (table 3), but there was a significant difference between the two groups in germane cognitive load, t (102) =2.22, p< 0.05 (table 4). On comparing the total cognitive load in both groups, there was a significant difference between the intervention and control groups in total cognitive load, t (102) = -2.14, p< 0.05 (table 5).

Table 2. The difference in intrinsic cognitive load between both groups. Data are presented as mean ± SD

Group	N	Intrinsic load			
		Mean (SD)	t	df	Sig. (2-tailed)
Intervention group	52	3.6± 1.5	-3.61	102	0.00*
Control group	52	4.8±1.9			

Table 3. The difference in extraneous cognitive load between both groups

Group	N	Extraneous cognitive load			
			Mean Rank	Mann-Whitney U	Asymp Sig. (2-tailed)
Intervention group	52		49.1	1170.5	0.238
Control group	52		55.99		

º (Mann-Whitney test is a non-parametric test was used).

* (Data are statistically significant at p<0.05)

Table 4. The difference in germane cognitive load between both groups

Group	N	Germane cognitive load			
		Mean (SD)	t	df	Sig. (2-tailed)
Intervention group	52	4.76±1.93	2.22	102	**0.028***
Control group	52	3.97±1.7			

* (Data are statistically significant at p<0.05)

Table 5. The difference in total cognitive load between both groups

Group	N	Total cognitive load			
		Mean (SD)	t	df	Sig. (2-tailed)
Intervention group	52	3.44 ±1	-2.14	102	**0.035***
Control group	52	3.95 ±1.35			

* (Data are statistically significant at p<0.05)

Discussion and conclusion

The current results showed that total cognitive load was lower in the intervention group, compared to the control group, especially in intrinsic load, which indicates that knowledge and skills have been consolidated in the long-term memory. On the other hand, the germane load was higher in the experimental group, which in turn indicates that cognitive resources in the working memory have been used to facilitate learning. This difference is probably due to the effect of the implementation of the instructional design framework.

These results were consistent with other studies that used CLT as a base for instructional designs where cognitive load principles have been proven to improve learning and performance. Examples of these educational settings include a model for anatomy lectures based on CLT Hadie et al., (2018), an online emergency medicine course that reproduced a real bedside medical round in the virtual environment based on CLT de Araujo Guerra Grangeia et al. (2016), and a series of professional development workshops Haji et al., (2015); Naismith et al., (2015). Regarding the intrinsic load, a significant difference between the intervention and control groups was detected. This significant difference may be attributed to the abdominal examination training guide and the demonstrational video for the abdominal examination which were used for pre-class learning in the intervention group.

As the intrinsic load comes from knowledge and skills that have not been consolidated in long-term memory Sweller et al., (2019), these pre-session resources can reduce the burden on the working memory of novice learners by applying principles of segmenting and pre-training. As learners without prior knowledge must use a significant proportion of the limited working memory capacity in accommodating new terminology and concepts, whereas learners with prior knowledge can progress to linking new information with the existing one Van Merriënboer et al. (2003).

Interestingly, the current study found no significant difference between the extraneous load experienced by the intervention and control groups, this could be due to the familiarity of all students (including the control group) with the setup of the simulated environment and the routine process of the training session. Adhering to a practice of routine for each session will enable the creation of ''simulation schemata'', thereby freeing working memory resources for learning during the session Fraser et al., (2012). Another reason for this non-significant result is the absence of distractors in the control group's training session as well as the intervention group. It was reported that the presence of distractors in the procedural space and lack of clarity or confusing instructions can contribute to the increase of the extraneous load Choi et al., (2014). Moreover, one of the main causes of the non-significant difference between extraneous loads in the two groups could be attributed to the recorded demonstrational video that is played during the session according to the rules of the clinical skills lab for both groups. This video is considered an application for example-based learning, which is one of the strategies of extraneous load reduction. Using a sequential worked example will reduce split-attention effect among learners and decrease intrinsic and extraneous cognitive load Saw (2017).

Lastly, the results of the current study showed higher scores on the germane load scale in the intervention group. This indicates that the instructional design framework is beneficial for learning. The design used the cognitive resources available in the working memory by decreasing extraneous load and facilitating germane load. Learning requires the acquisition and automation of schemas then alterations in long-term memory Sweller et al. (2019). The clinical scenario affected the germane load through activation of prior knowledge, as it could have triggered the retrieval of information about the content that the student had already stored in long-term memory. This activation of prior knowledge might not happen if the content was presented without context Kalyuga (2009). These results agree with Bergman et al., (2015), who hypothesised that the relevance and familiarity of the context of a paper-patient case may positively influence the germane load. However, surprisingly, they found that students who studied the content with context did not perform better than students who studied the content without context. The disagreement between the current study and Bergman et al., (2015) study could be due to differences in the learner's characteristics. Students in the latter study did not have prior knowledge about the topic. They did not engage in the scenario because of the complex vocabulary of the discipline. But in the current study, students are familiar with clinical scenarios about gastrointestinal problems. This is due to the scheduled teaching of this module at the same time as teaching abdominal examination. This parallel teaching enabled them to have prior knowledge, be familiar with the context, and get easily engaged in the clinical context.

The results of the current study show that the performance of the intervention group in abdominal examination assessment was significantly higher than in the control group. This may be related to the whole instructional design framework used for teaching skills to the intervention group. Thus, it is supposed that when the cognitive load (CL) associated with a training is within the working memory capacity, learning is promoted and performance improves. In addition to the contribution of the managed total cognitive load in this significant result, there is more than one teaching strategy in the instructional design framework that could have contributed to the better performance of the intervention group. The ultimate goal of instructional design is to promote learning processes. Hence, instructional design should be focused on the task itself, the design of learning materials, and the activation of the learning processes of learners Klepsch and Seufert (2020).

Firstly, the developed clinical skills training guide which is also a reason for managing intrinsic load as mentioned before. This finding matched Kahwage Neto et al., (2017) work who showed significant improvement in the students' evaluation after training with the guide.

Secondly, the Peyton model which was used for teaching may be attributed to the improvement of the intervention group performance. This is because Peyton's Step 3 is considered as the crucial instructional step in which a combination of motor imagery and skills performance happens Krautter et al., (2015). Also, the Peyton model allowed repetition and rehearsal of the skill. The assumption of the role of the Peyton model in improving the performance of the intervention group matches several previous studies. These studies reported that teaching complex manual skills, using Peyton’s four-step approach is a useful strategy, and improves the performance of students Herrmann-Werner et al., (2013) Gradl-Dietsch et al., (2016). Furthermore, the integration of the Peyton model with the demonstrational video could be a reason for the improved performance. This finding is aligned with the results of Bjerrum et al., (2013) who showed that integrating three modeling examples performed by the instructor into the bronchoscopy simulation training, which already included an instructional video, enhanced learning outcomes by optimising cognitive load during training.

Thirdly, the printed colored photos of abnormal abdominal findings could have contributed to the improvement of the performance of the intervention group. This is because these photos showed real abdominal signs, that helped students to apply their knowledge. In addition, it helped them to make sense of the learning event, which in turn enhanced the students’ learning. Furthermore, it engaged students in an environment that reproduced the actual clinical or work environment. The importance of these photos was supported by the students’ opinions, as the majority of students agreed that printed colored photos used in the training session were helpful.

Finally, Pendleton's rules that were used by tutors to give feedback to students in the intervention group could be another cause for the superiority of their performance. This is because feedback is the most influential teaching practice that can promote motor learning. Also, it is essential for strengthening, and transfer of learning Mariani et al., (2013). This reason agreed with previous studies that have identified feedback as the critical component leading to effective learning in a simulation-based learning environment Barry Issenberg et al., (2005); Motola et al., (2013).

In conclusion, this study highlights the importance of considering a design framework based on CLT for teaching in simulated environments. As suggested by the study results, using a model for teaching clinical skills, based on CLT, will improve total cognitive load and will facilitate learning. In addition, combining this framework with other methods for teaching clinical skills, such as the Peyton model, and methods for feedback (Pendleton method) will enhance overall learners' experience. Additional research work is still needed to measure the effect of this framework on knowledge retention and transfer. Furthermore, implementing such a framework in different contexts and content would contribute to the body of knowledge about this topic.

Limitations. This study has some limitations regarding sampling, where randomisation was not possible in this work. In addition, it would be better if we measured the impact of this design longitudinally on students' performance.

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