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Original Article

Creating an engaging and stimulating anatomy lecture environment using the Cognitive Load Theory-based Lecture Model: Students' experiences

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الملخص

أهداف البحث: هناك حاجة لعمل محاضرة نموذجية تفاعلية لمادة التشريح تشرك الطلبة في عملية التعلم. تبحث هذه الدراسة في تأثير إعطاء المحاضرات بالقواعد الإرشادية الجديدة، نظرية العبء المعرفي- القائم على محاضرة نموذجية، على المشاركة المعرفية للطلبة وتحفيزهم.

طرق البحث: تم أخذ عينة عشوائية تضمنت ١٩٧ مشاركا من ثلاث مؤسسات تعليمية. حضرت المجموعة الضابطة محاضرة حرة على التشريح الإجمالي للقلب، قدمها مؤهل في علم التشريح من كل مؤسسة. وحضرت مجموعة التدخل "نظرية العبء المعرفي- القائم على محاضرة نموذجية" لموضوع مماثل، قدمت بواسطة نفس المحاضر بعد ثلاثة أسابيع. حضر المحاضرون ورشة عمل عن نظرية العبء المعرفي- القائم على محاضرة نموذجية مما سمح لهم بالاستعداد للمحاضرة خلال ثلاثة أسابيع. تم قياس التصنيف الشخصي للطلبة على مشاركتهم المعرفية والتحفيز الذاتي فورا بعد المحاضرة باستخدام استبانة مشاركة المتعلمين وتحفيزهم التي تم التحقق من صحتها. تم تحليل الفروق بين المتغيرات، وتم تثليث النتائج مع نتائج مناقشات مجموعة التركيز التي استكشفت تجربة الطلبة عند حضورهم المحاضرة.

النتائج: كان لدى مجموعة التدخل مستوى أعلى بكثير للمشاركة المعرفية من المجموعة الضابطة، ولكن، لم يتم العثور على فرق كبير في نطاق التحفيز الذاتي. بالإضافة إلى ذلك، لمست مجموعة التدخل تجربة تعلم جيدة من المحاضرات.

الاستنتاجات: حفزت القواعد الإرشادية بنجاح المشاركة المعرفية للطلبة وخبرة التعلم، مما يدل على التحفيز الناجح للموارد ذات الصلة للطلبة. تحفيز هذه الموارد المعرفية ضروري لنجاح المعالجة المعرفية خصوصا عند تعلم موضوع صعب كعلم التشريح.

الكلمات المفتاحية: نظرية العبء المعرفي؛ المحاضرة؛ المشاركة المعرفية؛ التحفيز الذاتي؛ التعلم الذاتي الملموس

Abstract

Objective: There is a need to create a standard interactive anatomy lecture that can engage students in their learning process. This study investigated the impact of a new lecturing guideline, the Cognitive Load Theory-based Lecture Model (CLT-bLM), on students' cognitive engagement and motivation.

Methods: A randomised controlled trial involving 197 participants from three institutions was conducted. The control group attended a freestyle lecture on the gross anatomy of the heart, delivered by a qualified anatomist from each institution. The intervention group attended a CLT-bLM-based lecture on a similar topic, delivered by the same lecturer, three weeks thereafter. The lecturers had attended a CLT-bLM workshop that allowed them to prepare for the CLT-bLM-based lecture over the course of three weeks. The students' ratings on their cognitive engagement and internal motivation were evaluated immediately after the lecture using a validated

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Learners' Engagement and Motivation Questionnaire. The differences between variables were analysed and the results were triangulated with the focus group discussion findings that explored students' experience while attending the lecture.

Results: The intervention group has a significantly higher level of cognitive engagement than the control group; however, no significant difference in internal motivation score was found. In addition, the intervention group reported having a good learning experience from the lectures.

Conclusion: The guideline successfully stimulated students' cognitive engagement and learning experience, which indicates a successful stimulation of students' germane resources. Stimulation of these cognitive resources is essential for successful cognitive processing, especially when learning a difficult subject such as anatomy.

Keywords: Cognitive Load Theory; Cognitive engagement; Internal motivation; Lecture; Self-perceived learning

Introduction

Anatomy is a medical subject that elaborates on the macroscopic and microscopic structures of a normal human body. It is regarded as the central pillar of medical knowledge; medical students are required to know the usual anatomical structures in detail prior to studying subjects related to clinical applied knowledge.[1] Despite a continuous search for an effective teaching strategy in anatomy education, lecturing, which many educators have claimed is ineffective, has prevailed as a teaching method used to deliver anatomy information to medical students.[2–5] This is because anatomy is commonly perceived by medical students as a cognitively challenging subject that requires teachers' direct guidance during learning.[6,7] In fact, the delivering of anatomy lectures has become a common practice in many medical schools prior to other active learning activities such as cadaveric dissection and practical, tutorial, seminar, or problem-based learning.

As opposed to traditional anatomy lectures, modern anatomy lectures have been continuously improvised to suit the emerging changes of medical curriculum. The use of lectures is limited to delivering introductory concepts of an anatomy topic, and it is sometimes integrated with other medical subjects such as physiology, pathology, and radiology.[8,9] Clinical applied anatomy is often introduced during pre-clinical anatomy classes in order to stimulate students' interest and appreciation of value towards the subject.[10] To assist in the visualisation of anatomical structures, especially in situations where there is significant decline in cadaveric dissection classes,[11–13] anatomy educators have begun to use technology-based teaching aids during anatomy lectures.[2,14–16] However, the dynamic visualisation of anatomical structures using these teaching aids does not always benefit learning, especially when the learners are novices.[17,18]Therefore, it is essential to find a way to create a stimulating and engaging lecturing environment that can promote the visuospatial ability of the students.

In the context of human cognition, visuospatial ability reflects the capacity of working memory to process visuospatial input.[19] Prior to this cognitive process, the visual stimulus is first received by the sensory memory, which holds the information for less than one second.[20,21] With the presence of learner's 'attention focus', the visual information can be transferred from sensory to working memories. Within its limited capacity, the working memory — which contains both visual (visuospatial sketchpad) and auditory (phonological loop) centres[19] — converts the information into cognitive schema, which is an organised form of information,[22] and transfers the schema into the long-term memory for permanent storage.[23] Once the schema is stored in long-term memory, actual learning is said to occur.[24] Hence, to achieve the actual learning during a lecture, it is imperative to create a lecturing environment that can stimulate students 'attention focus' and foster deliberate investment of the working memory resources for schema construction and storage. This can be done by applying the evidence-based lecturing strategies of the Cognitive Load Theory-based Lecture Model (CLT-bLM),[25] which was developed using the principles of the Cognitive Load Theory (CLT) and the Cognitive Theory of Multimedia Learning (CTML).

CLT and CTML are instructional design theories that aim to produce teaching instruction methods — including multimedia instruction — that are intelligible to learners.[26] The central tenet of these theories is to align the design of these instructions with human cognitive architecture and function.[27] In cognitive science, actual learning is said to occur when the learner's working memory has successfully converted newly received information into cognitive schema, an organised form of information that can eventually be transferred and stored in the learner's long-term memory.[23,24] Unfortunately, the working memory has a very limited capacity, as it can only hold and process a limited amount of information at one time[28,29]; if this amount is exceeded, the result is unsuccessful schema construction. Hence, to ensure successful schema construction and storage, instruction should be designed and delivered in a manner that does not exceed the working memory capacity.

In order to create such instruction, it is paramount to ensure an appropriate selection of information that is to be incorporated into the instruction. In the CLT context, any input that is introduced during teaching and learning activities is known as the cognitive load.[30] The traditional formulation of CLT described three type of loads: intrinsic, extraneous, and germane loads.[30] The intrinsic load (IL) refers to input related to instructional content and therefore reflects the complexity of the instruction.[17,31] In other words, a difficult subject imposes a higher IL to learners compared to a less difficult subject. In addition, IL also depends on the learner's prior knowledge, as those who have prior knowledge on the subject matter experience lower IL than those without it.[31] The extraneous load (EL) is imposed by

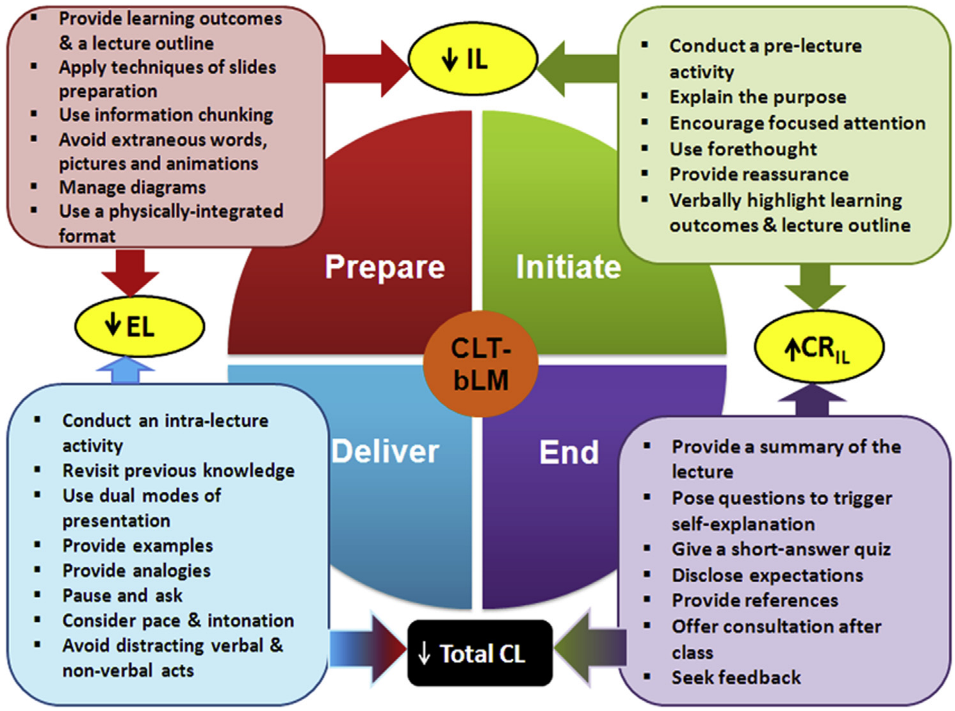

Figure 1: The Cognitive Load Theory-based Lecture Model.

any form of distractors during learning; hence, this load is often regarded as the 'unwanted' or 'bad' load.[32] By minimising the EL, capacity in the working memory can be spared for processing the IL.[33] In contrast, the germane load (GL) is described as the 'good load', as this load is regarded as contributing to actual learning.[30] Having said that, CLT researchers have argued about the existence of GL, as they have demonstrated theoretical and empirical difficulties in separating the GL from the IL.[34–37] Therefore, GL is no longer included in the new formulation of CLT; instead the germane working memory resources are regarded as being invested in the processing of the IL.[26] Hence, the aim of CLT-based instruction is to manage the IL according to the level of learners' expertise, reduce the EL, and increase the germane cognitive resources that can process the IL.[33]

Likewise, the CLT-bLM is a four-phased ('Prepare', 'Initiate', 'Deliver', and 'End') lecturing guideline that contains 27 strategies of effective lecturing, whereby each strategy adopts at least one CLT effect or CTML principle that reduces the IL and EL and increases cognitive resources to process the IL (CR_{IL}) (Figure 1). The CLT and CTML principles are not based on random assumptions; rather, they have been tested in many well-designed experimental studies and found to be effective.[38–42] For instance, the strategies of the 'Prepare' and 'Initiate' phases of CLT-bLM reduce IL through the application of the isolated-interacting elements effect of CLT and the pre-training and segmenting principles of the CTML. These three principles reduce the complexity of the topic while stimulating learners' prior knowledge. The EL is reduced through strategies in the 'Prepare' and 'Deliver' phases that adopt several CLT effects and CTML principles that have been proven to successfully reduce the EL (i.e. modality effect, split-attention effect, redundancy effect, worked example effect, guidance fading effect, completion example effect, signalling principle, contiguity principle, and coherence principle). The CR_{IL} is increased through strategies of the 'Initiate' and 'End' phases of the guideline that adopt the imagination effect, personalisation principle, and voice principle.

The CLT-bLM was proven to be effective in a study conducted by Hadie and colleagues[25]; this study evaluated the cognitive load of pre-clinical-year medical students after attending a CLT-bLM-based lecture on a difficult anatomy topic. It measured the students' cognitive load through direct (i.e. measurement of IL and EL through students' subjective ratings) and indirect (i.e. measurement of knowledge acquisition and retention) measures. The direct measurement of cognitive loads involves subjective ratings by learners on their individual or total cognitive loads, mental effort levels, and task difficulty,[43–45] while indirect measurement entails objective evaluation based on the outcome, input, and learning process-related variables.[46] Nevertheless, the objective measurement of learning outcomes was not a valid measurement on its own, as researchers could not determine whether the achieved learning outcome was due to the differences in cognitive load levels or alteration in other learning-related variables.[46] Instead, this form of measurement is commonly combined with other cognitive load measurements, as the combination increases the validity of cognitive load measurement through convergent validity evidence (i.e. relation to other variables).[47] Although the study by Hadie et al.[25] provides sufficient evidence on the efficacy of the CLT-bLM – as it has been proven to result in a reduction of IL and EL, as well as in increased knowledge acquisition and retention – it is important to explore the level of mental energy invested by the learners during exposure to a CLT-bLM-based lecture, as this can provide additional information on CR_{IL}, indicating actual learning.

Hence, this study was undertaken to investigate the impact of a CLT-bLM-based lecture on students' cognitive engagement and internal motivation level, which reflect the CR_{IL}.[26] The results were triangulated with the findings of focus group discussions that explored students' experiences while attending the research lecture.

Materials and Methods

Study design, study population and sampling method

This study utilised a randomised controlled trial with a parallel design. Our target population consisted of pre-clinical-year medical students from all Malaysian public medical schools. Purposive sampling with a homogeneous sampling method was employed to select subjects from a sampling frame that consisted of three medical schools. These schools use an integrated system-based curriculum, where anatomy is taught in the first two years of the medical degree programme. They teach anatomy using lectures, practical sessions, and tutorials. This study received three ethical approvals from the Human Research Ethics Committees of the participating institutions.

Sample size

The sample size for these variables were estimated using the Cohen Statistical Power Analysis,[48] as there is a scarcity of data on the comparison of cognitive engagement and internal motivation levels between two independent groups from a well-designed lecture-based experimental study. To achieve an optimum power of 0.80 (a smaller value than 0.80 would increase the Type II error and a larger value would increase the number of participants, which might not be necessary for this study) with the assumption of medium effect size ($d = 0.5$, an approximation of the observed intervention effect in various fields) Cohen[48] suggested that a sample size for Analysis of Variance (ANOVA) with two groups should contain 64 subjects per group with a Type I error (α) of 0.05 (Appendix A). Cohen[48] also suggested a medium effect size, as that has been noted to represent an effect that is observable to the naked eye of a careful observer. However, the sample size was readjusted to 138 subjects per group to address a 20% dropout rate and an 80% non-response rate expected in this study as the participants were invited through individual postal invitations.[49,50]

Group allocation

After the briefing session, 197 students agreed to participate in this study. Written consent forms were obtained from the participants, who were allocated into control and intervention groups using the stratified random allocation method to control the cognitive biases (i.e. gender, entrance qualification and band score for Malaysian University English Test [MUET]). The group allocation was performed by an independent research assistant and was made blind to the participants throughout the study period.

Lecture sessions

On Day-1 of the intervention, the control group at each institution attended a freestyle lecture on the topic of the gross anatomy of the heart, which was delivered by an anatomy lecturer from their own institution; the intervention group attended a CLT-bLM-based lecture on a similar topic that was delivered by the same lecturer on Day-21 of the intervention. The selection of lecture topic was based on students' lack of prior exposure to the topic in their actual medical curriculum.

The lecturers are qualified Malaysian anatomists who hold a Master of Science degree in Clinical Anatomy, have more than five years of experience teaching anatomy to undergraduate medical students, and have a good English proficiency level with a band score on the International English Language Testing System (IELTS) of higher than seven. The lecturers were given autonomy to prepare and deliver the freestyle lecture in the form that they normally practised. The researchers observed that each of the three freestyle lectures was didactically delivered with no break in the session or intra-lecture activities. The learning outcomes were not explicit, the slides were wordy, and the diagrams used in the lectures were filled with extraneous elements (e.g. unnecessary labels and animations). In addition, there was no room for student–lecturer interactions, as the lecturers were occupied with their teaching.

One day after the freestyle lecture, the lecturers attended a workshop on preparing and delivering a CLT-bLM-based lecture, which was conducted on Day-2 of the intervention. Subsequently, the lecturers were given three weeks to prepare a CLT-bLM-based lecture on a similar topic, which was to be delivered to the intervention group on Day-21 of the intervention. One day prior to the lecture, a mock lecture session was conducted at each institution to ensure that the lecturers had applied more than 80 percent of the CLT-bLM principles into their lectures. The lecture delivery for both groups in each institution was conducted in the same air-conditioned lecture hall that was fully equipped with audio-visual aids to ensure comparable learning environments.

Data collection and analysis

The data collection was performed using a validated instrument, the Learners' Engagement and Motivation Questionnaire. The inventory contains five items of cognitive engagement construct – developed by Webster and Ho[51] – and 12 items of internal motivation construct that were obtained from the domains 'effort and importance' and 'value and usefulness' of the validated Intrinsic Motivation Inventory.[52] The inventory used a seven-point semantic scale ranging from 'not at all true' to 'very true'. The questionnaire was distributed to the students immediately after the lecture session and they were asked to rate their perceptions of the listed items. Cognitive engagement and internal motivation scores were determined by calculating the mean score of the six items of the engagement construct and the twelve items of the internal motivation construct, respectively. An independent-t test was applied to test the between-group difference of the aforementioned variables using the Statistical Package for the Social Sciences (SPSS) software, version 22 (IBM Corp., Armonk, NY).

Focus group discussion

A total of 51 volunteer participants from both the intervention and control groups attended six separate focus group discussion sessions that explored students' experiences attending the research lecture. All sessions were conducted within two days post lecture. To ensure the discussion pertained to the allocated lecture intervention, each session was attended by five to six participants who had undergone a similar lecture session, and each session was moderated by a trained researcher who had previous experience conducting focus group discussion. To provide a comfortable environment, each session was conducted in a private meeting room and refreshments were provided for the participants. A circular seating arrangement was set up to promote a sense of equality among the participants. Each participant's pseudonym (nickname) was tagged in front of each seat to ensure participants' anonymity and to facilitate group interaction.

The session began with a brief introduction by the moderator, who introduced herself as a researcher with a minor role in the students' academic activities. The aims, expectations, and general rules of the focus group discussion were emphasised to encourage free-flow discussion and interaction among members. A verbal consent was obtained for audio-recording of the session, and the participants were ensured that their anonymity would be protected.

The moderator initiated the discussion by asking the students to complete the following sentence: 'The research lecture this morning/yesterday was … '. The subsequent discussion was moderated according to the participants' response to the trigger. The entire focus group discussion was recorded using a digital voice recorder, and field notes were taken to document the non-verbal reactions of the participants. All sessions lasted about 50–60 min. At the end of each session, the moderator summarised the major important points that had emerged from the discussion, and the participants were given the opportunity to confirm the summary and to make additional remarks on the statements. The moderator thanked the participants for their cooperation and discussed her willingness to share the research findings with the participants.

Upon completion of each focus group discussion session, the audio-recorded verbal discussion was transcribed into an electronic format using ATLAS.ti software, version 7.5 (Scientific Software Development, GmbH, Berlin). The text analysis tool in the ATLAS.ti software was used to perform a 'first cycle in-vivo coding',[53] of which the transcripts were chunked and decoded into smaller units according to phrases or keywords used by the participants. The preliminary codes determined during the focus group sessions were used as transitional links between the raw transcripts with the keywords. The keywords and phrases that shared similar features were encoded together into a common category, termed as open coding. The second stage involved 'second cycle pattern coding',[53] where the open codes that showed similar features and connections were then grouped under one category, termed as the axial code. At this stage, the whole open-coding framework was explored for any connection, overlapping, and duplication. During the final stage, the researcher applied the axial coding method,[53] where the content of each category and the interrelations between the axial codes were studied to develop one or more categories, termed as select codes. The select codes were then grouped into several categories according to their similarities and patterns. Throughout the coding process, the researcher journalised memos about the patterns and categories that occurred, which were subsequently used for comparison and triangulation during the data analysis, which contributed to the credibility and transferability of the data.[54,55]

Results

The dropout rate

In this study, the dropout participants were identified as those who withdrew from the study after giving their written consent to participate. Out of 197 consenting participants, 147 students (75 intervention and 72 control participants) attended the lecture session. Hence, the dropout rate of this study was 25.38%.

Students' cognitive engagement and internal motivation

The analysis revealed a significantly higher cognitive engagement score in the intervention group compared to that of the control group. However, there was no significant between-group difference in the students' internal motivation levels towards learning the topic. The results are summarised in Table 1.

Students' experience attending the research lecture

As the students expressed their feelings after attending the lecture session, it was apparent that their impression about the research lecture session had influenced their satisfaction and opinions regarding the lecture preparation and delivery. The analysis of the focus group discussion gave rise to four categories that underlay 19 select codes (i.e. subcategories), and the frequency of occurrence for each select code was calculated according to the groups (Table 2). Table 2 shows the unequal frequency of occurrence of select codes for each theme between the study groups. The percentage of occurrence for positive categories of codes (i.e. category-1: characteristics of a good lecture as perceived by students; and category-3: benefits of a good lecture for students) was higher in the intervention group, while the percentage of occurrence for negative categories of codes (i.e. category-2: characteristics of a bad lecture as perceived by students; and category-4: consequences of a bad lecture to students) was greater in the control group. This result indicates that the participants in the intervention, who had a significantly higher engagement score level compared to their counterparts in the control group, reported a perception that they had attended a good lecture and gained benefits from the lecture session. In contrast, the majority of the control group participants seemed to be dissatisfied with the lecture.

Despite not knowing which type of lecture they had received, many of the participants in the intervention group related positive feelings after attending the lecture. One student described the lecture as different from other lectures that he had previously attended, and another student was very excited because she was able to stay awake and pay attention throughout the lecture session.

> 'And then one more thing is that the flow of this lecture is quite unique. It was not something that we usually

Table 1: Difference of the students' engagement and internal motivation.

Variables	Groups; Mean (SD)		t-stats (df)	p-value	(95% CI)	Cohen effect size (d)
	Control	Intervention				
Cognitive engagement	4.618 (1.138)	5.522 (0.975)	−5.179 (145)	<0.001	(−1.250,0.559)	0.853
Internal motivation	5.595 (0.661)	5.521 (0.583)	−0.129 (145)	0.277	(−0.129, 0.277)	0.119

Independent-t-test was applied to determine means difference between the study groups. Significant level was set at 0.05; SD = Standard deviation; df = Degree of freedom; CI = Confidence interval. Cohen effect size was calculated using the Effect Size Calculator for T-Test, (Statistics, 2015). Cohen effect size thresholds: Small = 0.20; medium = 0.50 and large = 0.8, very large = 1.13 (Cohen, 1988).

Table 2: Frequency of occurrence for each select code according to groups.

Category	Select codes	Number of occurrence (n)			Frequency (%)	
		I	C	Total	I	C
Category 1: The characteristics of a good lecture perceived by students	Good lecture delivery	48	1	49	97.96	2.04
	Good diagram management	26	0	26	100.00	0
	Good teaching behaviours	37	0	37	100.00	0
	Interactive lecture	54	14	68	79.41	20.59
	Well-prepared teaching materials	60	0	60	100.00	0
Total		**225**	**15**	**240**	**93.75**	**6.25**
Category 2: The characteristics of a bad lecture perceived by students	Poor lecture delivery	8	26	34	23.53	76.47
	Poor teaching behaviours	1	15	16	6.25	93.75
	Poorly prepared teaching materials	11	27	38	28.95	71.05
	Complicated lecture	3	25	28	10.71	89.29
	Weakness of the lecture	16	28	44	36.36	63.63
Total		**39**	**121**	**160**	**24.38**	**75.63**
Category 3: Benefits of a good lecture to students	Instil good value and insight	11	1	12	91.67	8.33
	Stimulate and maintain awareness, concentration and focus attention	11	0	11	100.00	0
	Important and relevant session for medical students	26	4	30	86.67	13.33
	Increased motivation and curiosity	20	22	42	47.62	52.39
	Stimulate meaningful mental effort	12	3	15	80.00	20.00
	Stimulate meaningful physical activities	26	12	38	68.42	31.58
	Positive implication for future learning	61	22	83	73.49	26.51
Total		**167**	**64**	**231**	**72.39**	**27.71**
Category 4: Consequences of a bad lecture to students	Declining motivation	0	14	14	0	100.00
	Mental fatigue	13	47	60	21.67	78.33
Total		**13**	**61**	**74**	**17.57**	**82.43**

I = Intervention; C = Control.

experienced whenever we have lectures. We began with an assessment and a video on a heart attack. Usually, early in the morning we would feel sleepy, but this assessment and video kept us awake and aware. And then, when the lecturer came, we actually knew what to look for.' [Participant 1B]

'I could pay attention the whole time. Hmm … usually, I fell asleep every time during lectures, but this morning I was awake until the end. I feel like I have achieved a goal in that I didn't sleep during a lecture.' [Participant 5B]

In addition, two students spoke on how they were impressed with the presentation of diagrams during the lecture.

'One thing I liked about his diagrams was that when he goes elaborating it using appropriate animation. So it was actually like connecting puzzles piece, everything comes at once and it helped me to understand better. Besides, he labelled the diagrams using letters that were related to the text, so we can easily know which structures he was referring to. What usually happened in other lectures was that lecturers labelled the structures using their actual names. Sometimes, the labels were too small and too packed in. We could not see it clearly.' [Participant 2B]

'The way the lecturer explained the heart diagrams was very systematic. For example, when she explained about the left atrium, she gave different diagrams to explain different views of it. All the diagrams were crystal clear and I was able to imagine in three dimensions even though the diagrams were in 2 dimensions.' [Participant 3F]

In addition, students also described how they had benefitted from the analogy and visuospatial cues imparted during the lecture.

'When I was in the foundation course, I had difficulty understanding the shape and structure of organs. During the lecture just now, the lecturer gave an analogy: "the heart as a fallen pyramid". From that analogy, I could understand about the apex and base of the heart.' [Participant 1F]

'Each label was followed by an explanation. The labels were made explicit one by one using animation. Each label appeared only when the lecturer was explaining the structure. This technique directed my attention toward what she was explaining.' [Participant 2F]

In addition, one participant remarked on the lecturer's effort that had turned the lecture into an interactive and encouraging session:

'The lecture, to me, was encouraging, because the lecturer encouraged us to get involved in the lecture. When she said those who can answer the question will get a gift, it might sound a little bit childish to some students, but it actually encouraged me to pay more attention so that I could answer more questions. And definitely get more gifts. What I wanted to highlight is that the lecture was not a normal form of lecture. The lecturer interacted with us. It was two-way communication instead of a one-way passive lecture.' [Participant 3C]

Another participant acknowledged the good rapport developed by the lecturer at the beginning of the lecture. She highlighted that the stimulating lecture opening and good rapport had instilled in her an interest in learning the topic and provided her with reassurance about the lecturer's willingness to help:

'At the beginning of the lecture, the lecturer briefed us on the importance of learning the topic by giving some clinical-related application examples, such as the site for placing the ECG leads. As a first-year student, at first, I certainly did not know the relevance of learning the anatomy of the heart. But after listening to her, I got to know the importance of learning this topic and I felt that I am more interested to learn the topic. The lecturer reassured us that we could always stop her and ask questions, or we could ask her questions after class. She reassured us that if we could not understand 100% of the content, 70% is good enough. If we could not understand 70%, 50% is acceptable.' [Participant 4F]

One participant described how the questions posed during the lecture had motivated her to learn further:

'The questions during the quiz session were refreshing as well. When we were asked to name the labelled structures, I answered incorrectly. She immediately showed me the answer, which is good. I think I will remember the answer forever. That time I got it wrong. Perhaps, if I encounter the same question another time, I'll make sure to get it right.' [Participant 3B]

Some students spoke about how they experienced meaningful mental activities during the lecture:

'I had this self-questioning activity in mind during the lecture, especially when I encountered something that had piqued my curiosity. During the short break session, the lecturer asked us to close our eyes and imagine. I did that, and I tried to imagine. I kept asking myself to find answers to the questions. Even though it was a break session, my mind was still working.' [Participant 1F]

In summary, the students who attended the CLT-bLM-based lecture were satisfied with the lecture as they experienced positive feelings (i.e. happy, impressed, and motivated) and benefitted (i.e. they were able to pay attention, stayed focused, visualised complex structures, became involved with intra-lecture activities, understood the lecture content) from the lectures. This finding supports the finding of cognitive engagement level in the present study, as the students in the intervention group were found to have higher cognitive engagement during the lecture.

Discussion

In general, the CLT-bLM-based lecture successfully stimulated the students' cognitive engagement. Although the difference in the internal motivation scores was found to be not significant, the findings of the focus group discussion revealed otherwise. It was apparent that the students in the intervention group felt motivated to learn from the lecture, as they admitted to getting benefits from it. In view of these contradictory findings, we calculated the Cohen effect size for the internal motivation construct using the Effect Size Calculator for T-Test[56]; it was found to be less than 0.2, indicating that the result may not accurately reflect the impact of the actual intervention.

Cognitive engagement could be defined as the investment of mental effort or energy in an attempt to comprehend complex knowledge or master difficult skills.[57] In the present study, we measured cognitive engagement because it has been previously identified as one of the germane resources involved in cognitive processing. Earlier research indicated that cognitive engagement during learning improves performance and achievement of learning goals.[58–61] Greene and Miller[59] found a positive correlation between meaningful cognitive engagement with mid-term test performance in educational psychology students. Similarly, van Merriënboer[61] demonstrated an increase in training efficiency and transfer task performance when instructions were designed in a manner that could redirect learners' attention from extraneous to germane cognitive processing. In a lecturing context, it was reported that engaging lectures improve students' test performance[60] and satisfaction towards the learning task.[58] Hence, the previously reported findings of higher students' knowledge acquisition and retention after exposure to a CLT-bLM-based lecture[25] might be due to the high cognitive engagement level towards the lecture content.

It should be noted that with higher engagement, the students deliberately invested a higher amount of cognitive resources to process the intrinsic load (i.e. a type of cognitive load that is imposed by the content of instruction).[32] The high cognitive level of the intervention group could be due to the instructional manipulation the lecturers performed while preparing and delivering the CLT-bLM-based lecture. Although the main aim of the CLT-bLM-based lecture is to reduce the extraneous load and manage the intrinsic load in a way that allows for the freeing of working memory resources, this mechanism can only be effective if the learners can actively invest mental energy into the cognitive processing that utilises the freed resources.[33] Since all the participants were novices in the content area, the cognitive engagement could only be achieved through instructional manipulation that encourages the participants to stay focused and mentally alert during the lecture. Several principles of CLT-bLM that might enhance active cognitive engagement towards the lecture content include explaining the purpose, encouraging focused attention, using forethought, pausing and asking, providing analogies, and verbally highlighting the learning outcomes and lecture outline. This form of cognitive engagement enhancement allows for the deliberate investment of mental energy towards the learning task, and thus increases the participants' ability to master the knowledge, as explained by expert performance research.[62,63]

A previous study that measured learners' electrical brain activity using electroencephalography (EEG) identified three underlying mechanisms of engagement: information gathering, visual processing, and allocation of attention.[64] Considering these three factors, it was postulated that a CLT-bLM-based lecture manages to provide a lecturing environment that allows for efficient information gathering, stimulates the visual working memory that performs cognitive processing of visual input, and directs the learners' attention towards important information.

Efficient information-gathering during a lecture can be achieved only when the content is taught in various ways that induce elaborative processing,[65] a deep cognitive processing that encodes meaning of the learnt information in the working memory, rather than leaving it in its surface appearance. For instance, CLT-bLM encourages the lecturer to physically integrate the lecture content with previously learnt information and correlate the information with real-life examples through the application of analogy. When instructors do this, learners are able to incorporate meaning of the learnt information by correlating it with their previous knowledge without taxing the working memory capacity, a condition known as the split-attention effect of cognitive load.[39]

In addition, the present study seeks to enhance the learners' visual working memory capacity to perform meaningful cognitive processing. In contrast to iconic memory, visual working memory requires more effortful process for active maintenance of information.[21] Hence, manipulating instructional material with the aim to expand the visual working memory capacity and resources indirectly enhances cognitive engagement, as reported by Berka.[64] Through several CLT-bLM principles such as managing diagrams, using a physically integrated format, avoiding extraneous pictures and animations, incorporating visual cues, and providing analogies, the visual working memory is optimised. These principles adopt several CLT effects and CTML principles (modality effect, split-attention effect, redundancy effect, worked example effect, imagination effect, coherence principle, signalling principle, and contiguity principle) that have been proven to result in effective visual cognitive processing.[66]

Additionally, the cognitive engagement of the participants in this study was contingent on their ability to allocate their attention and maintain it until the end of lecture. The ability of learners to use their attention to maintain or suppress information in their working memory for the complete schema (i.e. an organised form of information that is readily stored in and retrieved from the long-term memory) construction process depends on the executive attention system.[67] This supervisory attentional system selects important information that is to be processed and inhibits irrelevant information during learning.[68] However, the attention system not only influences the information processing in working memory, but it also influences the early sensory perceptual stage (detection of information by sensory memory) during learning.[69] Hence, it is the role of the instructional designer to create instruction that can be easily captured by the sensory organs and learners' memory. This mechanism has already been adopted in CLT-bLM using various techniques that capture attention, such as pausing and asking, encouraging focused attention, providing visual cues, providing analogies, managing diagrams, and avoiding extraneous pictures and animations.

In contrast to the findings related to cognitive engagement, this study failed to prove the ability of CLT-bLM-based lectures to stimulate students' internal motivation towards learning the topic. As mentioned earlier, this insignificant finding might not be due to the actual impact of the CLT-bLM; rather, it might be affected by the limitations of the intervention (e.g. exposure to only one lecture session). This finding supports the fact that internal motivation is a multi-factorial construct. Although external factors such as learning environment and teachers' teaching behaviours play important roles in stimulating students' internal motivation, it has been reported that this form of motivation is more influenced by the learners' characteristic values such as perceived ability, effort, competence, anxiety level, and task goal orientation.[70,65] Perhaps during the lecture sessions — for both the control and the intervention groups — the focus of locality for engaging in the learning activities during the lectures was external to the students, as it was emphasised to them that the activities were for research purposes only. This means that the learning activities during the lectures were controlled behaviours that were externally motivated by the design of instruction, rather than internally motivated by the learners' goal orientation, as described by the self-determination theory.[71,66] This factor could have resulted in the insignificant between-group differences of the intrinsic motivation scores.

Nevertheless, if the CLT-bLM guideline is to be applied in a real lecture setting, it could stimulate higher internal motivation scores among the learners, as they would have a clear goal for attending the lecture. This is due to the fact that the CLT-bLM incorporates principles that have been proven to stimulate learners' internal motivation, such as emphasis on good teaching behaviours and providing a meaningful and supportive lecturing climate.[72,73,67,68] Indeed, in CLT research, internal motivation has been identified as an important element to ensure the learning of a complex task,[33,69] as it helps the learners to manage cognitive load through the stimulation of generative cognitive processing.[74,70] It has also been reported that more motivated learners are able to invest more of their working memory resources into dealing with complex instruction as compared to those who are less motivated, thus leading to better learning.[75,70]

Conclusion

In conclusion, the CLT-bLM is a lecturing guideline that can help lecturers to prepare and deliver an engaging and stimulating lecture. By using this guideline, lecturers are aware of how they should create their teaching materials in a manner that can complement human cognitive functions. It is clear that the present work provides additional significant evidence on the effectiveness of CLT-bLM. Despite compelling reasons to create a more student-centred teaching approach in higher institutions, the implementation of pedagogy-based teaching should not be ignored, as teachers' roles are still important in imparting difficult conceptual knowledge. With this guideline, lecturing methods would no longer be didactically driven; rather, a more organised and interactive lecture that can stimulate students' attention focus is expected.

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Disclosure statement

The authors declare no conflict of interest in this study.

Practice points

- Cognitive Load Theory-based Lecture Model is an evidence-based lecturing guideline that promotes cognitive engagement.
- Students perceived a good learning experience during the lecture.
- Students perceived benefits from the lecture.

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Appendix A. Supplementary data

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