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ORIGINAL RESEARCH PAPER

Developing E-learning Materials Based on Cognitive Load Theory to Improve Students' Learning Levels in Online Physics Education

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ABSTRACT

Background and Objectives: The emergence of COVID-19 has brought about a sudden shift to e-learning and virtual platforms. Teachers play a key role in developing e-learning content. Hence, they must be familiar with the theories related to the cognitive constructs and e-learning principles to both facilitate the learning process and enhance the rate of learning and retention among the students. The cognitive load might increase unless the e-learning and experiential content is not developed according to the cognitive load theory, particularly for teaching physics as a field that requires multimodal presentation of the content. This might hinder the students' learning and retention. In other words, if the principles of cognitive load theory are not observed in the design of electronic and multimedia content of course materials, the learning process will be disturbed and damaged due to the production of additional load beyond the memory capacity of the learners. The current study aimed to develop e-learning content for a concept in physics (e.g. pressure) based on the cognitive load theory. It further attempted to explore its possible impact on the learners' levels of learning (knowledge, understanding, application) and the degree of their retention.

Materials and Methods: The study adopted a quasi-experimental pre-test post-test design with an experimental and a control group. The statistical population included all female ninth graders in district 17, Tehran, the capital of Iran. The sample consisted of 120 learners via multistage stratified random sampling procedures. The participants were assigned to experimental and control groups. To gather the required data, a researcher-made test was used and its reliability was calculated via Cronbach's alpha as 0.85. The students took part in a three-week virtual empirical sciences course comprising six sixty-minute sessions. Before offering the course, the educational objectives of chapter 8 of the empirical sciences textbook in the ninth grade related to the subject "pressure" were determined using the teacher's manual and eliciting the experienced sciences and physics teachers' expert comments. Then, their level of cognitive processing was identified based on Bloom's taxonomy. The objectives were categorized into three groups of knowledge, understanding, and application. To analyze the data, analysis of covariance and an independent samples t-test were used via SPSS (20.00).

Findings: The results of the analysis of covariance for learning levels (knowledge, understanding, and application) demonstrated that developing e-learning materials based on the cognitive load theory enhanced the learners' levels of learning in the experimental group compared to those in the control group ($P < 0.05$). Moreover, the results of an independent samples t-test for the delayed post-test revealed a significant difference between the participants in experimental and control groups in terms of their degree of retention ($P < 0.01$).

Conclusions: The findings implied that considering the principles of the cognitive load theory in developing e-learning materials for physics would positively influence the learners' levels of learning and their degree of retention. Therefore, it is recommended to designers of e-learning content to consider the principles of cognitive load theory in the design and production of their content.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
37	2	6

مقاله پژوهشی

توسعه مواد آموزش الکترونیکی بر اساس تئوری بار شناختی برای بهبود سطوح یادگیری دانش‌آموزان در آموزش آنلاین فیزیک

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چکیده

پیشینه و اهداف: امروزه به دلایل مختلفی از جمله ظهور بیماری کرونا، شاهد استقبال نظام های آموزشی از آموزش های غیرحضوری هستیم. در این زمان، نقش اصلی در طراحی آموزشی دوره های آموزش غیرحضوری را معلمان هر درس برعهده دارند؛ بنابراین آن ها باید با نظریه های مربوط به ساختار شناختی و چگونگی یادگیری دانش آموزان از محتواهای الکترونیکی آشنا باشند تا آموزش های آن ها ضمن تسهیل فرآیند یادگیری، سبب بالا بردن سطوح یادگیری و افزایش میزان یادداری مطالب آموزشی در دانش آموزان نیز شود. زیرا چنانچه محتواهای الکترونیکی و چندرسانه ای طراحی شده به خصوص در درسی مانند فیزیک که از انواع رسانه ها و بازنمایی های متعدد برای انتقال مفاهیم بهره می گیرد طبق اصولی سازگار با ساختار شناختی یادگیرندگان طراحی نشود، ممکن است باعث واردآمدن بارشناختی اضافه به حافظه ی یادگیرندگان شود و این امر مانعی برای فرآیند یادگیری و یادداری مطلب در یادگیرندگان باشد. لذا پژوهش حاضر باهدف طراحی یک محتوای الکترونیکی برای درس فیزیک (مثلاً مبحث فشار) بر اساس اصول نظریه بارشناختی و بررسی تأثیر آن بر سطوح یادگیری (دانش، فهمیدن و به‌کاربستن) و میزان یادداری دانش‌آموزان از مبحث آموزشی انجام شد.

روش‌ها: روش پژوهش نیمه‌آزمایشی از نوع طرح پیش‌آزمون - پس‌آزمون با گروه کنترل بود. جامعه آماری پژوهش، شامل کلیه دانش‌آموزان دختر پایه نهم دوره متوسطه اول مدارس عادی آموزش‌وپرورش ناحیه ۱۷ استان تهران است که در سال ۱۴۰۱-۱۴۰۰ مشغول به تحصیل بودند. نمونه‌گیری از نوع تصادفی خوشه‌ای چندمرحله‌ای و تخصیص تصادفی در گروه‌های آزمایش و کنترل انجام‌گرفته است. حجم نمونه آماری تحقیق ۱۲۰ نفر است که در دو گروه همسان آزمایش و کنترل قرار گرفتند. برای جمع‌آوری داده‌های سطوح یادگیری و میزان یادداری از یک آزمون پیشرفت تحصیلی محقق ساخته به صورت پیش‌آزمون-پس‌آزمون استفاده شد که روایی صوری و محتوایی آن توسط دبیران با تجربه علوم‌تجربی و اساتید آموزش فیزیک تایید و پایایی آن به روش آلفای‌کرونباخ ۰/۸۵ سنجیده شده بود. اجرای دورهٔ آموزشی این پژوهش به‌صورت مجازی و در بستر سامانه شاد (شبکه اجتماعی دانش‌آموزی) در طی ۳ هفته آموزشی، ۶ جلسهٔ ۶۰ دقیقه‌ای در کلاس‌های مجازی علوم‌تجربی پایه نهم انجام‌گرفته است. قبل از شروع دورهٔ آموزشی، ابتدا طرح درس‌ها و محتوای آموزشی مربوط به یک مبحث از فیزیک (مبحث فشار و آثار آن) برای گروه کنترل به شیوه کلاس‌های مجازی متداول تهیه و تدوین شدند و سپس با مطالعه دقیق مبانی نظری و تجربی نظریه بارشناختی، طرح درس‌ها و محتواها با رعایت اصول نظریه بار شناختی برای گروه آزمایش تهیه و تدوین گردید. به منظور تجزیه و تحلیل داده ها از نرم افزار SPSS 20 استفاده شد.

یافته‌ها: نتایج آزمون تحلیل کوواریانس برای سطوح یادگیری نشان داد، طراحی محتوای الکترونیکی مبتنی بر نظریه بارشناختی، سبب ارتقای بیشتر سطوح یادگیری(دانش، به فهمیدن و به کاربستن) دانش‌آموزان گروه آزمایش نسبت به گروه کنترل می‌شود($p < ۰/۰۵$). همچنین نتیجه آزمون تی مستقل برای آزمون یادداری نشان می‌دهد، بین گروه کنترل و آزمایش در میزان یادداری آن‌ها از مبحث تدریس شده تفاوت معناداری وجود دارد($p < ۰/۰۱$).

نتیجه‌گیری: باتوجه‌به نتایج به‌دست‌آمده از مطالعه حاضر می‌توان نتیجه‌گیری کرد که رعایت اصول طراحی آموزشی مبتنی بر نظریه بارشناختی در تولید محتوای آموزشی الکترونیکی درس فیزیک، تأثیر مثبت قابل‌توجهی بر روی سطوح یادگیری و میزان یادداری دانش‌آموزان از مباحث آموزشی دارد. لذا به طراحان محتواهای آموزش الکترونیکی توصیه می‌شود تا اصول نظریه ی بارشناختی را در طراحی و تولید محتوا های خود مدنظر قرار دهند.

Introduction

The global emergence of COVID-19 has led several countries to set social distance regulations to avoid the spread of the disease. Obviously, the spread of the pandemic disease and its subsequent limitations led to a major disorder in the educational systems all across the world and brought about a sudden shift from traditional face-to-face classes to e-learning and virtual platforms. Unfortunately, several teachers replicated the principles of face-to-face classes in online settings regardless of the potentials and capacities of the e-learning environments while they simultaneously expected to achieve the optimal goals relying on e-learning and technology-based education.

To make better decisions for designing and developing the content for virtual classes, the teachers are required to get familiar not only with the effective methods but also their underlying rationales. As a teacher, we are mostly inclined to try out new ways to help the learners. Hence, we select the transient modes of activities despite analyzing the existing evidence on their effectiveness [1]. As a result, in addition to technical issues and the attractiveness of the electronic content, learning efficiency in online classes needs to be prioritized. It has been proved that well-designed electronic content would lead to increased learning outcomes [2]. Due to the difference between face-to-face and e-learning, making a successful shift from the former to the latter one seems to be complicated particularly for such subjects as physics, which by itself requires repetition and adaptation to the environment and entails higher-order thinking skills [3]. Researchers hold that developing and implementing educational content to form an accurate perception of the concepts makes a tremendous impact on how the learners acquire them since having a good understanding of the learners' learning procedures contributes to the more desired planning and implementation of the materials [4].

Bloom's taxonomy of the learning levels is one of the globally known theoretical frameworks for describing learning [5] and presents three domains namely cognitive, affective, and psychomotor for categorizing the learning objectives. However, learning is not the only ultimate goal of educational programs. Rather, lifelong learning is the desired outcome. The cognitive domain of this taxonomy entails such objectives as recalling, retrieving knowledge and developing mental skills and capabilities. Six categories were considered for the cognitive domain including knowledge, comprehension, application, analysis, synthesis, and evaluation. To lead the students towards achieving these levels, material developers must design the content based on the human brain capacity.

Hence, to enhance the learning levels in an e-learning context, material developers must develop structurally organized content [6]. The educational programmers must ensure that the content gears to the learners' cognitive processing and enhanced learning. To this end, numerous factors including the learning environment, learning objectives, content difficulty, multimedia format, and their impact on cognitive loading must be considered [7]. Cognitive loading occurs when the cognitive processing is beyond the learner's cognitive capacity [8].

Cognitive loading theory is a human memory- and brain-based theory encompassing a long-term and a working memory [9-10]. Working memory refers to a system that is responsible for transient storage and manipulation of information. It acts as a mental working memory that is flexible enough to support daily cognitive routines, requiring both processing and storing information (e.g. mental calculations). However, daily memory capacity is limited, and imposing extra cognitive requirements results in losing a huge bulk of information [11]. As a result, the general load of mental activities imposed on the memory at once is called cognitive loading [12].

Three kinds of cognitive load have been proposed in this theoretical framework including intrinsic cognitive load, extraneous cognitive load, and germane cognitive load [12]. The load that must be learned due to the nature and interaction among the content elements is called intrinsic cognitive load; the load that is created through the mode of presenting information and prevents the accurate schemata from being created is called extraneous cognitive load. Contrarily, germane cognitive load is formed when the imposed load by the educational features improves the schemata formation and makes a positive impact on learning [13]. Hence, educational programmers must increase the germane cognitive load to a large extent, decrease the extraneous cognitive load, and control the intrinsic cognitive load [10].

Learning environments can influence the cognitive load and thereby, make an impact on learners' understanding, thinking, and learning [14]. Accordingly, changing the learning environment from a face-to-face class to an electronic setting requires fundamental changes in planning and developing content so that the learners can experience deep and meaningful learning. Deep learning depends on the type of learners' cognitive processes while learning a topic. These processes involve: I. Selection: paying attention to important aspects of input, II. Organization: organizing the input in a coherent way, III. Integration: relating the input to the existing knowledge in long-term memory [15]. Multimedia educational programmers must avoid extraneous cognitive load since spending more energy for processing information leads the learners to have lower cognitive capacity for being involved in the learning experience [16]. Multimedia content means a combination of several modes of presentation including text (oral or written), static graphic designs (pictures, diagrams, etc.), and dynamic graphic designs (animations, movies, etc.) [17]. Multimedia presentation of information is effective in learning science, namely natural sciences [18] and physics [19]. Students learn physics via various tools such as words, pictures, diagrams, tables, movies, etc. which can be applied to describing physical phenomena. It seems that several presentation modes are employed in transferring information and supporting knowledge in teaching physics. The results of various studies have demonstrated that multidimensional presentation of information promoted the learners' conceptual understanding of physical issues and improved their problem-solving skills [20,21]. Although using various presentation modes enjoys the potential to support the learning procedures, it may result in extraneous cognitive load among the learners and have a negative impact on their learning procedures unless their cognitive structure and limited capacity of the working memory are taken into account [22].

According to Mayer, [23,24] educational content must be based on individuals' brain capacity and how they process information. The cognitive load theory provides a set of principles resulting from numerous studies on optimal educational materials development [8,10,24,27]. These principles include:

A**.** Coherence principle (omitting the extra and unnecessary materials leads to better learning).

B. Segmenting principle (segmenting complicated content is simplified into more controllable parts.

C. Signaling principle (cognitive load is lowered by presenting clues to the learners regarding the selection and organization of the content).
D. Multimedia principle (applying a combination of words and pictures is more effective than merely using words).
E. Modality principle (a combination of audio-visual resources is more efficient than presenting the content through one of these senses).
F. Spatial contiguity principle (relevant words and pictures are better to be proximate).
G. Temporal contiguity principle (simultaneous presentation of audio-visual resources makes it unnecessary to keep one slide in the working memory till the next slide is shown).
H. Redundancy principle (redundancy occurs when the same content is presented in the oral and written format and hinders the information processing).
I. Individualization principle (considering individual differences in assigning tasks and regulating their level of difficulty leads to better results).
J. Feedback principle (providing the learners with feedback results in the required cognitive processing for deeper learning).
K. Expertise reversal principle (the learners' differences in terms of their levels of knowledge must be considered (i.e. presenting information must be different for the beginners and experts)).

Research has shown that the cognitive load of the working memory could be lowered provided that multimedia learning is facilitated by following the principles of the cognitive loading theory [28]. Bearing this in mind, it seems that injecting the principles of cognitive load theory into the e-learning materials would significantly influence the learners' levels of learning and retention in such subjects as physics (e.g. pressure, etc.) which require various modes of presentation. Physics entails abstract concepts and the learners mostly lack the required levels of accurate understanding and recalling to notice and apply them in their daily lives. Accordingly, the current study was conducted to test the following hypotheses:
I. Developing e-learning materials based on the cognitive load theory makes a significant impact on the learners' levels of learning (i.e. knowledge, comprehension, and application).
II. Developing e-learning materials based on the cognitive load theory makes a significant impact on the learners' retention of the theme "Pressure" in physics.

Review of the Related Literature

The results of Mayer et al.'s [29] study indicated the negative effect of injecting additional and even interesting but irrelevant details in hindering learning and retention among the learners. They justified their findings relying on the cognitive load theory and multimedia learning. Furthermore, Schauer et al. [30] conducted a study and demonstrated that integrative e-learning for effective teaching of physics would lower the learners' cognitive load by supporting their individual comprehension procedures, providing multimedia access to knowledge, and catering for their individual differences.

In another study, Takir and Aksu [31] investigated the possible impact of the developed materials based on cognitive load theory on the seventh-grade students' accomplishments in Algebra. They demonstrated the facilitative and positive effect of such materials on the students' achievement and learning. Moreover, Andrade et al. [32] conducted a quasi-experimental study and explored the influence of multimedia materials and their difficulty level based on cognitive load theory and the students' learning outcomes. They randomly assigned the students to three groups including a group receiving text and graphics, a group receiving voice and text and graphics, and a group receiving video, voice, text, and graphics. The results of their analysis revealed that the first group, with lower intrinsic cognitive load, gained higher scores in the post-test. Similarly, the students with the higher germane cognitive load had higher scores in the post-test. Also, in the second and third groups, the students with lower extraneous cognitive load obtained higher scores in the post-test. The results of a study by Camos and Portrat [33] demonstrated that repetition and cognitive review were needed to increase the information learning rate in the participants' working memories. They also found out that applying cognitive-load-based principles would enhance the learners' retention.

Additionally, in a study by Grech [34] in Malt, multimedia principles of learning were used to develop the PowerPoint slides. The findings showed that taking into account the principles of cognitive load theory and multimedia learning in developing the slides led to a lowered imposed cognitive load on the working memory and expedited the learning. Moreover, Becker et al. [35] studied the use of Tablet-based visual analysis in enhancing learning of such concepts as static and accelerating movement to confirm the significant role of lowering cognitive load on learning efficiency. Their analysis demonstrated that extraneous cognitive load during the experiment-based learning procedure was significantly lower in technology-based teaching (if the principles of cognitive load theory and multimedia learning are followed) compared to that in traditional education. Moreover, Tindall-ford et al. [36] showed that presenting the basic courses of electrical engineering would be more preferred provided that audio-visual resources were employed. They took into account the memory cognitive load and estimation of the educational effectiveness to analyze the data.

A review of the existing literature on the cognitive load theory indicates that the principles have been employed for designing educational multimedia and software to complement face-to-face instructions. The emergence of COVID-19 and the sudden shift to virtual education and the application of e-learning content in online courses seem to have created a niche, exploring the influence of employing the principles of cognitive load theory in designing the e-learning content on the students' levels of learning and retention. Most studies have focused on the challenges, demerits, and merits of online courses; teachers, particularly basic sciences and physics teachers, have been searching for appropriate techniques and software to present the content on virtual platforms. Hence, the current study attempted to fill this void by highlighting the possible impact of implementing the principles of the cognitive load theory in developing the e-learning content on the students' levels of learning and retention in physics classes.

Method

The current applied study adopted a quasi-experimental design via administering pre-test and post-test in an experimental and a control group.

Participants

The statistical population consisted of all the female ninth graders in Tehran, District 17 in the academic year 2021-2022. Multistage stratified random sampling procedures were used and a total number of 120 learners were included in the sample. They were divided into two groups of 60 and were assigned to the experimental and control groups.

Instruments

To gather the required data, a researcher-made test was used. It included 20 multiple-choice items which were developed relying on the objective-content table, subject, and Bloom's taxonomy based on the Physics textbook. The items were given to experienced teachers of science and physics to be checked in terms of content validity. To check for the test reliability, Cronbach's alpha coefficient was calculated as 0.80, indicating an acceptable degree of reliability. It is worth noting that the same test was used for the delayed post-test.

Procedure

The students took part in a three-week virtual empirical sciences course comprising six sixty-minute sessions. Before offering the course, the educational objectives of chapter 8 of the empirical sciences textbook in the ninth grade related to the subject "pressure" were determined using the teacher's manual and eliciting the experienced sciences and physics teachers' expert comments. Then, their level of cognitive processing was identified based on Bloom's taxonomy. The objectives were categorized into three groups of knowledge, understanding, and application. Accordingly, the test items were developed as follows: 6 items at the level of knowledge, 12 items at the level of understanding, and 2 items at the level of application. Following that, the virtual classes lesson plans were developed and confirmed by the experienced teachers. It is worth noting that the lesson plans for the experimental group were designed based on the theoretical and empirical principles of cognitive load theory. Afterward, the content was prepared. The pre-test was administered to both experimental and control groups. In this regard, the control group received the same instruction in the virtual classes and the experimental group received the cognitive-load-based instruction. Finally, the post-test was administered and the learners' scores were recorded. The same researcher-made test was used in both pre-test and post-test stages. To assess the students' long-term retention, the delayed post-test was administered after a two-week interval and the scores were recorded. Finally, it should be mentioned that we used available data through the local source which was provided by our own research team, so all the data can be provided.

Design

The materials were designed based on the cognitive load theory for the experimental group. Having reviewed the existing literature, the content was developed based on the cognitive load theory and multimedia design. The following issues were taken into account:

A. Before designing the educational content, the pre-test scores of the experimental group students were analyzed to ensure the basic level of knowledge about pressure among them (Expertise reversal principle).

B. For designing the content, several audio-visual media were employed. Several media including text, pictures, sound, and films were used in order not to confine the scope of the educational content to merely two or more particular media (Multimedia principle).

C. All the videos and voices were prepared by the content developer and other colleagues' files were not used. Moreover, to simulate the face-to-face classes and board, a light pen was used to write, i.e. writing by means of software was avoided (Individualization principle).

D. The educational program was implemented in the form of flipped classes. In this way, the educational content of each session was uploaded on Shad for the experimental group and the students were given time to watch the files and learn. The beginning of each session was allocated to examining the homework and asking questions (Self-speed observing principle).

E. Taking into account the audio-visual channels, the content was developed in a way that the visual content lacked the text so that the capacity of the channel was not fully saturated (Modality principle).

F. The clarity was considered in choosing the pictures to convey the message more conveniently. The low number and high quality were taken into account to avoid using pictures of cognitive overload. To this end, the music was not included in the educational content; eliminating the extra sounds could draw the students' attention. Moreover, no extra pictures were used to decorate the class environment (Coherence principle).

G. A mouse was used to show the content on the videos. Moreover, to draw the students' attention to the major points, pens of different colors, boxes, and margins were used (Signaling principle).

H. The chapter was divided into several sections and short video files were prepared for each section to avoid long and nonstop videos. Each topic was completely tackled in each video file (Segmenting principle).

I. In multimedia files, the slide with a picture of the concept of pressure was followed by the slides including the relevant text and explanations. Moreover, the presentation of the information was accompanied by the relevant concepts in each video file. The text, pictures, and sounds were relevant and coherent (Spatial contiguity principle).

J. As regards the experiments, the explanations were presented while the experiment was being conducted. The coordination of the audio and video files was considered (Temporal contiguity principle).

K. The teacher's explanations of the experiments in the video files were not accompanied by the transcription of the experimental procedures (Redundancy principle).

Since the students were familiarized with the concept of "pressure" for the first time, it was tried to divide the content into separate video files to control the possibly imposed cognitive load. A step-by-step approach was adopted to present the new content in which the prerequisites were provided and the underlying concepts (e.g. force, floor, etc.) were reviewed.

As different media could be used to present the concept of "pressure", inappropriate use of the educational tools may lead to an increased cognitive load; hence, the link between concepts and the relevance of the sub-themes was considered to present a clear picture of the target content. To this end, attractive content and decorative features that might deviate the students were excluded from the files.

Fig. 1 displays one of the slides for the experimental group in which cognitive load theory principles were taken into consideration.

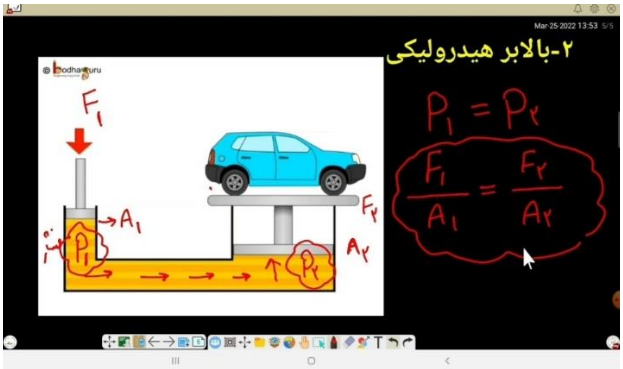

Fig. 1: Part of the multimedia content for the experimental group (observing such principles as Multimedia, Coherence, Modality, Spatial contiguity, Temporal contiguity, and Signaling).

Appropriate cognitive load is essential to learning and can be represented by the learners' memory attempts to create and automatize their mental schemata. Repeated use of the knowledge and skills would lead to autonomous performance, which in turn, overcome the limitations of the working memory. To increase the appropriate cognitive load, such procedures can be taken as presenting more examples, posing more questions, providing problem-solving tasks, stretching the learners' imagination, giving a summary of the content, illustrating the relationship between and among the content, and gradual omission of the guidelines. Fig. 2 shows the content for the experimental group which entailed educational designing procedures to increase the appropriate cognitive load.

Fig. 2: Part of the multimedia content for the experimtal group (observing such principles as Multimedia, Modality, Redundancy and Individualization).

Results and Findings

To analyze the data, SPSS (Version 20) was used. To answer the research question related to learning based on their levels of cognitive processing (knowledge, understanding, and application), co-variance analysis was used. To check the data obtained from the delayed post-test, an independent samples t-test was run. To test the first hypothesis, the scores related to the level of learning of the test items were separately analyzed at three levels of knowledge, understanding, and application. The results of covariance analysis for the knowledge level are presented in Table 1.

According to Table 1, omitting the impact of the pre-test and considering the F coefficient, the results revealed a significant difference among the moderated mean values for the knowledge level between experimental and control groups ($P \leq 0.05$). Hence, developing the e-content based on the principles of cognitive load theory significantly influenced the learners' level of knowledge in the "pressure" subject. Table 2 displays the results of the analysis of the data related to the understanding level.

As Table 2 shows, omitting the impact of the pre-test and considering the F coefficient, the results revealed a significant difference among the moderated mean values for the understanding level between experimental and control groups ($P \leq 0.05$). Hence, developing the e-content based on the principles of cognitive load theory significantly impacted the learners' level of understanding in the "pressure" subject. Table 3 illustrates the results of analysis of the data related to the application level.

As Table 3 indicates, omitting the impact of the pre-test and considering the F coefficient, the results revealed a significant difference among the moderated mean values for the understanding level between experimental and control groups ($P \leq 0.05$). Hence, developing the e-content based on the principles of cognitive load theory significantly influenced the learners' level of applying in the "pressure" subject.

According to the results, it might be concluded that developing the e-learning content based on the principles of the cognitive load theory would make a tremendous impact on the students' levels of learning while they were taught the "pressure" subject. Table 4 demonstrates the results of descriptive statistics for the second hypothesis.

Table 1: Results of covariance analysis for the test items at the knowledge level

Source	SS	df	Ms	F	Sig	Effect size
Pre-test	1727.676	1	1727.676	1125.146	0.000	0.906
Group	75.595	1	75.595	49.231	0.000	0.296
Error	6.945	1	6.945	4.523	0.036	0.037
Total	179.655	117	1.536			

Table 2: Results of covariance analysis for the test items at the understanding level

Source	SS	df	Ms	F	Sig	Effect size
Pre-test	50.423	1	50.423	29.475	0.000	0.304
Group	4.314	1	4.314	2.522	0.0115	0.31
Error	196.730	115	1.711			
Total	13517.000	118				

Table 3: Results of covariance analysis for the test items at the application level

Source	SS	Df	Ms	F	Sig	Effect size
Pre-test	0.070	1	0.070	0.431	0.013	0.104
Group	0.468	1	0.468	2.866	0.043	0.124
Error	19.113	117	0.163			
Total	21.000	120				

Table 4: Descriptive statistics for delayed post-test

Groups	Number	Mean
Control	14.933	14.933
Experimental	16.983	16.983

Before running an independent samples t-test, the variances of both groups were checked via Levene's test (See Table 5), indicating no significant difference between the experimental and control groups.

Having ensured the homogeneity of the two groups, an independent samples t-test was run. Table 6 displays the results.

Table 5: Levene's test of homogeneity of variances

Variance	df1	df2	F	Sig
Retention	1	118	0.42	0.51

As Table 6 shows, there was a significant difference between the experimental and control groups (t= -4.88, $p \leq 0.05$). Accordingly, considering the principles of cognitive load theory and the limitations of the working memory in developing the e-learning content related to pressure increased the learners' retention in the experimental group.

Table 6: Results of the t-test for the second hypothesis

Variable	Group	Mean difference	Standard deviation difference	Levene's test	T	P
0.000	Control / Experimental	-2.05	0/42	4.01	-4.88	0.000

Discussion

The current study aimed to investigate the impact of observing the cognitive loading theory in designing electronic content of a concept in physics (pressure) on the students' levels of learning (knowledge, understanding, applying) and their retention of this concept. The findings revealed that the students who received cognitive loading theory-based multimedia content outperformed those in the control group. The results showed that accessing various levels of learning in multimedia content would make learning meaningful, and thereby, the students would be enabled to establish a meaningful link between the presented content and processing the information in their working memory. As a result, they would be able to identify the key concepts, organize the information in their memory, and merge this information into the previously existing bulk of knowledge. Paying attention to the cognitive constructs, underlying the cognitive loading theory, contributes to designing such meaningful and effective content for educational settings. Hence, in online education, the limitations of the working memory and principles for overcoming these obstacles must be considered so that the extra cognitive loading is omitted, and thereby, learning becomes easier so that the content helps the learners enhance their levels of learning.

The findings of the study also demonstrated a significant difference between the experimental and control groups in terms of the retention of the presented content after a two-week interval. This might indicate that multimedia content allows the learners to practice at their own appropriate time repeatedly, which results in a higher degree of retention. Designing the content based on the principles of the cognitive load theory, working memory storage, and retrieving information in long-term memory would make learning more meaningful and effective (van Merriënboer & Sweler, 2005; van Merriënboer & Kester, 2005). In this regard, the results were in line with those of previously conducted studies (Mayer et al., 2001; Schauer et al., 2007; Takir & Aksu, 2012; Andrade et al., 2015; Grech, 2018; Becker et al., 2020).

Conclusions

Attending to the students' cognitive constructs and taking into account the characteristics and limitations of the working memory and observing the cognitive load theory principles in designing the electronic content (e.g. physics which requires several media to represent the concepts) would enhance the levels of the students' learning (i.e. knowledge, understanding, applying) and increase the retention of the content.

Hence, it is recommended to pay attention to the use of media in teaching physics since it would lead to a higher degree of learning and facilitate meaningful learning, thereby, enabling the learners to establish a link between the information presented visually and information processed verbally in the working memory. This leads to effective pruning of information so that the audio-visual channels are not occupied by unnecessary and irrelevant extra information [8]. Indeed, if e-learning was confined to transferring information to the students in an undesirable procedure, numerous great lecturers could be asked to record the relevant speeches and provide the students with them [37]. Accordingly, multimedia planners must learn not only the technical considerations and layout designing of the e-learning content but also the strategies for effective presentation of information to avoid imposing extra cognitive load and facilitate the smooth flow of knowledge constructs in the learners' long-term memory.

Despite its implications and applications, the study had some limitations. The sample size was small and only female learners were included in the study. Some other limitations included the focus on one subject in one grade and the low speed of the internet for uploading and downloading the content in e-learning settings.

According to the findings of the current study, teachers in general and basic sciences teachers, in particular, are recommended to become familiar with the cognitive constructs and cognitive load theory to develop the educational content (in face-to-face or online classes) that enhance the students' level of learning and, by no means, confine the material development to the technical and physical layout considerations. Accordingly, similar studies to the present one can be carried out for other concepts in physics, other subjects, and other grades.

Authors' Contribution

The article was extracted from the MA thesis of the first author, who was responsible for conducting research, collecting the required data, and analyzing the data. The second author was the supervisor and the responsibility for the content is hers. In addition, the second author was responsible for the topic, design of the study, and extracting the results. The third author helped in organizing and writing the manuscript and enhanced and revised the early draft of the paper.

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Conflict of Interest

There is no conflict of interest.

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