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Research on the Design of Online Course Teaching Interfaces and Knowledge Presentation Methods under Balanced Cognitive Load

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Abstract: This paper aims to explore the impact of high or low cognitive load on learners' learning effectiveness during the online learning process, as well as to achieve the goal of learners efficiently completing online learning tasks. Based on the theory of balanced cognitive load, the paper delves into the factors that may cause changes in learners' cognitive load within online courses. Through methods such as in-depth user interviews, negative experience points in the online learning process were collected and a detailed analysis of the corresponding types of cognitive load was conducted. The PAAS scale was utilized for the measurement and assessment of cognitive load, determining the extent of cognitive load at each negative experience point. In response to the issues identified, the paper proposes strategies to improve or eliminate learners' negative touchpoints from the following aspects: first, optimizing the hierarchical design of the instructional interface; second, implementing multi-channel information input; third, reinforcing the guidance of key information; and fourth, split-attention effect. These measures are intended to optimize the presentation of information on the instructional interface, reduce the cognitive burden on learners, and thereby enhance their cognitive validity, ensuring the efficiency of online learning.

Keywords: Balanced Cognitive Load; Online Courses; Instructional Interface Design; Knowledge Presentation

1. Introduction

Against the backdrop of the rapid development of digital and information-based education, online and blended teaching models in higher education are increasingly prevalent. Facing the growing demand for digital and information-based education in modern education, the design of efficient online teaching methods to alleviate learners' confusion in the face of vast and complex knowledge systems, while also stimulating their interest in online learning and enhancing their psychological satisfaction, has become a critical issue in the field of online education that needs to be addressed. Studies have shown that the difficulty learners face in acquiring knowledge during the teaching process mainly stems from the cognitive load being too high or too low when the brain processes information [1]. At present, most learners obtain course content through online teaching platforms. However, existing online courses commonly suffer from issues such as an unreasonable interface layout, a lack of interactive methods, and a failure to align with learners' behavioral habits. These problems often lead to cognitive load overload in learners, thereby affecting learning efficiency. The interaction between learners and the online teaching interface is a dynamic process. Sometimes, due to the simplicity of the interface design, learners may experience cognitive load that is too low, leading to distraction; at other times, because of the inappropriate layout of the knowledge structure, learners may experience cognitive load that is too high, resulting in insufficient cognitive resources and subsequently affecting learning outcomes. The root cause of these issues lies in the design flaws of the online course teaching interface or the unreasonable knowledge presentation methods, leading to an imbalance in learners' cognitive load.

2. The Relationship between Cognitive Load and Online Courses

Cognitive load refers to the total amount of activity that an individual's cognitive system can handle during a specific period when performing a specific activity [2]. This concept was initially proposed by the Australian psychologist John Sweller in 1988. Sweller points out that the human knowledge structure consists of two parts: working memory and long-term memory, and the capacity of working memory is limited. As the amount of tasks individuals undertake during the process of receiving, processing, and processing information increases, so does the cognitive load [3]. Since then, many educationalists and educational psychologists have started to pay attention to the issue of cognitive load in the teaching process. For example, Sweller and his colleagues classified cognitive load into three categories based on its different sources: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load [4]. In addition, researchers have focused on the relationship between individual differences in learners and cognitive load theory, exploring how factors such as prior knowledge, cognitive abilities, and self-regulatory behaviors affect the capacity of working memory [5,6]. In the online learning environment, learners' prior knowledge and experience are crucial to learning outcomes. If learners lack sufficient prior knowledge during the online learning process, they will have to spend more time processing and processing information when understanding and completing tasks, which not only increases the burden on working memory but also affects cognitive performance [7]. According to the theory of cognitive load, presenting information in a combination of text and images can accelerate learners' construction of mental models, thus promoting deep understanding [8]. This indicates that the way information is presented has a significant impact on learners' extraneous cognitive load. It is evident that scholars both domestically and internationally have explored the cognitive load issues that arise during learners' knowledge acquisition from various perspectives, such as the classification of cognitive load, multimedia design, and knowledge presentation, and have achieved many interim results. However, in order to truly improve the teaching quality of online courses and effectively promote learners' knowledge acquisition, we still need to start from a balanced perspective and delve into the factors that generate cognitive load in the teaching process and the methods of knowledge presentation. Currently, the information layout and knowledge presentation of online teaching interfaces mainly affect learners' cognitive processes through senses such as vision and hearing, and complete knowledge learning through brain information processing. External cognitive load mainly acts on the input and processing stages of cognition, while schema construction promotes information processing through the formation of schemas, and cognitive abilities affect the processing and storage stages of information.

From existing research on online course teaching, it is evident that the transmission of knowledge is a process that moves from an initial state to the acquisition of knowledge by learners, i.e., the "learner-knowledge" interaction process. This interaction is influenced by various factors, including the learning materials [9], the learning environment [10], the learning tasks, and the learners themselves. Currently, the knowledge presentation methods commonly used in online course teaching include textual and visual representations, information visualization, and animation demonstrations. However, from the perspective of user experience, learners can clearly perceive the psychological changes caused by cognitive load during the learning process. Therefore, we can guide learners to describe the changes in their state, emotions, experiences, effort levels, and difficulties at different stages of the learning process through the user experience dimension. This allows us to extract the key elements that affect the cognitive load of the online course teaching interface.

3. Research Methods and Process

3.1 Research Objects and Selection of Online Courses

This study uses an online course on the history of art design as the learning material. In the preliminary research, a random sampling method was employed to select 160 undergraduate students from a university, with an equal number of males and females, each comprising 80 students. All students were aged between 18 to 23 years old, primarily in their second or third year of undergraduate studies. A total of 160 questionnaires were distributed, and 160 valid questionnaires were collected. All the respondents were art design students who had completed online courses related to art design history, with majors mainly in fields such as visual communication design, digital media art, environmental design, and product design. The characteristics of the research subjects are shown in Table 1.

Based on the data obtained from the questionnaire, an analysis of the use of online course teaching platforms by university students in China revealed that the China University MOOC (CUMOOC) website had the highest number of users, accounting for 52.7%. The other major platforms included Chaoxing (Xuexitong), Xueyin Online, and Tsinghua Open Course, with respective percentages of 25.6%, 15.2%, and 5.6%. Other learning platforms accounted for approximately 0.9%. Additionally, more than 70% of the learners expressed that the current interface presentation of online teaching platforms was too monotonous, and the highlighting of key knowledge points in the interface was insufficiently evident. Therefore, based on the results of the preliminary questionnaire research, courses related to the CUMOOC website were ultimately selected as the research subjects.

Table 1. Basic Characteristics of Research Subjects

Characteristics of research subjects	Gender		Grade			Major			
	Male	Female	Second year of university	Third year of university	Fourth year of university	Visual Communication Design	Digital Media Art	Environmental Design	Product design
Quantity	80	80	80	60	20	50	50	30	30
Proportion	50%	50%	50%	37.5%	12.5%	31.25%	31.25%	18.75%	18.75%

3.2 Research Tools and Process

Firstly, different forms of online course interfaces from the China University MOOC (CUMOOC) website were selected as the research objects. Through recruitment and screening, 10 participants were selected who met the criteria for this experiment and were all art and design students currently enrolled in a university. All participants had completed online courses related to the history of art and design theory. The participants were required to use the computer equipment provided in the experiment to complete the selected course chapters, with no time constraints.

Secondly, an observation method was used to record the participants' experience process. Additionally, user interviews were conducted with the participants before, during, and after the course learning to understand their feelings, thoughts, and needs at different stages of online learning. This process aimed to extract the design factors that affect the learning interface of the online course.

Thirdly, the factors extracted from the experiment were categorized by cognitive load factors. The factors with high frequency from the participant interviews were analyzed to determine the impact of these factors on cognitive load.

Finally, the participants were asked to fill out the PAAS scale for the extracted factors. This scale uses Level 5 Likert scale to quantify the cognitive load experienced by learners during the learning process.

4. Analysis of Research Results

4.1 Dimension Description and Classification of Factors Affecting Cognitive Load under the Theory of Cognitive Load

Through an in-depth analysis of the experimental results and user interview data, we identified the key factors that influence the cognitive load experienced by learners during online learning and conducted dimensional division and frequency statistical analysis on these factors. We categorized and integrated the factors that affect learners' preferences and the interface factors that impact learning efficiency during online learning.

On this basis, we conducted an in-depth analysis of the over 20 factors that influence cognitive load due to the teaching interface during online learning. Ultimately, we summarized and classified eight main issues that affect the layout of online teaching interfaces. These issues include: methods of knowledge presentation, clarity of information, color combinations and text-image visualization, ambiguity in the hierarchy of textual information, abruptness of pop-up information, suitability of the teacher's personal image and course background, display of task progress, and the smoothness of interface (PPT) switching, among others. The specific content can be found in Table 2.

Table 2. Factors and Descriptions Affecting Cognitive Load Dimensions

Factors affecting cognitive load	Specific behavior	Types of cognitive load
Single way of presenting knowledge	In teaching videos, the delivery of knowledge is typically limited to text or a combination of text and images, which makes the presentation monotonous.	External cognitive load
Information is blurry and difficult to recognize	The font size on the interface is too small, and the key content is not emphasized.	External cognitive load
Color matching and graphic visualization	The colors used in PowerPoint slides are numerous, making it visually tiring and uncomfortable for the eyes to read the font color for difficult concepts.	External cognitive load
Unreasonable use of hierarchical text information	Currently, online teaching videos tend to use interruptions in text to explain content, lacking a sense of hierarchy between lines and paragraphs, making it difficult for learners to grasp the key information.	External cognitive load
Bouncing information is too abrupt	Mid-lesson exercises appear abruptly and can disrupt the learners' sense of immersion when pop-up windows appear.	Internal cognitive load
Teacher's Personal Image and Curriculum Background	The teacher's attire in the teaching videos can distract students' attention. It is recommended that the interface background be simple and bright to avoid visual clutter.	Internal cognitive load
Scene (PPT) switching is unnatural	Unnatural transitions between PowerPoint slides or interface elements can also break the learners' sense of immersion.	Internal cognitive load
Unclear task progress	Learners often lack clarity about their current progress in the learning process.	Internal cognitive load

4.2 Analysis of Priority of Design Factors for Online Teaching Interfaces under the Theory of Cognitive Load

Based on the cognitive load factors that affect the layout of online teaching interfaces summarized in the previous section, and in conjunction with the theory of balanced cognitive load, this study employed the PASS subjective cognitive load measurement scale for quantitative evaluation. During this process, the participants were asked to subjectively evaluate the cognitive load factors identified in the experiment, with the assessment dimensions including task difficulty and required psychological effort. The PASS scale is a Level 5 Likert scale (1 representing the least effort required and 5 representing the maximum effort required). After reliability analysis, the Cronbach'sαcoefficients for all dimensions exceeded 0.70, confirming the high reliability of the questionnaire. In this study, a total of 120 PASS scales were distributed, and 117 valid scales were collected, with all measurement subjects being university students. Descriptive statistical analysis was conducted on the collected scale data, and the analysis results of each dimension are detailed in Table 3.

From the Table 3, it is clearly evident that the coefficient of variation (CV) for all variables does not exceed 0.15, indicating that there are no outliers in the data. Through the comparative analysis of the mean and median of each factor, we found that the factors affecting learners' cognitive load generally have a high psychological effort index, with the presentation of knowledge, color combinations and text-image visualization, the hierarchy of textual information, and the clarity of information being the more significant priorities. Therefore, this study will focus on the presentation of knowledge, color combinations and text-image visualization, the hierarchy of textual information, and the clarity of information as the key optimization points for the design of online course teaching interfaces and knowledge presentation.

Table 3. Descriptive Analysis of cognitive Load Factors in Online Teaching Interface

Factors affecting cognitive load	SS	M	SD	Median	Variance	CV
Single way of presenting knowledge	117	3.975	1.354	4	1.832	0.101
Unclear task progress	117	2.688	1.298	3	1.686	0.083
Color matching and graphic visualization	117	4.362	1.305	4	1.702	0.088

Bouncing information is too abrupt	117	2.875	1.391	3	1.934	0.084
Teacher's Personal Image and Curriculum Background	117	2.987	1.307	3	1.709	0.038
Information is blurry and difficult to recognize	117	3885	1.315	4	1.731	0.121
Unreasonable use of hierarchical text information	117	4.524	1.375	4	1.756	0.144
Scene (PPT) switching is unnatural	117	2.655	1.257	3	1.635	0.086

5. Design Methods for Balanced Cognitive Load in Online Course Teaching Interfaces

5.1 Multichannel Information Input

During the learning process, learners can utilize different senses to bear the cognitive load generated by learning activities, and the amount of cognitive load each sense processes varies, leading to differences in the cognitive resources learners invest. In the current online learning environment, learners primarily process knowledge information through auditory and visual channels. According to the principle of the channel effect, working memory processes visual and auditory information independently, with one part focused on visual information and the other on auditory information [11]. Therefore, when only a single information presentation method is used, it may only activate a part of the working memory, while other areas remain underutilized. In contrast, the use of multichannel effects can increase the efficiency of working memory, thus enhancing learning outcomes. Currently, the transmission of information in online courses mainly relies on auditory channels, while visual information is mainly presented through words and images on the interface. These visual elements serve to highlight key and difficult information, but sometimes these cues may not be sufficiently prominent. Therefore, when designing online course teaching interfaces, special attention should be paid to effectively combining visual and auditory information. This can be achieved through visual aids such as charts and animations, complemented by verbal explanations, to enhance learners' immersion and information reception abilities.

5.2 Building Hierarchical and Structured Information

When the amount of information received by an individual exceeds their cognitive processing capacity, learners encounter difficulties in understanding [12]. Effective hierarchical design can more effectively present knowledge to learners and reduce the burden of information processing. Therefore, the knowledge display on online course interfaces should avoid the use of large amounts of continuous text. Such a design may make it difficult for learners to understand the knowledge content presented in a short time, thus increasing the load of information processing, leading to information redundancy, and causing excessive external cognitive load. When designing the layout of the teaching interface, it should be distinguished and combined according to the type and importance of the knowledge being presented to highlight key information. For example, by using information visualization techniques, important knowledge can be prioritized in the interface, guiding learners to focus on the new knowledge before they encounter it, and then gradually introduce related knowledge points, thereby reducing the cognitive difficulty for learners when absorbing new knowledge.

5.3 Minimizing Attentional Diversion to Reduce Cognitive Fatigue in Learners

When learning materials necessitate learners to allocate their attention across various dispersed pieces of information, this can potentially interfere with the learning process [13]. For learners, handling an abundance of dispersed information requires a certain cognitive resource expenditure to integrate the information, which is directly attributable to the manner in which knowledge is presented. Similarly, the knowledge presentation in online teaching interfaces should strive to minimize attentional diversion. Although this effect may initially alleviate the burden on working memory for beginners, as learners accumulate knowledge, attentional diversion can lead to cognitive fatigue and subsequently increase cognitive load. To address this issue, the teaching interface can be optimized through two strategies: reducing the number of dispersed information sources and incorporating break reminders into the teaching schedule. Firstly, diverse dispersed information sources should be integrated to limit knowledge information to no more than two formats, such as images combined with text, animations combined with text, and so on. Additionally, in the information presentation, it is appropriate to integrate these two information sources together, for example, by embedding text within images. Furthermore, the design of the online teaching interface can include interactive features with rest time reminders to prompt learners to take breaks and maintain a balanced approach to learning and rest.

6. Conclusion

In online course teaching, learners often experience a certain degree of boredom and frustration in their knowledge acquisition, primarily due to the imbalance of cognitive load in the "learner-knowledge" interaction process. To enhance the efficiency of knowledge acquisition, strengthen the learning experience, and increase learner interest during online learning, this study took a balanced cognitive load perspective. Based on an in-depth analysis of the "learner-knowledge" interaction process, relevant experiments were conducted on existing online teaching platforms. By collecting and analyzing user experience questionnaires and data from learners, we summarized the factors affecting learners' cognitive load due to interface layout and knowledge presentation in online learning. Moreover, we explored the design layout and knowledge presentation methods of online teaching interfaces based on the theory of balanced cognitive load and proposed corresponding optimization suggestions.

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