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Article

Students' Technology, Cognitive, and Content Knowledge (TSCCK) Instructional Model Effect on Cognitive Load and Learning Achievement

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Abstract: The application of scientific and technological approaches in education has been increasing year by year. We evaluated the effect of a TSCCK model based on the cognitive load theory on the cognitive load and learning achievement of vocational students: this model had six components: (1) analysis; (2) content development; (3) cloud development; (4) learning activity development; (5) model implementation; and (6) model revision. We used 62 students randomly selected from 115 students taking an "E-commerce data analysis and processing" course and used cluster random sampling. A total of 31 students were taught with instructions based on the TSCCK model, while 31 students were taught with a traditional method. The instruments used included lesson plans for the TSCCK group developed using the cognitive load theory and the workload profile self-rating scale (WP scale) used to measure the student cognitive load for both groups. The students who learned with TSCCK had significantly lower cognitive load (WP scale) scores than the students who learned with the traditional method, and their achievement scores were higher. The MANOVA confirmed that both the achievement scores and cognitive load measures for the two groups were significantly different at the 0.05 level.

Keywords: TSCCK model; cognitive load; learning achievement; cloud

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1. Introduction

The human world today has undergone constant developments, and the most critical point is the adoption of "scientific and technological means", which greatly advanced human life. The key to the continuous development of science is education, that is, the cultivation of people. For example, in China, because the government and people have attached great importance to education, the country's overall national strength has greatly improved within just a few decades. In education today, a teacher should not only master traditional teaching methods but also integrate "modern information technology" into the classroom and adopt a variety of teaching methods. The "Education Informatization 2.0 Action Plan" issued by the Ministry of Education of China is a new educational concept, "Education Informatization" [1]. This refers to the comprehensive and deep use of modern information technology to promote educational reform and development. Simply put, it requires blending modern new media technology into education to enhance its quality and efficiency. Education informatization has two aspects: teaching informatization and big data. Teaching informatization [1–3] is the application of information technology in all aspects of teaching and enhances its quality and efficiency. Teaching informatization is the core of education information. In teaching process, teachers normally use multimedia, networks, AI, and other technologies to assist their instruction. For example, during history lessons, when teaching ancient Chinese architecture, many magnificent buildings in ancient China no longer exist, sacrificed to the passage of time, but we could reproduce and experience real historical scenes at that time via multimedia, the internet, AI, and other technologies. By creating teaching scenarios based on multimedia information technology, compared with the traditional teaching mode dominated by instruction, this approach could help students learn better, strengthen their enthusiasm for learning, and create a good atmosphere to learn history. According to psychological and social science studies, this phenomenon refers to cognitive overload or cognitive load. [4–7], which means that "before meaningful learning can begin, the learner may be overwhelmed by a large number of interactive information elements that therefore need to be processed simultaneously" [8].

For example, in lessons about traditional culture in a tourism management major, there is often a single teaching method. Teachers still use a traditional teaching method, namely "infuse teaching", in which they write information on the blackboard for students to learn and memorize. This single, mechanical teaching method is often boring for students [9].

1.1. Vocational Education Cloud

In the context of this study, the "cloud" is a resource base, the < 职教云 > or "Vocational Education Cloud" is a collection of applications and databases built by the Chinese Ministry of Education (https://zjy2.icve.com.cn/portal/login.html: accessed on 9 July 2022), to satisfy the requirements of the manual of professional education teaching resource case construction [10]. The cloud is physically distributed over schools, and each teacher has access to it for use in classes. The content could be divided into three parts: before class, during class, and after class. Before class, teachers obtain teaching information resources from the cloud and combine them to satisfy the needs of a particular class. In class, teachers extract relevant resources and functions for "information-based" teaching, including check-ins, brainstorming, playing animations directly from the cloud, etc. After class, teachers assign tests and homework, and the system records student learning trajectories automatically.

1.2. Why Is the TSCCK Model Suitable for Vocational Students?

The TSCCK model refers to the following:

- Student technology knowledge (STK);
- Student cognitive knowledge (SCK);
- Student content knowledge (SK).

In recent years, China has witnessed rapid socioeconomic development and an urgent need for many highly skilled personnel. Therefore, specialized training for skilled personnel in vocational colleges has emerged. Higher vocational colleges, as an important part of China's higher education, now emphasize training technical application-oriented talents, distinct from general higher education. For example, teachers in vocational colleges could adopt information technology to organize students in their colleges to learn technical skills as well as general knowledge. In teaching, teachers could effectively design teaching activities and define the major role of higher vocational students [11] by centering on students.

In vocational colleges, the emphasis is on the cultivation of students' operational skills. The TSCCK model focuses on the cultivation of technology knowledge and how to train and improve student technology knowledge. As we all know, vocational school students focus on practical knowledge so that they can directly take up work after graduation. They generally do not need employers to provide pre-job training, thanks to the practical work in school. For example, vocational colleges hire experts in intelligent manufacturing appointed by the cooperative enterprise. They are excellent senior engineers and experts; their experience lets students better understand the current level of professional knowledge, i.e., to introduce cutting-edge technology that the students would need in the future to prepare for practice and employment in the future.

In addition, vocational schools also organize enterprise training for the teacher team from time to time so that they can understand and master current technological frontiers to better connect the teaching content with the industry trends [12]. The cloud for technical support integrates various teaching resources, with teachers as the driver, to design curriculum teaching activities. The cloud platform and teaching design (TSCCK) model could compensate for difficulties in arranging students' on-site practice, especially for some dangerous and complex concepts that professional workers find difficult to explain on the spot. For example, teaching needs some material support, and these materials are often expensive. Vocational college funds are limited, and sometimes, the schools cannot afford to construct a mechanics training room. Without a training room, teachers could use information technology to simulate the real environment in class while the cloud provides technical support. For example, by teaching an "architectural mechanics" course at the initial stage, teachers could use the cloud to display pictures and videos of a construction site to create a more realistic and safe training environment [12]. In addition, during teaching, the three basic ideas of the TSCCK model: technology (STK), cognitive (SCK), and content knowledge (SK) could be combined and integrated by teachers. In this way, professional teaching and industry are closely interconnected, so the teaching effect of vocational college courses is fundamentally improved.

Based on the cognitive load theory in vocabulary acquisition, our study developed a TSCCK model using the cloud; a key aim was to decrease cognitive load and enhance learning. As examples of the TSCCK model instructional steps, we describe the design fundamentals of an "E-commerce data analysis and processing" course, where we improved the course activities using the cloud as a primary resource. Given the improvement in learning we achieved, we consider that it lays a foundation for further research on this model in other areas of technology-based teaching.

1.3. Previous Work and Background

1.3.1. Cognitive Load Theory in Instruction

The cognitive load theory [13] uses modern cognitive psychology research to show how to facilitate learning and teaching design; it involves a wide range of application capabilities and operational values and leads to positive development. The 21st century is an era of information. The times require people to "learn how to learn"; to absorb key knowledge from a vast ocean of information, one must learn quickly and efficiently. This is a basic characteristic of modern learning, as well as an essential quality and pursuit of modern learners. The main purpose of this study was to investigate how to promote the germane load of students under the background of modern information-based teaching within the TSCCK model.

It is required not only to adopt an appropriate teaching design to support students and lower both extraneous and intrinsic cognitive load [13] but also to enable students to learn how to use germane cognitive load. For this reason, in the context of modern information technology, teachers need to read research on cognitive load to strengthen the management of student cognitive load and efficient teaching.

First of all, in teaching, the manner of speaking of teachers directly influences students' cognitive processing and load when listening to lectures. For example, when teaching mathematics, many concepts are abstract. While listening to lectures, students consume cognitive resources and feel tired if they use abstract thinking for cognitive processing. Thus, mathematics teachers should express themselves in a clear, accurate, concise, and logical manner when designing classroom presentations [14] to ease the burden of language cognitive processing.

Secondly, to reduce cognitive load, sample teaching [15] was found to be a good teaching model, which could lower the cognitive load and enable students to pay more attention to the general structural characteristics of problems, as well as the principles, rules, and algorithms to be adopted in specific circumstances, so as to enhance students' schematic and automatic acquisitions [13]. For example, when teaching statistics in the sixth grade of elementary school, teachers may select real-life examples that the students are very familiar with [14]; for example, their daily schedule structure or the family's living expenses plan, or other projects based on simple demographic details. These examples were closely associated with student life and study, as well as the schema stored in their long-term memory and relevant knowledge and experience. The students were familiar with them, so their cognitive learning load was reduced. Therefore, during teaching, examples familiar to students were used as subjects, which improved the ease of learning significantly.

To this point, the courseware design and application of the cognitive load theory need to be addressed. According to the theory, extraneous cognitive load is associated with the organization and presentation of materials. Thus, in order to reduce the load intensity, when designing courseware, one should organize relevant teaching materials reasonably. For example, when teaching quadrilaterals in eighth-grade mathematics [14], teachers were advised to design visualizations showing the correlation and differences between various quadrilaterals, e.g., general quadrilaterals, trapezoids, parallelograms, rectangles, rhombuses, and squares; a comprehensive diagram could describe the logical relationship between the various quadrilaterals visually and intuitively, and teachers could use the diagrams and text together during the lesson. In this way, not only could the resources of student cognitive processing be saved and their inherent cognitive load lowered, but students could also build a correlation between the speech and image models so as to facilitate their meaningful learning.

1.3.2. TSCCK Background

Considering the cognitive load theory (CLT) is very important when designing teaching programs. In particular, we should consider the participation and identification of users when adopting technological means for cognition [8]. Learners' working memory ability could influence their cognitive load [16]. The cognitive load theory considers that adopting different teaching designs and learning materials may lead to different cognitive loads and experience styles and influence learner interaction styles because the individual working memory capacity is limited [16,17]. Therefore, to improve learning, it is necessary to explore the difficulty in learning materials and teaching design. Images are not only an important intermediary between languages and concepts but also a mode of physical experience [18]. The working memory and long-term memory of learners are part of the cognitive load theory. This theory holds that since working memory has a limited capacity, the cognitive structure of learners' working memory could be integrated through reasonable teaching design to lower the cognitive load [16]. The way learners interact and experience the learning environment is influenced by teaching design and the difficulty in learning materials [16,17]. The cognitive load theory is considered one of the most significant theories in teaching design. When applying technology to teaching design, teachers should identify the cognitive processes that learners activate [16]. Mayer [19,20] introduced the principle of spatial continuity, which showed that if learners used both text and photographs in the learning of words, this would lower their cognitive load and improve their learning effect, compared with those who used text alone in a multimedia learning environment.

Accordingly, compared with learners with higher cognitive loads, learners with lower intrinsic cognitive loads tend to occupy less working memory capacities, and information could be converted into long-term memory for storage [21]. Galy & Melan [22] posited that the total quantity of resources in three categories was cumulative and fixed. If the extraneous cognitive load includes more resources, there would be fewer resources in the working memory, and it would be hard for learners to convert short-term memory into long-term memory as they learn. By examining the application of the cognitive load theory by some instructional designers to structured design fields (generally well-structured designs and complex ill-conditioned designs), we could see that researchers would be able to replicate more realistic research into a problem-solving context and identify the domains that are more applicable to a variety of strategies. Further, instructional designers in charge of training would have a better understanding of embedding the cognitive load theory in situational learning [23]. In an effort to respond the problem of the cognitive load effects in fields other than mathematics and science, empirical research is required to uphold the role of cognitive load [24,25].

For example, Oksa et al. [26] discovered that when high school freshmen were provided with modern English annotations while learning Shakespeare's plays, their cognitive load performance was lowered. Si et al. [27] observed that undergraduates, who solved programming problems with worked examples, managed cognitive load better and thus better constructed and automated schemas. Several other cognitive load effects were observed in other studies, including the minimization of distraction through the simultaneous presentation of materials [28], expertise reversal effect [26,29], and benefits of fading steps within a solution as learners acquired problem-solving skills [27].

2. Methods

Our study used the following steps:

- Identify the research objectives;
- Clarify the details with the population and the experimental class;
- Describe the research instruments: including the lesson plans, WP scale, and e-commerce data analysis and processing test.

2.1. Research Objectives

We compared the cognitive load and learning achievement between students learning with the TSCCK model and those who learnt with the traditional method.

The hypotheses were:

Students who learnt with the TSCCK model

H1a: had lower cognitive load and

H1b: higher learning achievement.

2.2. Population and Sample

The details of the population and the experimental class are set out in Table 1.

Table 1. Details of the population and the experimental class.

School Location	Kaili	107.99848° W, 26.58727° N
Name	Guizhou Vocational Technology College of Electronics & Information	
Course	E-commerce data analysis and processing	
Duration	4 weeks	Second semester of the 2021–2022 academic year
Student age range	18–21 years	
Level	Second year	
Total population	115	
Sampling strategy	Select 62 students from 115 students using random cluster sampling	
Class size	Experimental (with TSCCK)	31 (4 female and 27 male)
	Traditional	31 (9 female and 22 male)

There were two variables in the study:

1. The independent variable: the TSCCK model with the cloud versus a traditional method.
2. The dependent variables: students' cognitive load and learning achievement.

The "E-commerce data analysis and processing" course combined theory and practice; it was designed to teach the basic concepts of e-commerce data analysis and processing systematically. Students became familiar with the analysis of online shop data, including data collection, data sorting, data analysis, data processing, data visualization, etc. This course was suitable for students majoring in e-commerce.