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Cognitive Load Theory on Virtual Mathematics Laboratory: Systematic Literature Review

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Abstract.
The primary goal of cognitive load theory is to improve the learning of complex cognitive tasks by transforming current scientific knowledge on how cognitive structures and processes are organized into guidelines for instructional design. Cognitive load theory assumes that the bottleneck for acquiring new secondary biological knowledge is the limited working memory capacity. In the ideal situation, the working memory resources required for learning do not exceed the available resources. Despite this, in reality, there will often be a high cognitive load, or even "overload," for two reasons. First, dealing with interactive information elements in complex cognition imposes a high intrinsic working memory load. Second, learners also have to use working memory resources for activities that are extraneous to performing and learning tasks, that is, activities that are not productive for learning. Virtual Laboratory is a form of animation that can visualize abstract phenomena or complex experiments in natural laboratories to increase learning activities and develop problem-solving skills. A virtual math laboratory was created to optimize dual coding memory, namely verbal and audio learning. The investigation tracked the approved reporting Items for Systematics Reviews and Meta-Analysis (PRISMA) guidelines, illustrating the outcomes of the literature searches and articles selection process. It is used to provide that the selection process is replicable and transparent. We accomplished a computerized bibliometric analysis from 2002-2022 for articles retrieved from the SCOPUS database. Data were collected in July 2022.

Keywords: cognitive load theory, virtual laboratory, mathematics education

1. Introduction

The teacher's understanding of students' initial knowledge is essential to increasing learning capacity and reducing cognitive content. To improve learning capacity and reduce students' cognitive content, teachers need to understand the basic knowledge that will be used to assist students in improving learning performance in teaching (Schnotz et al., 2007). Assume that a solid evidence base cognitive load theory provides theoretical and empirical support for an explicit teaching model. Research in cognitive load theory shows that teaching techniques are most effective when designed according to how the human brain learns and uses knowledge. Furthermore, cognitive load theory explicitly supports the most effective teaching model since cognitive load theory provides a way in which the human brain learns most effectively (5-7). Explicit teaching includes how teachers clearly show students what to do and how to do it versus students having to find and construct information from what they have obtained (3-4). This theory of cognitive charge is arisen from the work of the educational psychologist John Sweller and his colleagues in the 1980s and 1990s (5,6). The implications of the limitations of working memory on teaching design are almost invaluable. Anything beyond the most uncomplicated cognitive activity seems to overwhelm working memory (3-6).

Cognitive load theory is identified in three different types : intrinsic load, extraneous load and germane load (8,17,19,20). These three types are generally assumed by combining them between intrinsic load + extraneous load + germane load = total cognitive load. Cognitive overload occurs when the total cognitive load exceeds the working memory capacity of the learner (2,9,10,11). Intrinsic cognitive load is related to difficulties in the subject being studied in this case material (5,8,14,19,20). Intrinsic cognitive load is needed from the cognitive load type. Two factors that are particularly concerning are the complexity of the material and the basic knowledge of the learner (8,15,17). This means that learning materials are sometimes difficult for novice learners but may be easy for expert learners. For example, the summation of the return numbers will be very difficult for elementary school students in grade 1, but it will be very easy for students in grade 5 elementary school. Many theories reveal and agree that intrinsic cognitive load can be made an alternative to teaching techniques that can make complex material easier to learn. Extraneous cognitive load is related to how the subject matter is taught; according to Merrienboer & Sweller, the extraneous load is a load that is not needed in learning (schema construction & automation). Extraneous load is a cognitive load that does not directly contribute to learning. A combination of high intrinsic and high extraneous cognitive load may be fatal to learning because working memory may be substantially exceeded. It may be essential to design instruction in a manner that reduces extraneous cognitive load (8. 18,16). **Germane cognitive** load means the process of transferring information from working memory into long-term memory through schema construction (8,20). Germane cognitive can be understood in simple terminology that germane load is a good cognitive load type compared to extraneous, which is a bad cognitive load type. Cognitive load theory decides that instructional material has high effectiveness when it can reduce extraneous load (irrelevant to learning) and increase the germane load (directly related to learning). Germane load provides instructional design support and aids in effective learning (16,19).

The condition of digital learning today demands creativity and innovation, which is very high for teachers in delivering subject matter. Literacy and numeracy skills are also one of the top priorities in the goals of every learning in school. Mathematics is one of the subjects that are very relevant for the acceleration of literacy and numeracy development for students (21). Furthermore, this study examines the theoretical basis of cognitive load theory related to the virtual laboratory. The method used is a literature review. Our investigation followed the preferred reporting items for systematic Reviews and Meta-analysis (PRISMA) guidelines, illustrating the outcomes of the literature searches and article selection process (12). The achieved from this review provide an overview of the CLT concept map with a virtual laboratory, according to the researchers.

2. Method

The investigation pursued the elected reporting Items for Systematics Reviews and Meta-Analysis (PRISMA) guidelines, illustrating the outcomes of the literature searches and articles selection process. PRISMA consists of a checklist describing the protocol offshored for selecting the collection of articles used in a systematic literature review (13). It is used to ensure that the selection process is replicable and transparent. We performed a computerized bibliometric analysis from 2002-2022 for articles retrieved from the SCOPUS database. Data were collected in July 2022.

To establish all publications related to this field, we defined the consecutive query: TS: Virtual Laboratory" AND "Cognitive Load Theory." TS stands for the topic, that is, the search of the considered words in the title, abstract, and keywords list.

3. Result and Discussion

The contrast of the number of publications from selected papers for virtual laboratory with the general movement of all articles published in the subject category "Virtual Laboratory" AND "Cognitive Load Theory" starting from 2002, there has been an increase in a citation (Figure 1)

Thematic map clearly displays the clusters and keywords from 2002-2022 ("prior analysis") identified by the co-occurrence network. The X-axis represents the centrality (i.e., the degree of interaction of a network cluster in contrast with other clusters) and gives information about the priority of a theme. The Y – Axis symbolizes the density (i. e

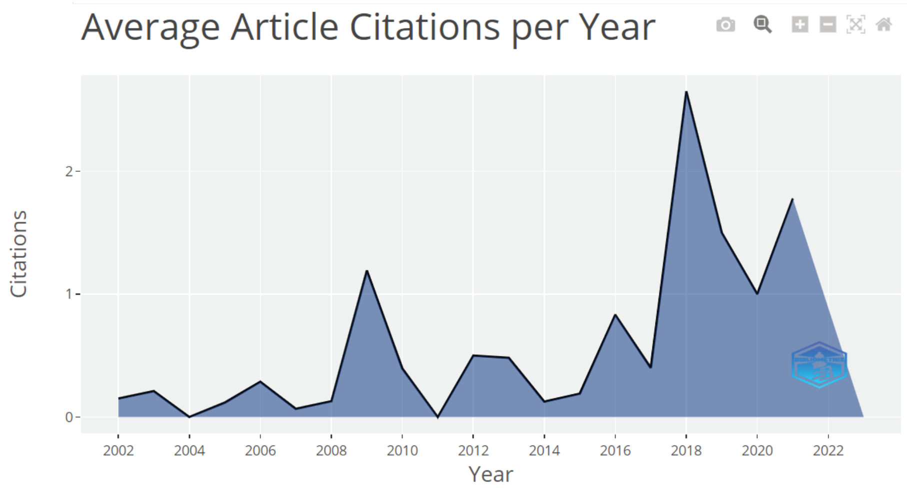

Figure 1: Average Article Citations per year 2002-2022.

measures the internal strength of a cluster network, which can be assumed to calculate the theme's development. Appropriately, the first quadrant identifies motor themes that are well developed and essentials themes for the structuring of a research field). The second quadrant is plotted highly developed and isolated themes (i.e., themes of limited importance for the field). The third quadrant contains emerging or declining themes (i.e., themes weakly developed and marginal); in the fourth quadrant falls basic and transversal themes (i.e., they concerns general topics that are transversal to different research areas of the field.

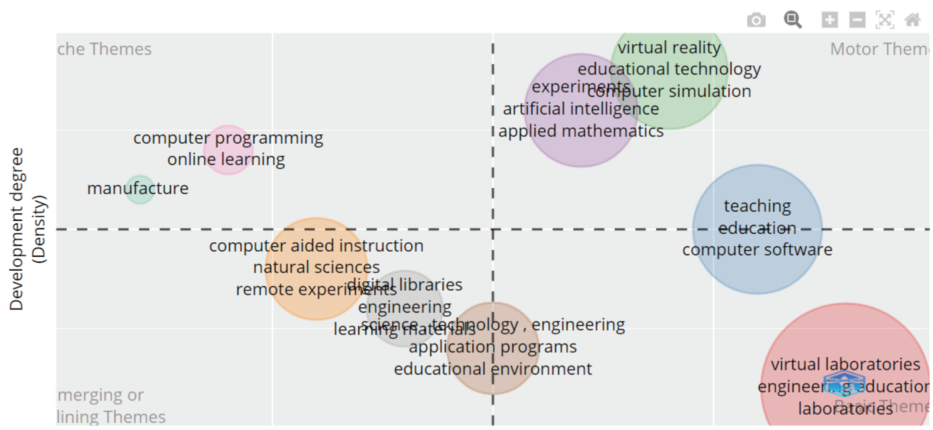

Figure 2: Tematic Map 2022-2022.

The analysis of keywords in the "prior analysis" identified six clusters, represented in a thematic map, according to their centrality and density ranking. A cluster was delineated by high centrality and high density and was positioned in the first quadrant as a motor theme. It included the words "virtual reality" a second cluster with good

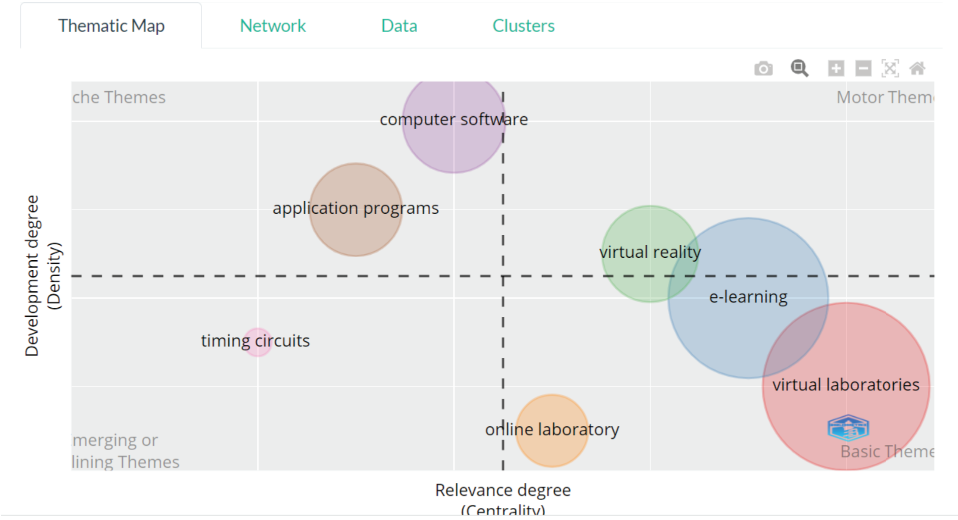

Figure 3: Thematic Map For Density.

centrality and density identified another well-developed theme, including keywords plus ”computers software” and ”applications programs.” It was an essential and transversal well-developed theme. Finally, an isolated theme with a high density and low centrality, including the only word ”timing circuits,” was positioned in the 3rd quadrant, which meant that it had limited importance for the field. Therefore, the words ”e-learning,” ”virtual laboratory,” and online laboratory are the most common keywords.

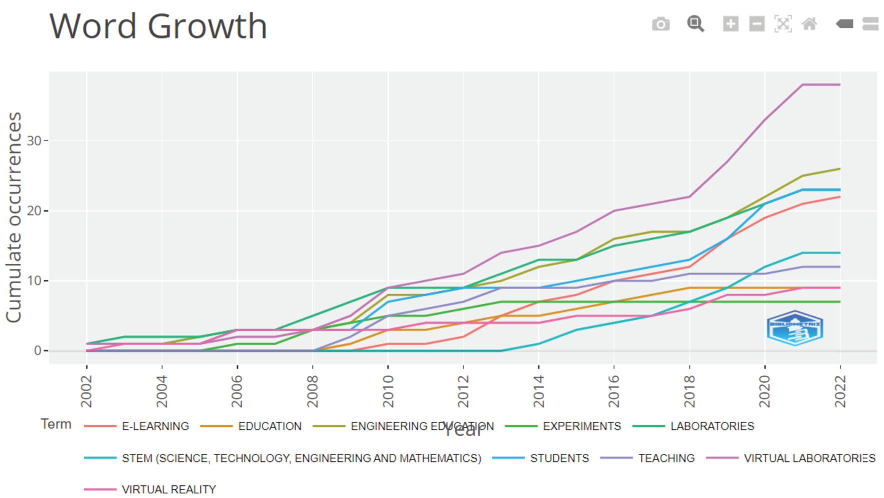

Figure 4: Word growth 2002-2022.

Figure 4 shows that virtual laboratory research has continuously increased significantly in the last two decades, followed by virtual reality STEM and e-learning.

3.1. Discussion

The first goal of the present paper was to verify whether the virtual laboratory and cognitive load theory were attracting the interest of scholars more than the studies on virtual laboratory and cognitive load theory. Our data shows that scientific production for virtual laboratory and cognitive load theory studies is more consistent in a recent analysis than in earlier analyses. Additionally, the growing trend in studies on virtual laboratories, starting from 2002, exceeds the number of papers in the subject category. Why the number of studies started growing around 2022 is had to say. The most cited papers in this field came around this period and dealt with virtual laboratories. However, our data show that the interest in the theme is related to the virtual laboratory in **Figure 5**.

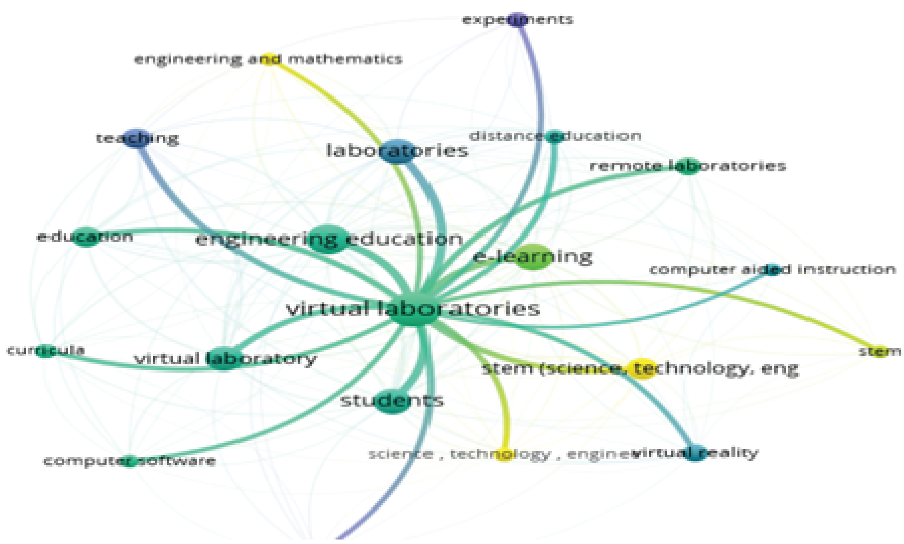

Figure 5: Research interest related to the virtual laboratory.

This study has considerable circumspection, mainly related to the instrument of bibliometric analysis per second. Indeed, although our selection has bounded false-positive, false-negative results are always present in bibliometric research, as it is impossible to achieve a perfect and all-enveloping research objection.

4. Conclusion

Lastly, it was celebrated that most of the existing literature is on the growing movement in the virtual laboratory and cognitive load theory. The growing progress of publications on virtual laboratory and cognitive load theory in our analysis started to overlap in 2002.

Therefore, it is evident from our data that virtual reality and online learning is the most aspect of the developing trend of the virtual laboratory.

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