

Optimising Instructional Design Strategies to Mitigate Cognitive Overload

Cymbeline Harilal, Cebelihle Sokhela, Mariana Van Der Walt

Private Higher Education: South Africa

cymbeline033@gmail.com

cebelihleh@gmail.com

Pronkmvdw@gmail.com

Abstract: A lack of unified instructional design strategies to mitigate cognitive overload in higher education necessitated this study to explore how instructional design could mitigate cognitive overload in first-year commerce students. Grounded in the Cognitive Load Theory (CLT), which posits that excessive information impedes conducive student learning experiences and metacognition. The research is situated within a South African private higher education institution (PHEI) and explores a qualitative analysis using a three-pronged approach. Firstly, a literature review on CLT and its application in instructional design impacting students' learning experiences was conducted. Secondly, the researchers evaluated the institution's 2023 instructional design of modules and their presentation through the learning management system (LMS) using multimedia learning. The purposive sample consisted of eight first-year modules within the Bachelor of Commerce degree program to assess the learning design elements against the principles of CLT. The researchers, being three instructional designers used secondary data and peer-reviewed the module evaluations to validate the findings and verify the impact of CLT on students' learning based on the institution's existing instructional design strategy. By evaluating the PHEI's current instructional design practices against CLT principles, this study aimed to identify effective strategies to manage cognitive load and enhance the student learning experience within the higher education context. The research findings of this study indicated that the integration of CLT into instructional design could mitigate cognitive overload, thereby improving the student learning experience, and metacognition and providing guidelines for the refinement of instructional design strategies. The value of the research outcomes was anticipated to contribute to the development of improved instructional design strategies using multi-media learning to address cognitive load. The value of the research outcomes was anticipated to contribute to the development of improved instructional design frameworks and strategies that addressed cognitive load, enabling effective and conducive learning environments in higher education. These insights aimed to guide future research in curriculum design and teaching and learning practices in higher education and to recommend instructional design strategies to manage cognitive load thus mitigating the challenges of cognitive overload experienced by students and enhancing the student learning experience.

Keywords: Cognitive Load Theory (CLT), Cognitive overload, Higher education, Instructional design, Metacognition, Student learning experience, Multimedia

1. Introduction

Instructional design is essential for understanding and applying Cognitive Load Theory (CLT), a framework addressing challenges in learning and problem-solving due to working memory limitations (Chandler and Sweller, 1991). CLT suggests that these challenges are not fixed but can be mitigated through well-designed instructional strategies. This study, conducted at a private higher education institution (PHEI) in South Africa, aimed to optimize instructional strategies to reduce cognitive overload, with a specific focus on multimedia learning. The research examined the design and delivery of the 2023 first-year Bachelor of Commerce modules using a learning management system (LMS). An evaluation of eight modules using a bespoke tool informed by CLT principles was employed. Recent advancements in CLT have introduced distinctions between "old" and "new" CLT, with scholars urging transparency in the theoretical choices made by researchers (Duran, Zavgorodniaia and Sorva, 2022). The role of instructor-managed strategies in multimedia learning has gained attention as critical for enhancing student outcomes (Castro-Alonso et al., 2021). This paper reviews the relevant literature, outlines the qualitative methodology used, and discusses how CLT-informed strategies can reduce cognitive overload and improve student learning and metacognition.

2. Literature Review

The concept of cognitive load (CL) was first presented by Sweller (1988) related to the effectiveness of conventional problem-solving methods for acquiring domain-specific knowledge and skills. Sweller (1988) indicated that working memory has a limited capacity and stressed the importance of minimising extraneous cognitive load to maximise learning. Specifically, Sweller (1988, p265) noted "Human short-term memory is severely limited and any problem that requires a large number of items to be stored in short-term memory may contribute to an excessive cognitive load". The theory emanated in the 1980s and progressed in the 1990s when CLT investigated cognitive processes and instructional design. CLT emphasizes the significance of instructional

design where complex cognitive tasks manifested through the quantity and interaction of information are simultaneously processed and the cognitive processes that occur before learning is initiated (Kala and Ayas, 2023). The literature delves into human memory and CLT types, strategies and multimedia learning.

2.1 Memory and CLT Types

The Multi-Store memory model (Jawabri and Cascella, 2024) relates to three separate memory stores, and that memory is transferred between these three stores in a linear sequence. The three stores are sensory register memory, short-term memory (STM) and long-term memory (LTM). Each store of memory differs in the way information is processed, encoding how much is stored (capacity) and for how long (duration). The passing from one store to another is similar to the computer input, process and output hence the description and the information processing model. Sensory stimuli through human organs enter the first store of sensory and the interaction with this information may enter the STM if it is given meaning (rehearsal) it is passed to LTM (Jawabri and Cascella, 2024). There are three discrete types of CL namely: Intrinsic, extraneous, and germane (Clark and Kimmons, 2023). CLT relates to instructional implications concerned with the structure of the ways information and activities are presented to learners, where the load exceeds working memory and is not automated by learners, the extraneous CL should be reduced through non-conventional procedures (Paas, Renkl and Sweller, 2004). The general assertion of CLT is that the capacity of working memory is limited (Chandler and Sweller, 1991) is not disputed. de Jong (2010) explored questions and the boundaries of CL theory and identified several problematic conceptual, methodological and application-related issues. Technical issues and conceptual misunderstandings regarding the efficiency measure, the original measure is a measure of the quality of the resulting knowledge and not of the instructional condition (de Jong, 2010). Germane load arises from the additional cognitive effort dedicated to deeper learning, which includes reflection and self-explanation (Clark and Kimmons, 2023).

2.2 CLT Strategies and Multimedia Learning

Castro-Alonso *et al.*, (2021) averred that to optimise instructional materials and manage CL, several strategies can be employed, using the multimedia principle (Mayers, 2002) suggests using visual elements to complement text. The split-attention or spatial contiguity principle integrates visualisations and text close to each other whilst the redundancy effect involves eliminating unnecessary information Castro-Alonso *et al.*,(2021), the signalling principle emphasises essential information, while the transient information effect, or segmenting principle, allows for controlling the pace of animations and videos. Instructional designers can use these strategies to determine their level of agency in the learning process.

The CLT effects by Sweller *et al* (2011) were explored in the summary that follows and captures the key cognitive load effects, providing a concise overview of how different instructional strategies can impact learning efficiency.

Goal-free: Sweller *et al* (2011); and Paas and Kirschner (2012) state that the goal-free effect is when novice learners solve problems backward if there is a specific goal, this is heavier on the cognitive goal as opposed to a goal-free, for example, if the goal was given in a specific problem and students need to solve this, the problem should ask for many possibilities of solutions rather than one, for example, to calculate a specific variable, the goal should be to calculate as many as possible

Worked example: Referred to within the CLT suggests that using examples, especially for novice learners would assist learners and is considered superior to unguided problem solving to reduce CL and facilitate knowledge retention. Providing explicit step-by-step instructions in the first few steps will help students during the learning process (Chen, Retnowati, Chan and Kalyuga, 2023).

Split attention: Arises when information is presented separately in space or time, such as a diagram on one screen and text on another. This forces learners to switch between sources, increasing CL and disrupting the learning experience by consuming working memory and breaking the explanatory chain. Effective instructional design must consider CL and adapt to learners' experience levels to optimise outcomes (Ayres and Cierniak, 2012).

Modality: Using the dual auditory and visual channels can enhance learning by distributing CL. Using both visual and auditory modes together is more effective than presenting information in just one mode. For example, a diagram must be shown visually, but the accompanying text can be spoken instead of written. This approach reduces the CL on visual working memory to process the information across both auditory and visual systems (Low, 2012).

Redundancy: Occurs when learning is impeded by the presentation of more information than necessary. For example, when the same content is provided in multiple forms, such as pictures, text, and audio, reducing it to only the essential format can enhance learning. Similarly, eliminating the full text when a summary is available can also improve learning outcomes (Jin, 2012).

Expertise reversal: As learners advance from novices to experts, instructional methods should be adjusted to gradually remove scaffolding, thereby encouraging independent learning. This process is known as the expertise reversal effect. For example, novice drivers may process information piece by piece, while experienced drivers integrate information into a cohesive schema that guides their behaviour automatically (Sweller, Ayres and Kalyuga, 2011c).

Guidance fading: Involves gradually decreasing the amount of guidance given to learners as their knowledge or skills improve. This includes reducing the information provided and the support in the learning process (Renkl, 2012). High levels of guidance can hinder advanced learners. In novice learners, it is important as part of instructional design to reduce the extraneous load that distracts learners from learning the central concepts and principles still to be learned

Imagination: Refers to the imagination effect within a CLT, for novice learners the number of interacting elements may exceed the capacity of the working memory rendering an imagination procedure ineffective (Sweller, Ayres and Kalyuga, 2011a). Contrarily experienced learners could have sufficient task-relevant schematic knowledge stored in long-term memory where associations can be made making substantial familiar information to be processed within the working memory. Thus the imagining may be more suitable for expert learners than novice learners

Self-explanation: Connected to the imagination effect involves mentally simulating procedures and relating them to established domain principles (Clark, Nguye, and Sweller, 2006). It was found that in more experienced learners, explaining procedures and solutions in worked examples improved learning (Singh, Marcus and Ayres, 2012).

Element interactivity: Estimates the complexity of learning materials based on learners' knowledge level (Sweller, Ayres and Kalyuga, 2011a). Design must consider element interactivity to manage and reduce extraneous CL in complex materials is crucial to prevent exceeding working memory capacity, while expert learners may not benefit from such adjustments due to the expertise reversal effect

Collective working memory: CLT research indicates that in complex tasks, groups outperform individuals due to the distribution of information across collective working memories. Collaborative learning mitigates individual working memory constraints through the collective working memory effect and collaborative interactions are crucial to effective group problem-solving (Kirschner, Paas and Kirschner, 2011).

Multimedia learning: Effective strategies include using visuals alongside the text (multimedia principle), integrating text and visuals spatially (spatial contiguity principle), removing redundant information (coherence principle), using cues to highlight key content (signalling principle), and segmenting complex materials into manageable parts (segmenting principle), these approaches are grounded in cognitive theories and aim to enhance learning by reducing CL and improving retention through instructional design (Mayer 2002; Castro-Alonso et al. 2021). The transient information principle in multimedia learning focuses on the distinction between information that is temporary or lasts for short periods, and permanent information (Singh, Marcus and Ayres, 2012). Learning is improved when the information is presented in a permanent form thus it reduces CL and improves self-efficacy, consistent with CLT (Niegemann and Heidig, 2012).

2.3 Metacognition

Cognition is about thinking but the metacognitive process refers to planning, monitoring, evaluation of understanding and performance, being aware of one's thinking and learning, and importantly conducting the reflective exercise of the metacognitive processes (Chick, 2013). The importance of metacognition strategies helps learners transfer knowledge to working memory, enabling them to manipulate and summarise information effectively by incorporating strategies that develop students' problem-solving, critical thinking, and learning management skills should be promoted. Collaboration and communication are important for metacognitive development (Tezer, 2024).

In summary, the literature reviewed instructional design through CLT focused on balancing the types of cognitive loads. Strategies such as the goal-free and worked-example effects, multimedia principles, and collaborative learning were discussed. The optimization of instructional materials considers visuals, reduces redundant

information, segments complex content, and adapts methods as learners gain expertise. Metacognitive learning delved into self-regulation and reflection to improve retention and learning efficiency.

3. Methodology

This study employed a qualitative research design explored how instructional design strategies can mitigate cognitive load in first-year commerce modules at a South African (PHEI). A qualitative approach is ideal for this study as it allows for an in-depth examination of instructional materials, to assess their alignment with CLT principles and identify strategies to mitigate cognitive overload. This approach aligns with the research objectives and the study's primary question of how instructional design can be optimized to reduce cognitive overload in online learning environments (Creswell and Poth, 2007).

A qualitative document analysis was chosen as the most appropriate method for this study because it focuses on analysing secondary data, specifically the instructional content used in the selected modules. This approach enabled a systematic evaluation of textual and visual content to determine its CL characteristics. Document analysis has been widely accepted as a rigorous method for analysing instructional materials in educational research (Bowen, 2009), and it aligns with the study's focus on cognitive load and instructional design principles (Sweller, Ayres and Kalyuga, 2011a).

The rationale behind this approach lies in its ability to provide rich, contextualized insights into the structure and organization of instructional materials, which is central to addressing the research questions. The qualitative nature of this study also ensures that subtle but important aspects of instructional design, such as sequencing and content structure, are thoroughly examined (Merriam and Tisdell, 2015).

Data was drawn from secondary sources, specifically the instructional materials of eight purposively sampled first-year commerce modules on the LMS. The LMS was selected because it provides a comprehensive view of the course content delivered to students. This method ensures that the data collection aligns directly with the research objective of evaluating the cognitive load in existing instructional materials (Bryman, 2016). Ethical considerations were adopted by obtaining an ethical clearance waiver from the PHEI the reference number is R15960.

The instructional materials were analysed using a bespoke evaluation tool developed by the research team, designed to assess the content's alignment with CLT principles, drawing on established theories in cognitive and multimedia learning (Sweller, Ayres and Kalyuga, 2011a; Sweller, Ayres and Kalyuga, 2011b, Sweller, Ayres and Kalyuga, 2011c and Mayer, 2002). The evaluation tool consisted of closed-ended questions with a five-point Likert scale and open-ended questions focusing on content structure, organization, multimedia use, and instructional strategies. The questions were developed based on established cognitive load strategies and multimedia learning guidelines (Castro-Alonso et al., 2021).

The instructional materials were evaluated using a content analysis method based on a bespoke evaluation tool. Three researchers independently assessed each module, focusing on elements contributing to cognitive overload, such as content density, sequencing issues, and misaligned multimedia. After independent evaluations, a peer review process resolved discrepancies through discussion, ensuring consensus (Johnson, Adkins, and Chauvin, 2020). The evaluation tool was refined through pilot testing to improve reliability and ensure accurate measurement of cognitive load indicators. Triangulation was employed by cross-referencing findings with the literature, enhancing the study's validity and reliability (Kimberlin and Winterstein, 2008; Johnson et al., 2020).

4. Results

The analysis of the instructional design frameworks revealed several key insights into the alignment of current practices with the principles of CLT. The guidelines used to evaluate the design of modules and their accompanying LMS presentation were included in an online qualitative questionnaire using Google Forms to ensure consistency and provide computer-aided analytics to the responses from the three researchers. Eight modules in MSWord™ format were renamed as modules A, B, C, D, E, F, G, and H. Twelve main questions extended into twenty-seven questions that included sub-questions were completed between the three researchers. An initial pilot run was conducted. Important improvements were made. All the modules were evaluated by the researchers against this guidelines tool, the results were finalised in the Google form, the results were exported to MSEXcel™, where pivot tables assisted the interpretation of data. The table represents the evaluation of modules.

| Evaluation of Instructional Design Using CLT: Questionnaire |
|---|
| Module |
| 1. Worked examples: Are there any worked examples in the current design? |
| 2. Are there worked examples where needed in the module? |
| 3. Are the worked examples clear and allow for scaffolded learning? |
| 4. The worked examples are scaffolded to allow for independent problem solving. |
| 5. [The information in the current design is taxing the working memory.] |
| [The information in the design is chunked, or sectioned logically.] |
| [The information in the design is repeated.] |
| [The images are presented in a manner where the text is next to the image, rather than on the image.] |
| [The images are essential and clear.] |
| [There is a balance between graphics and text.] |
| [Scenarios cover essential information .] |
| [Diagrams and infographics are simple and clear.] |
| 6. Presentation of essential information [Essential information grouped together.] |
| [The design provides a logical manner in which the essential information is laid out including additional material where applicable.] |
| [Visuals and text are close to each other.] |
| [Feedback is provided next to relevant questions.] |
| [The steps or directions for an activity are presented on the same screen.] |
| [The visual cues to assist students with the grouping of essential information.] |
| [The material is personalised in terms of using everyday language and demographics of the target audience.] |
| [Attention is drawn to vital information by emphasising key points with for eg. Arrows, callouts, highlights or bold text.] |
| 7. Oral and visual presentation [There is a balance between oral and visual presentation in the current design.] |
| [There is more than one form of media used in the current design.] |
| [There is a combination of visual cues and oral presentation in the current design.] |
| [The visuals aid in assisting in clarifying meaning or enhancing comprehension.] |
| [There is a section that deals with the connection with prior knowledge.] |
| [There are activities that link to prior knowledge.] |
| 8. How would you improve this module? |
| 9. The module integrates the principles of CLT. |
| 10. Are there areas in the module that allow for metacognition in students - provide an explanation. |

11. Provide relevant examples of where CLT is present and where not and how can the lack of CLT be improved.

12. Feedback on the Evaluation.

4.1 Alignment of Current Instructional Design Strategies with CLT Principles

The document analysis indicated that while some instructional design elements incorporate CLT principles, there is a notable inconsistency in their application across different modules. For instance, worked examples are utilised in the majority of the modules where applicable, however, the effective use can be revisited by allowing for more independent problem-solving or a scaffolded approach posited through the worked example effect (Sweller et al, 2011 Chen et al., 2023). Inessential information could be eliminated to decrease extraneous CL and strain on the working memory based on the following feedback from the evaluation of the instructional design of modules. Chunking or sectioning some of the information better in some of the modules may lead to a decrease in strain on the working memory and a better experience for the student which aligns with the segmenting principle to manage CL (Castro-Alonso et al., 2021). Repeated information is present in the instructional design of modules contributing to extraneous CL. Images are presented in a manner where the text is next to the image rather than on as per the coherence and redundancy principles (Castro-Alonso et al., 2021). There is a strong indication the diagrams and infographics present in the instructional design of modules are simple and clear. The majority of responses indicated a balance between graphics and text and the essential information is covered by the scenarios.

Essential information is presented in a logical manner that includes additional material where applicable. Visuals and text are presented close together including some visual and oral cues to assist students in grouping essential information aligning with the modality and redundancy principles (Mayer, 2002). There is a strong indication that feedback is not provided next to relevant questions potentially exacerbating extraneous load. The steps for activities are provided on the same screen, and attention is drawn to vital information by emphasising key points with either arrows, highlights or bold text. A connection with prior knowledge exists in the material predominantly in the activities that contribute to reducing strain on the extraneous load as well as the working memory. Material is personalised in terms of using everyday language and demographics of the target audience aligned with the personalisation principle (Mayer, 2002). Visual and oral presentation assists in clarifying the meaning or enhancing comprehension to contribute to a lesser strain on working memory, aligning with the modality principle (Mayer, 2002). The instructional design of modules contains more than one form of media being used that contributes to a better balance between oral and visual presentation noted in the spatial contiguity principle (Castro-Alonso et al., 2021).

Feedback received to establish whether the existing design of modules integrated CLT principles has even spread in terms of feedback on whether it is integrated or not. This was further investigated for improvement of the different modules' instructional design. Some feedback provided by the researchers who acted as evaluators of instructional material to improve the said modules is as follows by each instructional designer (ID):

ID1 stated, "At the onset, the text is overwhelming – it will appear to be cluttered." This was also mentioned by ID2: "Better integration of graphics." ID2 added, "Clearer images and more oral presentations."

ID3 emphasized, "Improve the images," a suggestion common among all IDs. ID1 suggested, "Include step-by-step instructions with visual and audio elements that support learning." ID3 supported this and added, "Eliminate videos that are distracting, for example, showing students in the video and not the actual content. Eliminate images that do not link to the topic."

A perspective introduced by ID3—"Make the module more current and focused, use more images in better quality, and chunk material better."—was consistently applied by all IDs. ID2 also mentioned, "More signalling and callouts would aid in preparing students; the information can be designed to show on the same screen, and videos can be used to explain the concepts more clearly."

Consensus was found in the ID review concerning ID1's recommendation to "Provide more feedback on the questions asked."

4.2 Integration of CLT into Existing Instructional Design Strategies

The study identified several potential areas for integrating CLT more systematically into instructional design. Key strategies include the use of scaffolding to manage intrinsic CL, the elimination of redundant information to reduce extraneous load, and the incorporation of problem-solving activities that promote germane CL. Implementing these strategies could help mitigate cognitive overload, particularly in content-heavy modules. In the PHEI one can include some of the strategies to overcome CL, for example, having the problem-solving activities marked as such. It is also important to eliminate redundant information especially when it is cluttering the pages and may overwhelm the students.

4.3 Support for CLT-Integrated Instructional Design

The findings suggest that instructional strategies that promote metacognitive activities, such as self-explanation and reflection (Chick, 2013), are effective in enhancing deeper learning. Modules that incorporate CLT principles, particularly those emphasising germane CL, show higher levels of student engagement in metacognitive processes. This indicates that well-designed instructional materials not only aid in content comprehension but also in the development of critical thinking and problem-solving skills. Tezer (2024) averred that well-designed instructional materials allow for planning, problem-solving, creative thinking and reflection, this was found in most of the modules, however, there is room for improvement.

5. Discussion

The results emphasise the critical role of CLT in optimising instructional design to enhance student learning outcomes. The inconsistencies in the application of CLT principles across modules highlight the need for a more standardised approach to instructional design within the institution. By systematically integrating CLT into instructional strategies, instructional designers can create more effective learning environments that manage CL and support metacognitive development. Future studies should explore whether intentionally integrating Cognitive Load Theory (CLT) into module design, based on the 2023 design of modules where CLT was not deliberately applied, improves learning outcomes to address the gap identified by the researchers being the lack of unified instructional design strategies to mitigate cognitive overload, including multimedia learning.

6. Limitations

Primary data could be included that seeks students' perspectives, The limitations identified in this study include the research focused on a specific cohort of first-year commerce modules at a single South African PHEI, which may limit the generalisability of the findings. Secondary data may not fully capture the complexities of instructional design and student learning experiences.

7. Recommendation and Future Research

For future research, it is recommended to incorporate primary data collection methods, such as interviews and surveys, to gain a more comprehensive understanding of the impact of CLT-based instructional design on students' learning experiences. Research efforts should focus on optimizing instructional design strategies on a larger scale, to include diverse academic disciplines and public higher education contexts. Future studies should further explore the integration of CLT principles and multimedia learning in mitigating cognitive overload. This would address the research gap by evaluating a broader range of instructional design strategies aimed at enhancing student learning through effective multimedia learning techniques.

8. Conclusion

This study explored the value of integrating CLT into instructional design to mitigate cognitive overload and enhance student learning experiences. By integrating instructional strategies with CLT principles, effective and supportive learning environments would facilitate conducive learning and metacognitive development. The findings provide a foundation for further research and practice in optimizing instructional design to support student success in higher education. Future studies should explore the application of CLT-based strategies across diverse educational contexts and student populations to build on the insights gained from this research.

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