Mitigating Information Overload in an Online Undergraduate Learning Environment

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SUMMARY

Information overload (IO) is a concern becoming increasingly pertinent in education over the past few years, further amplified by the transition towards using more technology in the classroom. While there is currently no set definition for IO, it is often defined as an excess of information that disrupts knowledge processing. As the effects of the COVID-19 pandemic intensified in March of 2020, post-secondary institutions transitioned to online learning. Elements including learning management systems and video conferencing software heighten the effects of IO online. As such, it is of utmost importance that instructors find ways to optimize their online course design to ensure student success. While course content may not always be able to change drastically, the modes of delivery have potential to alleviate some IO.

The main objective of this research is to investigate different strategies undergraduate instructors can employ to mitigate IO in online learning. Cognitive load theory is examined to identify instructional strategies that can be used to mitigate IO. This review will describe the construction of: (1) a review of cognitive load theory and the need for mitigating IO and (2) a practice guide purposed with providing undergraduate instructors with strategies to mitigate IO in online courses. The strategies presented in the practice guide are be based on ways to reduce extraneous load within cognitive load theory. This research is currently relevant as the optimization of online courses has the potential to directly benefit students and improve their academic performance.

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COGNITIVE LOAD THEORY

Biologically Primary and Secondary Knowledge

Cognitive load theory is a framework that gathers knowledge about the human cognition to provide instructional recommendations (Sweller et al., 2011). There are two types of knowledge within this context: (1) biologically primary knowledge and (2) biologically secondary knowledge (Sweller, 2020). Biologically primary knowledge is information that humans have evolved to acquire. The information that falls in this first category was selected for by natural selection, as it helped increase humans' evolutionary fitness. This knowledge acquisition occurs without any explicit training and comes easily to humans. Some of these skills include face perception and recognition, language perception and production, and movement. These are all skills that are crucial to human survival, both thousands of years ago and today. Much of this skill development occurs at a very young age, and often occurs subconsciously. This is due to instinct blindness, that is, humans' inability to understand and appreciate the complexity of certain processes because of how automatic they are. Biologically primary knowledge acts as a foundation for biologically secondary knowledge (Sweller, 2020).

On the other hand, biologically secondary knowledge cannot be intrinsically acquired through evolution; it must be learned for cultural reasons. A prime example of this is the ability to write: in modern societies, writing abilities are crucial; however, this was not required thousands of years ago for survival, so natural selection did not favour the development of this skill. Moreover, unlike biologically primary knowledge, which is acquired subconsciously and without explicit tutoring, biologically secondary knowledge requires conscious effort. However, while humans have not evolved the ability to naturally acquire biologically secondary knowledge, the cognitive systems required for this acquisition have evolved since then, allowing us to acquire an abundant quantity of secondary knowledge (Sweller, 2020).

Intrinsic, Extraneous, and Germane Loads

There are three main components of cognitive load to consider: intrinsic load, extraneous load, and germane load. These different types of cognitive load all affect information processing through our working memory and long-term memory differently. However, interaction between these types of cognitive load is still possible. As such, they must be considered both separately and together when reflecting on their role in instructional design (Sweller et al., 2011).

Intrinsic cognitive load is related to the inherent nature of the learning material; it is tied to the nature and complexity of the material. Intrinsic load of material cannot be reduced or altered unless it is separated into smaller pieces that are simpler to process. It is also influenced by knowledge present in the learner's long-term memory. For example, learning introductory algebra will be much easier for a grade 12 student, who already possesses the fundamental knowledge in their long-term memory, than for a grade 6 student who is learning it for the first time. Conversely, extraneous cognitive load is related to the instructional design and presentation of the material. Unlike intrinsic load, extraneous load can be alleviated through appropriate instructional strategies. Extraneous load acts as 'noise', making it more difficult to process the intrinsic load. This can include unrelated and superfluous elements within the instructional material or anything that is not conducive to learning. This can present itself as a poorly designed learning management systems (LMS) or lecture videos. Moreover, it is possible to further differentiate between extraneous load and germane load. Extraneous load focuses on the effort required to process instructional information, while germane load relates to the effort required to form schemas, which are used to encode information into long-term memory. While high levels of intrinsic and extraneous load are detrimental to student learning, high levels of germane load actually indicate that a student is learning by forming schemas in their long-term memory (Sweller et al., 1998, 2011).

Schema Formation

Information is stored in long-term memory in the form of schemas. They organize different information according to the categories for which it will be used (Sweller et al., 1998). Schemas exist in varying levels of complexity; when someone is first introduced to a concept, they will form a lower-level schema, which they later continue to build upon to form a more complex and advanced schema. Not only do schemas provide a mechanism to organize information into long-term memory, but they also reduce working memory load. This is because working memory can only hold a limited number of items; however, there is no limit on the complexity of these items (Sweller et al., 1998). As such, a complex schema that is rich with information will count as one element, just as a lower-level schema would. This means that the use of complex schemas by the working memory is beneficial as it provides more information, while not overloading the working memory.

Once schemas are created in long-term memory, they can be effectively transferred into working memory as needed to complete a task. Information can be processed either consciously or automatically. Conscious processing utilizes mostly the working memory while automatic processing can bypass the use of the working memory, as it relies primarily on schemas. Automaticity of information processing occurs after a great deal of practice, which happens concurrently with advancing the complexity of schemas (Sweller et al., 1998). For example, an adult who has had much practice with reading and possesses very developed schemas for reading will not need to process each letter individually. On the other hand, a child who is just learning to read does not have fully developed schemas as yet and will require more effort and attention when reading, including individually processing letters.

ONLINE LEARNING

In recent years, there has been a gradual transition to online learning. This began even before the start of the COVID-19 pandemic in March 2020 (Habib et al., 2021). This transition has become even more important now that the Internet is playing a much larger role in the younger generations' lives. In the past, the Internet was primarily used to gather information via search engines (Frolova et al., 2020). However, it is becoming a bigger and more diverse space, with its usage including not only acquiring information but also entertainment, skill-building, or even building a career. With this greater use of the Internet, it is only natural that education would begin to transition towards the use of more digital elements as well.

While digital strategies and tools are currently being implemented in education, whether elementary, secondary, or post-secondary, they are still considered to be 'additional tools' and supplementary to learning (Frolova et al., 2020). This view is changing as there will be more importance placed on virtual education in the near future. This is especially true as the world was forced to experience an abrupt transition to online learning due to the COVID-19 pandemic. Students and instructors have both observed the benefits of virtual learning, and even when returning to in-person learning will be possible, it is likely that aspects of virtual learning will continue to be used due to their convenience (Frolova et al., 2020).

It may actually be possible for students to learn more effectively online, if the circumstances are right. A study conducted by Costley (2019) highlighted the importance of student social presence in learning, especially in an online environment. This study's results showed a significant positive relationship between student social presence in a course and germane cognitive load, which can be used synonymously with learning. This is based on the idea that student interaction and discourse about course content facilitates learning and promotes higher-order critical thinking. The study found that students who engage in more student-to-student interaction will remember more from the course than students who only studied individually. It is often proposed that students can further their understanding of a topic by teaching it to others. Moreover, it has been proposed that student-to-student interaction is required for learning and cognitive development to occur. As such, ensuring that students have the opportunity to engage with other students in relation to the course content is of great importance. Students may actually feel more comfortable engaging with other students through chats or course forums, compared to in-person courses, which could favour critical thinking (Costley, 2019).

Student Concerns About Online Learning

When undergraduate courses rapidly switched to online delivery last year, students had many concerns due to the uncertainty of the situation. A survey conducted by Kedraka and Kaltsidis (2020) investigated students' feelings about the switch to online classes. They evaluated student concerns directly after the switch had occurred and their concerns at the time of the survey, in May 2020. Student responses showed that while they were initially anxious and experienced insecurity about the future of their studies, they were also curious about what would happen in the coming months. Additionally, some students felt joy at the thought of classes being suspended for what was initially believed to be a short period of time. By May 2020, the three dominant emotions were anxiety, anguish, and insecurity. Overall, the emotions felt later were more negative than those felt initially. As more time passed, students also experienced more concrete concerns about their online classes. For example, students were concerned about difficulties in communication, whether with the instructor or with other students. They also experienced concerns about instructors' skills with the digital tools required to deliver online courses.

Overall, students understood the need for distance learning, especially due to the severity of the COVID-19 pandemic at the time. However, they still hoped to return to in-person instruction soon and wanted to go back to their 'normal life'. Considering that distance learning might continue being used, even if only partially, it is crucial that instructors find ways to improve the student experience (Kedraka & Kaltsidis, 2020).

Instructor Concerns About Online Learning

The concerns instructors have with online learning are very different than those experienced by students; they were more worried about their ability to deliver courses virtually. One overlapping concern with those of students is about their technological skills, although the concern comes from a different perspective (Abu-Shanab et al., 2020). Here, instructors' knowledge on technology and LMS predicted how willing they would be to try using them. That is, a instructor who is more skilled at using technology would be more likely to use it in their courses than one who was less skilled. Normally, this would not be a serious issue; however, given the switch of the vast majority of post-secondary institutions to online learning, instructors do not have much of a choice. Interestingly, overall self-confidence of instructors also acted as a predictor of their willingness to use a LMS (Abu-Shanab et al., 2020).

Moreover, it was noted that a instructor's attitude towards technology influenced how beneficial students found its use. For instance, if a instructor had a very negative attitude towards technology and always complained about how difficult they found using it, students would likely benefit less from its use (Fageeh, 2015). This demonstrates the importance of providing instructors with adequate technology training so their skills, confidence using it, and overall attitude improve, ultimately benefiting students.

Advantages of Online Learning

There are many advantages of online learning. Firstly, it provides more opportunity for self-directed and self-paced learning. This can be beneficial as students may feel more in control of their education and that they are able to learn content at a speed which works best for them. Students enjoyed being able to set their own schedules and being able to revisit lectures or pause videos if needed (Kollalpitiya et al., 2020). Additionally, online learning provides greater flexibility and more variety of courses being offered. When compared to in-person instruction, which is often limited by the number of instructors and campus resources, online instruction reduces many of these barriers, and might even allow students to take courses from various universities across the world. Moreover, online learning reduces many costs that are tied to in-person learning (Frolova et al., 2020).

Disadvantages of Online Learning

However, there are also drawbacks and challenges associated with online education. For example, it may contribute to dehumanization and formalization of education; when learning digitally, it is much harder to form close relationships with instructors and to feel comfortable asking questions or engaging with the course. There might even be courses that are taught without a set instructor, making them more impersonal. Another challenge associated with online learning is a decrease in the formation of interpersonal skills for students. When in-person, students are more likely to interact with one another and with instructors, which facilitates the building of interpersonal skills. However, this interaction with others is minimized through digital learning and may harm the development of these skills. Moreover, it is common for instructors to not be fully equipped to deliver online courses. It is of the utmost importance that instructors are adequately trained in online course delivery. Additionally, the autonomous and self-paced nature of online learning can also act as a disadvantage. Students may find it challenging to find motivation to complete their schoolwork, which is further amplified by the fatigue associated with the COVID-19 pandemic (Kedraka & Kaltsidis, 2020). Finally, one of the most substantial challenges associated with online learning is information overload (Frolova et al., 2020).

INFORMATION OVERLOAD

Although there is no formal and set definition for information overload (IO), it is often defined as a state in which information flow exceeds one's cognitive capacities to process it, which disrupts their ability to accurately process the information (Virkus et al., 2018). It can lead to impaired critical thinking and decision-making. In the context of education, IO might stress students and make them feel overwhelmed with the assignments and projects they must work on.

IO can occur in different pedagogical aspects. For instance, most undergraduate-level university courses cover an extensive range of content. As a result, students are presented with a lot of information when studying for midterms and final exams, especially if the content is cumulative. This is even more evident if students are cramming because they had not been studying consistently throughout the term. Research by Murayama, et al. (2016) investigated the point at which students chose to stop learning new information when presented with an abundance of new information. Results from this study found that participants' metacognitive skills were impaired as many chose to keep receiving new information, leading to poor test performance. These findings can be thought of as representative of students cramming—when faced with a tight deadline (e.g., a midterm coming up in a few days), students will feel pressured to cover the course material as fast as they can to make up for lost time. However, similar to the findings highlighted by Murayama et al., (2016), students will not be able to retain all this information and will not perform at their best on their midterm. These findings add to the evidence that spaced learning—the practice of learning material consistently over a longer period of time—is most effective for deep learning and understanding of material. Unfortunately, when students are fully immersed in a semester at university, it can be challenging to self-reflect on how effective their study habits are. As such, it is important that course design does not add additional IO to their learning.

Information Overload and Instructional Design

There are many components of virtual learning that can place an unnecessary burden on students' ability to learn and process information, leading to IO. Course content might be high in extraneous load, including many unnecessary elements, making it more difficult to process information. This in turn reduces germane load, which is greatest when a student is actively learning information through the formation of schemas into their long-term memory. Essentially, there is a positive correlation between IO and extraneous cognitive load but a negative correlation between IO and germane load (Matthew & De Villiers, 2020).

Clear instructions and explanations are crucial to effective course delivery regardless of in-person or online format and it has become even more important in a virtual setting (Costley, 2020). Since students are learning from their own homes, their ability to ask questions and engage with course content has been drastically reduced. As previously mentioned, there are many additional challenges associated with online learning. Namely, students find it more difficult to engage with the content, participate in class, and form connections with other students (Kedraka & Kaltsidis, 2020). There are other technological difficulties that can arise from issues with software or user error, which can add stress to both students and instructors. Amidst all the challenges associated with online learning, the overarching goal should be to reduce extraneous load in course instruction where possible in order to maximize germane load, thereby increasing active learning (Costley, 2020).

According to Leppink, et al. (2013), common ways of increasing extraneous load include ineffective explanations/instructions regarding learning and explanations/instructions consisting of unclear language. These can all be mitigated quite easily through effective communication and clear guidelines of what instructors expect from students.

One key element of the transition to online learning is the preparedness of the instructors. Evidence suggests that the effectiveness of digital tools in pedagogy is strongly correlated with instructors' competence using those tools and their motivation and willingness to learn to use them. As a result, it is essential that instructors are properly trained to use digital platforms when teaching online, to ensure that IO through increased extraneous load is minimized (Frolova et al., 2020). Moreover, the perceived utility of digital tools is a crucial factor in the willingness of instructors to learn how to use it. That is, if instructors believe that a specific digital tool will be beneficial to their students, they are more likely to put in the required effort to learn how to use it than if they did not think their students would gain much from it (Frolova et al., 2020).

Student Perception of Information Overload

IO is a concern that a substantial portion of students have experienced at some point throughout their education. A study conducted by Virkus, Mandre, and Pals, (2018) investigating IO in students from four disciplines within Science, Technology, Engineering, and Mathematics (STEM) found that 81% of participants admitted to having experienced IO at some point in their undergraduate career. However, while it had been experienced by so many students in STEM, only about half of respondents viewed this as a real concern. A potential cause of this disparity is that students may perceive IO as something they cannot resolve and an element that is simply a part of the online education component (Virkus et al., 2018). When interviewing students for this study, they found that the most common problems relating to IO were issues with concentration, sleeping, fatigue, and headaches. Moreover, one student acknowledged the importance of information literacy skills, as they stated it helped them manage IO (Virkus et al., 2018). As previously mentioned, IO often presents itself as 'noise' that disrupts information processing. This noise can present itself in many different ways, which will vary depending on whether instruction is in-person or online. One of the primary complaints brought forward by students is that it can be challenging to distinguish between relevant elements from the large quantity of unnecessary information (Virkus et al., 2018).

Chen, Pedersen, and Murphy (2011) investigated factors that influenced students' perceived IO in learning through computer-mediated communication (CMC). Data was collected using semi-structured interviews and a background questionnaire, to be able to qualitatively analyze data. Results of the study found that students had an increased risk of IO if they had low levels of prior knowledge on the subject, English proficiency, or skills required for participation through CMC. They also found that there were six broad categories contributing to student perception of IO: (1) connection problems; (2) navigation difficulties; (3) discomfort with online communication; (4) demands of ongoing discussions and readings; (5) difficulty in organizing learning; and (6) problems with understanding text-based readings (Chen et al., 2011). Connection problems involved difficulties with logging into conference systems; these issues were either caused by a firewall or being unable to set up a connection. Next, navigation difficulties involved challenges with browsing through conferencing and learning management systems. Discomfort with online communication was primarily due to lack of skills with using the online interface, such as having difficulties reading from a computer screen. Moreover, students experienced challenges with staying up to date with discussions and readings, as many students had other responsibilities, whether family duties or a job. Similarly, students also experienced difficulties with organizing their learning as they had other commitments and had to balance school with other responsibilities. Finally, some students had difficulties with text-based readings that were required for their courses; this was especially pronounced for students with a native language other than English. When considering the challenges that students face, there are some that can be alleviated through changes in course design while others cannot. While instructors may not be able to resolve all these problems, designing their online courses in a way to reduce IO as much as possible may help students focus their energy on resolving their other challenges themselves.

IO not only has the potential to disrupt information processing and studying, but it can also have detrimental effects on student wellbeing. Alhenieidi and Smith (2020) found an inverse correlation between IO due to noise and student wellbeing. Wellbeing is a concept that can be difficult to define; in this study, student wellbeing was measured using an adapted version of the Demands-Resources-Individual Effects model (Williams et al., 2017). The model was adapted for students to include a stronger focus on academic attainment, perceptions of workload, work efficiency, and course load (Alhenieidi & Smith, 2020). Factors influencing student wellbeing positively included a social support system, psychological capital (e.g., self-esteem and optimism), while elements such as student stressors and negative coping strategies (e.g., self-blame and avoidance) impacted it negatively. It is essential that students have a good sense of wellbeing, as poor wellbeing can lead to burnout (Alhenieidi & Smith, 2020). Since the inverse correlation was found between noise-based IO and student wellbeing, it is crucial that post-secondary institutions and instructors find effective methods to reduce IO.

SUGGESTIONS FOR REDUCING INFORMATION OVERLOAD

In recent years, information overload has become increasingly prevalent in online components of undergraduate courses. With the switch to online learning, this issue has become even more significant.

The following suggestions aim to provide undergraduate instructors with recommendations pertaining to their course design. These suggestions are informed by cognitive load theory, which considers the human cognitive framework along with the structure of information. Instructional design that is based on cognitive load theory produces cognitive load effects, where students with this type of instruction outperform students who receive more traditional instruction (Matthew & De Villiers, 2020).

Student Perception of Information Overload

It is important that LMS' such as D2L Brightspace or Moodle are well designed and organized to optimize student use. If a LMS is hard to navigate, it will increase extraneous cognitive load, as there are many unnecessary elements that can attract the student's attention.

SIGNALING

Signaling refers to the use of visual signals to cue and guide learners through content in a logical way (Matthew & De Villiers, 2020). This can include directions on how to complete a task or where to find specific information. The use of signaling reduces extraneous load, making the LMS easier to navigate, allowing the student to allocate their cognitive resources to learning.

Signaling can be done using special text formatting (e.g., bolding, italicizing, underlining) or through the use of various icons. Here, the emphasis is placed on visual elements of instruction. Signaling ties itself into many other aspects of course design, such as the design of lecture slides (Matthew & De Villiers, 2020).

SEGMENTING

Segmenting refers to the intentional inclusion of pauses to group relevant sections of information together and separate them into logical segments (Matthew & De Villiers, 2020). This can be done for multimedia specifically, or for any aspect of online learning in general. This allows the learner to process pieces of information together based on how they are grouped; the student can pause and reflect on a certain topic before moving onto the next topic. Since the student is able to fully process one section before proceeding to the next, this reduces extraneous cognitive load, as they are not still processing the previous section. Evidence has demonstrated that students who are presented with information that is separated into logical sections with breaks between sections outperform students who are presented with the same information without breaks (Mayer et al., 1999).

The use of segmenting can be implemented in a LMS similarly to signaling. Using headers, sub-headers, and section dividers among others can be used to segment information, thereby reducing extraneous load. The use of segmenting is particularly important when presenting large quantities of information, especially if the information is dense (Matthew & De Villiers, 2020).

COHERENCE

Another key element of making a LMS easy to navigate is its overall coherence. Often, an LMS will include various multimedia elements such as visual and auditory components. It is essential that these elements work together, instead of against each other (Matthew & De Villiers, 2020). Visual and auditory elements are actually processed by different channels within one's working memory (Mayer & Moreno, 2003). It is possible for a single channel to be overpopulated, leading to cognitive overload. As a result, one can experience visual cognitive overload, but not auditory cognitive overload, or vice versa.

One simple way of mitigating this problem is by finding a good balance of different multimedia elements. Instead of only using visual elements, a mix of both visual and audio components should be employed, so that both the working memory channels are being used, with neither being overloaded.

Moreover, another aspect that is integrated into coherence of a LMS is consistency, also referred to as its 'look and feel'. Having good consistency between pages of a LMS will reduce information overload. This reduction occurs because students become more familiar with the layout of the LMS and will not need to anticipate where to look to find information. This allows them to spend more cognitive resources on the content itself (Matthew & De Villiers, 2020).

For example, one way in which consistency can be implemented into a LMS is how course content is presented. Specifically, documents can always be started with the section header, followed by learning objectives, and before transitioning into content. For the content itself, it can be separated using the same layout of headers and sub-headers so students can become familiar with the presentation. Furthermore, this will make it easier for students to refer back to course content later if required (e.g., they know that learning objectives will always be at the top of the page).

Promoting Higher-Level Thinking

One aspect of in-person learning that students miss the most is interaction, whether that be with their peers or their instructors. Though many students might be living at home with family or in student housing with peers, they may still experience the effects of social isolation. Many students found that going to class and being on campus helped them socialize with others. The lack of interaction students face during the COVID-19 pandemic is a leading cause of lack of motivation (Kedraka & Kaltsidis, 2020). As such, it is important that online courses try to include elements with student interaction if possible, as that may help improve student performance.

Not only does the lack of social interaction have negative impacts on student wellbeing, it has also been shown to have negative effects on student performance. Costley (2019) found that students who were more engaged in student-to-student interaction performed better in their courses. They were more likely to engage in critical thinking and active learning. Moreover, they also had better long-term retention of the class material.

One way this can be translated into instructional design is to implement group projects within courses, so that students can work collaboratively but also regain some social interaction. This may be especially beneficial in larger courses, where students may not otherwise know their peers. Another option to promote student-to-student interaction in courses is the addition of 'breakout rooms'. While these are a relatively new concept, they allow for the participants on a conference call to be split into smaller groups. This has great potential for synchronous classes, as instructors can teach the content in the main room with all students, and then send students into smaller groups in breakout rooms to discuss a certain topic or answer a question. This way, students are much more likely to participate, compared to a large call, which can be intimidating. Moreover, another way to promote student-to-student engagement is through the use of discussion boards within the LMS being used. This encourages students to provide feedback or answer questions their peers may have, all while learning more as well.

Using Worked Examples

When students are first introduced to a certain topic, they do not have all the fundamental knowledge to solve problems quickly and effortlessly. One way to enhance students' understanding of a concept is through the integration of worked examples (Sweller, 2020). For many subjects in STEM, including but not limited to mathematics, chemistry, and physics, working through practice problems is an effective way of learning. Solving practice problems acts as active learning, as opposed to simply passively reading over class notes or a textbook.

However, students require some foundational knowledge to be able to solve practice problems and for these problems to be beneficial to them. Worked examples are a great way to provide this foundation. Research has demonstrated that students who are provided with worked examples in addition to practice problems perform better than those who only receive the practice problems (Sweller, 2020). Worked examples help students succeed by reducing extraneous cognitive load. Normally, when a student is working to solve a problem, they must identify the steps required to solve that question. If that student is a novice, this process can be very effortful, and not always fruitful to learning. If a student is having a hard time identifying the required steps for a problem, they may become frustrated before they even have the opportunity to attempt the question (Sweller, 2020). As such, worked examples are a great way to guide students when they are first being introduced to a new topic. Worked examples provide the clearly outlined steps required for a specific problem, thereby relieving the associated extraneous load. Students are then able to focus their cognitive resources on understanding the steps themselves, rather than using these resources to identify the steps.

The use of worked examples is especially crucial for novice learners. When they are first introduced to a new subject, they do not have much existing knowledge on the topic stored in their long-term memory. As a result, they must use their working memory to solve problems. Contrarily, a more experienced student will have more information stored in their long-term memory, making the process of retrieving this information much quicker. As a student learns more about a topic, they will become less reliant on worked examples and more reliant on the knowledge in their long-term memory (Sweller, 2020).

Avoiding Redundancy and the Expertise Reversal Effect

The redundancy effect occurs when information is repeated more than is required, resulting in an increase in information overload. This effect is most prevalent when there are superficial elements that must be processed or when element interactivity is low (Sweller, 2020). Moreover, the redundancy effect mostly occurs when one's level of expertise is higher than that required to complete a task. As expertise increases, intrinsic load of content decreases; this means the learner possesses more knowledge in their long-term memory and they require less effort from their working memory. This is known as the expertise reversal effect (Sweller, 2020). Since the experts have already formed the necessary schemas, solving more problems is much better practice than looking through a worked example. Also, element interactivity decreases as expertise increases, which can potentially have instructional consequences. In fact, the advantages seen with cognitive load effects used in instructional style decrease as someone gains more expertise. This can sometimes even lead to a reversal of the cognitive load effect, resulting in lower student performance (Sweller, 2020).

For instance, if we consider the worked example effect mentioned above, worked examples are very useful for novice learners on a topic. However, they can actually be detrimental to experts on a subject because they already know the steps required to solve a problem. For them, worked examples are not effective because they already have the steps for the problem stored in their long-term memory and can easily retrieve them for use by their working memory; here, the worked example acts as 'noise', leading to the expertise reversal effect.

One important element to consider when accounting for students of different levels in one course would be to distinguish between content that all students should learn and the content that is supplementary and can be used if students are having a hard time with certain concepts. This way, students who might still be novices can make good use of worked examples and other additional resources, while more advanced students can choose to skip these if they so choose. As with any aspect of instructional design, balance is key; instructors should strive to find a balance that will benefit all their students, whether they are novices or have more expertise on the subject.

On a similar note, it can be very beneficial for students if the distinction between testable and non-testable material is made clear (Kaylor, 2014). Students will often be frantically trying to copy down all information that is presented during a lecture to ensure they are well prepared for tests and assignments. If an instructor is presenting a topic or an example that is not testable and 'just for fun', it is essential to make the distinction clear. This can include using a special icon, changing the colour of the slide, or even using an interesting border—anything that will stand out and that is clearly indicated to students will work. This will allow students to focus on listening to what instructors are saying, as opposed to struggling to write down all the notes.

Reducing Working Memory Depletion

The working memory depletion effect is a more recently studied effect being studied that influences student performance in online classes. An assumption of cognitive load theory is that for any given individual, their working memory characteristics are fixed. However, this may not fully be the case. Working memory capacity can be depleted after intense cognitive effort and will require rest to return to its full capacity (Sweller, 2020). This is further evidence that supports the spaced practice effect, where students perform better if they study for the same amount of time, but over a longer period of time.

There are a couple of ways in which it is possible to reduce the effects of working memory depletion on student performance. First, instructors can implement regular quizzes or in-class participation to ensure students are staying caught up with the course content. This approach tries to minimize the number of students that will 'cram' and study all of the course content before a midterm or final exam. While there may still be students who do this, this behaviour will harm their overall grade as they may not have all the knowledge on a regular basis. Second, there are websites and applications where students must complete homework but must do it in a spaced manner. The application will not allow them to cover all of the questions in one sitting, forcing them to plan ahead and stay updated with the course material. While these solutions may not ensure every single student is consistently reviewing course content, it will encourage most students to do so. While the overarching purpose of the practice is not to maintain high grades, this will act as motivation for students, who will ultimately benefit with respect to their learning and knowledge of the course content.

CONCLUSION

Cognitive load theory has now been used to inform instructional design for decades, as there have been considerable benefits to student learning when doing so. Understanding the nuances of the different types of cognitive load allow instructors to minimize extraneous elements within the courses, leading to improved student learning and performance. Given the widespread transition to online learning at an undergraduate level due to the onset of the COVID-19 pandemic, it is essential that instructors consider the importance of cognitive load and its impact on learning when designing their courses. There are several strategies, as discussed in this review, that can be employed to reduce information overload, allowing students to focus their cognitive resources on learning the course content itself. Future studies should investigate the direct effect of these strategies on student performance and their applicability within online learning, as opposed to traditional in-person learning.

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