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Shifting online: 12 tips for online teaching derived from contemporary educational psychology research

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Abstract

Background: As a result of the COVID-19 pandemic, many teachers found themselves making a rapid and often challenging shift from in-person classroom teaching to teaching in an online environment. As teachers continue to learn about working in this new environment, research in cognitive and learning sciences, specifically findings from cognitive load theory and related areas, can provide meaningful strategies for teaching in this 'new normal'.

Objectives: This paper describes 12 tips derived from contemporary research in educational psychology, focusing particularly on empirically supported strategies that teachers may apply in their online classroom to ensure that learning is optimized.

Implications for Practice: These strategies are generalizable across age groups and learning areas, and are categorized into one of two themes: approaches to optimize the design of online learning materials, and instructional strategies to support student learning. A discussion follows, outlining how teachers may apply these strategies in different contexts, with a brief overview of emerging efforts that aim to bridge cognitive load theory and self-regulated learning research.

KEYWORDS
cognitive load theory, cognitive theory of multimedia learning, generative and self-regulated learning, online teaching and learning

1 | INTRODUCTION

On March 11, 2020, the World Health Organization declared COVID-19 a global pandemic (Cucinotta & Vanelli, 2020). In response, many countries adopted measures intended to limit the spread of the virus that causes the disease by closing parts of the economy (Hirsch, 2020). Within this context, many educational institutions had no choice but to shift their on-campus teaching to online delivery to protect the health of their students and staff. During this time, Howard et al. (2021) reported that 68.1% of teachers across 20 countries (primarily in Europe and the Asia Pacific regions) were required by their institutions to shift teaching to an online modality, with 24.4% reporting it was expected but not mandatory. Given the widespread reliance on online teaching and the variation both in previous online teaching experience and institutional support, it is no surprise that most online teaching in the early phase of the COVID-19 pandemic took the form of 'Emergency Remote Teaching'—the use of synchronous web-conferencing technologies to deliver an on-campus experience using online technologies (Karakaya, 2021). Yet we know that, in the words of Karakaya, "effective online learning is the result of a meticulous planning and instructional design" (p. 296). Therefore, many educators started to search for reliable information on how to effectively design learning materials, activities, and assessments for online teaching (Robinson et al., 2020).

The aim of this article is to provide practical guidelines for effective online teaching practice and the adaptation of equivalent in-class strategies through a discussion of relevant findings from contemporary educational psychology research. While research exploring online education is broad and can focus on the technical set-up of environments or the learning technologies used, research in educational psychology primarily focuses on how to ensure that students learn while engaging in complex learning experiences such as problem-solving (cf. Mayer, 2020). Broadly, learning is the acquisition of skills, knowledge and abilities through study, experience, or being taught by others; while problem-solving is a type of complex skill that involves moving through a set of procedures (and any associated rules) to achieve an appropriate goal (Renkl, 2005). As such, the tips provided in this article can support teachers who are interested in learning more about effective online instruction, independent of the learning technologies they use.

Many of the tips that will be detailed are informed and explained by cognitive load theory (CLT), which is a leading theory in educational research. While there is a large body of research exploring online teaching and learning specifically (see Martin et al., 2019; Martin et al., 2020; Mayer, 2019), CLT and related research within educational psychology provide many evidence-based guidelines for how to optimize learning itself.

This article, therefore, serves to collate long-established instructional implications derived from work in CLT and related areas, while incorporating more contemporary research findings and instructional effects from a period closely preceding the COVID-19 pandemic so that it may provide up-to-date guidance to instructors who are new to teaching online. Whether adapting in-class presentation slides into a narrated video lecture, transferring one's own physical 'presence' into an online setting, or simply stimulating students to engage in their own learning processes, the effects identified through educational research can inform a wide array of online teaching and learning practice.

2 | COGNITIVE LOAD THEORY

Cognitive load theory (Sweller et al., 2011) and the related cognitive theory of multimedia learning (see Mayer, 2020) comprise an area of educational research that explores how certain instructional interventions and strategies affect processing in human memory during learning experiences, and the longer-term consequences that these experiences have on learning. Findings from this research can thus inform the design of instructional materials, including how information can be effectively presented as well as which strategies students and teachers can use to make learning experiences more effective—both areas that teachers are responsible for.

Many teachers may be familiar with Mayer's cognitive theory of multimedia learning (see Mayer, 2020), an area of research that draws many parallels with CLT. We have chosen to focus on CLT and educational psychology research, as this research extends beyond the use of multimedia learning materials to how instructional design (e.g. the design of learning materials and the use of specific instructional strategies) can support learners as they engage with a variety of materials, and specific study strategies that can enhance learning, unrelated to multimedia assets. Given that online learning encompasses much more than interacting with multimedia assets, CLT and its orbiting areas of research can provide meaningful insights into the breadth of teaching and learning online.

CLT is predicated on a limited working memory capacity. Working memory is part of the human cognitive system and describes the temporary storage and processing of novel and existing information, with a limited capacity and duration (see Baddeley & Hitch, 1974; Miller, 1956; Miller et al., 1960; Sepp et al., 2019). CLT's central focus is on the exploration of complex learning experiences (e.g. solving problems and gaining understanding), as opposed to simple memorisation (e.g. learning terminology or word lists). These complex learning experiences are framed through a concept called element interactivity (see Leahy & Sweller, 2020), which describes the complexity in the relationships and interaction between different elements in a learning experience (e.g. the quantity of different ideas and actions that must be 'juggled' in human memory to complete a problem or learn a new concept)—the higher the element interactivity, the more complex the task. It is important to note that the effects presented in this paper have all been identified in cases where element interactivity is considered high (i.e. a complex learning experiences). As such, the effects and derived principles presented here may differ if learners are not investing significant cognitive resources in the task. In other words, if the task is easy or requires very little effort, the presented tips may not bring many benefits to learning.

CLT describes two important types of cognitive load (the cognitive resources required to complete a task) (Kalyuga, 2011; Sweller et al., 2011). First, extraneous cognitive load describes the cognitive resources devoted to processing information not directly related to problem solving and learning, such as distracting or difficult to process learning materials or activities. The aim is to reduce this type of cognitive load through the intentional design of learning materials or and instructional strategies used by teachers. Second, intrinsic cognitive load refers to the cognitive resources devoted to problem solving or learning based on the inherent complexity of the materials and task itself. Intrinsic load generally depends on students' experiences and levels of expertise, and thus should not be reduced or maximized. Instead, intrinsic load should be effectively managed through materials and tasks that are not too simple and not too complex for learners, meaning that students would be able to work on tasks that are optimal for their existing level of expertise (Kalyuga, 2011; Sweller et al., 2011).

Inherent in the investigation of teaching and learning is the fact that many learning experiences involve multiple modalities, such as visual text-based materials and pictures, sound-based audio narrations and podcasts, and multimedia materials such as videos and animations. Many of these materials require students to shift their attention between elements and perform tasks devoted to exploring relationships between concepts, and to gain an increased understanding of a topic. As such, CLT is particularly relevant for online teaching and learning contexts, because it investigates the effects of engaging with these materials and its findings can inform the design of the materials as well as any teaching strategies related to their delivery. Indeed, Sweller (2020) provides a detailed discussion of many CLT effects and their theoretical alignment with the use of educational technology. It should be noted that CLT effects are sometimes framed in two categories—those that can make learning more effective, and those that can inhibit learning, with derived implications for teachers on what to do, and what not to do, to support student learning. Additionally, teachers may also wish to consider how these effects may interact and potentially conflict and how they can be best applied for their own context.

In the following sections, an overview of 12 relevant effects and principles derived from CLT and related areas of research is provided, including specific tips for how these effects can inform online teaching practice and support the learning process (for a brief overview of these tips, please see Table 1 in the Discussion section). These tips should generalize across different age groups and can be effectively applied for many different learning areas (see discussion for an elaboration of this issue). While these tips have broad application and may be applied for many different purposes, this article groups the tips into two common thematic teaching and learning areas, namely learning material design and instructional strategies to support learning.

3 | APPROACHES TO OPTIMIZE THE DESIGN OF ONLINE LEARNING MATERIALS

Learning materials can take many forms, including text, visualizations, audio, animations, and videos. As the design of these materials can either impair or support student learning, this section provides eight tips with accompanying theoretical backgrounds and explanations to ensure that the design of learning materials for online contexts support learning.

TABLE 1 Summary of tips informed by contemporary educational psychology research.

Identified effect/ Principle	Tip
Approaches to optimize the design of online learning materials	
Split attention	When presenting visual information such as diagrams or graphs with explanatory text, place text within the diagram, at spatially nearby locations, instead of off to the side or below, like a map legend.
Modality	When using multimedia, ensure that auditory (verbal) explanations support visual materials (text or images) without being redundant.
Redundancy	Like modality, when presenting novel information to learners, ensure that auditory and written explanations do not replicate already-presented visual information exactly, but instead highlight key points and serve to enhance learner understanding. If redundant information is present, consider removing it.
Signalling (cueing)	When presenting novel information, add visual cues to guide learner attention to key areas either by using colour, symbols or text on diagrams.
Transient Information	When using multimedia materials, ensure that new concepts are not covered too quickly, and instead slow down the presentation, 'chunk' information into smaller, more digestible resources, or allow students agency to control playback of these materials.
Instructor visible	When teaching online instructor presence is crucial to establishing community through social connections. Additionally, when presenting information through video or multimedia, a visible instructor who gestures, or provides other visible cues to guide attention can support learning.
Human movement	Like the first-person perspective effect, when presenting procedural motor tasks for students to learn, use animations, and present them from a first-person perspective.
First-person perspective	In learning domains that involve procedural motor tasks such as learning a new skill using one's hands, presenting video demonstrations from the first person, instead of the third person perspective, can support learning.
Instructional strategies to support learning	
Example-based learning	In STEM domains that involve problem-solving based on established rules and sequences, provide worked out examples for students to study in conjunction with practice tasks/questions. These examples can take many forms such as video explanations with visible instructors, static examples with steps labelled or examples with erroneous steps for learners to study. Additionally, asking students to create mini-lessons for their peers based on presented examples can support student understanding of the problem and build problem-solving skills.
Tracing	When studying visual learning materials such as diagrams or charts, teachers can encourage students to trace or use other hand gestures if they find it beneficial for their own learning
Spacing	When learning online, allow time for learners to 'reset', allowing space for them to rest and replenish their cognitive resources before continuing, either in a synchronous learning environment or asynchronous lessons
Generative learning	In contrast to passive absorption of novel concepts and traditional studying techniques, learners benefit from generation and creation of their own understanding. Teachers can encourage active engagement with new ideas through summarizing, practice testing, and the creation of video tutorials to teach others

3.1 | Avoid split attention

When visualizations (e.g. diagrams, pictures, maps, or graphs) are presented with corresponding or explanatory text elements spatially distanced from visual elements (e.g. a map with place names presented in a list below the map), the learner must devote cognitive resources to integrate both sources of information by splitting and shifting their attention between the two. This split attention effect, as described by Ayres and Sweller (2014), occurs when two (or more) sources of information must be processed simultaneously in working memory, resulting in an increase in extraneous cognitive load. A solution to avoid split attention is to spatially integrate the two different sources of information (see Castro-Alonso et al., 2019; see also Castro-Alonso, de Koning, et al., 2021). This effect is similar to the spatial contiguity principle identified by Mayer (2020), which also speaks the benefits associated with placing corresponding images and text in closer proximity to one another, albeit without framing this phenomenon in terms of specific cognitive load mechanisms. In the case of diagrams, this usually takes the form of placing explanatory text within the diagram (see Figure 1), as close to the relevant features as possible (e.g. a map with place names presented where the places are, instead of in a list below).

Several studies have supported that this integration of information leads to higher learning outcomes than the so-called 'split attention formats'. Most of this research has dealt with texts supplementing visualizations, either in static diagrams (e.g. Tindall-Ford et al., 1997) or in animations or videos (e.g. Craig et al., 2002; Mayer & Moreno, 1998). However, even two texts or two visualizations can result in split attention. For example, Chandler and Sweller (1992) observed that two text passages were more effective when shown integrated rather than separated, and Bauhoff et al. (2012) reported similar findings with two diagrams.

When using visual explainers, such as infographics or diagrams, instructors may consider creating or choosing diagrams that are 'split-attention compliant', meaning explanatory text is embedded within the diagram, and not below or off to the side. This will reduce the cognitive processing required to integrate the visual information with the text.

3.2 | Include two modalities

Instead of simply presenting learning materials with text and diagrams, many online teachers choose to provide videos, animations, or live online lectures. For these types of learning materials, instead of the integration of text with diagrams, an explanation is usually provided through an audio narration. Building upon the split attention effect, the modality effect (see Castro-Alonso et al., 2019; Castro-Alonso & Sweller, 2019; Low & Sweller, 2014) describes how students can benefit when information is presented in two modalities, rather than one. When audio narrations are used to explain visual information such as a diagram, there is only one source of visual information, so split attention is avoided (see Figure 2). Several examples, including reviews and meta-analyses (e.g. Ginns, 2005; Moreno, 2006; Reinwein, 2012) support the modality effect.

When teaching concepts that require diagrams or visual representations, instructors may wish to include an audio explanation, instead of textual descriptions. For example, when adapting in-class presentations that include diagrams or other visual materials, adding audio narrations instead of text-based explanations in a video version of the presentation would more effectively support learning in an online environment. Additionally, the modality and split attention effects also suggest that important visual information should be prioritized and secondary sources of visual information such as subtitles or distractors (e.g. tool buttons, side windows, or online alerts) should be minimized.

3.3 | Avoid redundancy

In many situations, teachers may wish to add additional information to their learning materials with the intention of enriching or elaborating on already presented concepts. While this additional information may be relevant, it is not always necessary for learning. Building upon the modality and split attention effects, subsequent research in CLT found specific exceptions to benefits observed by presenting learning

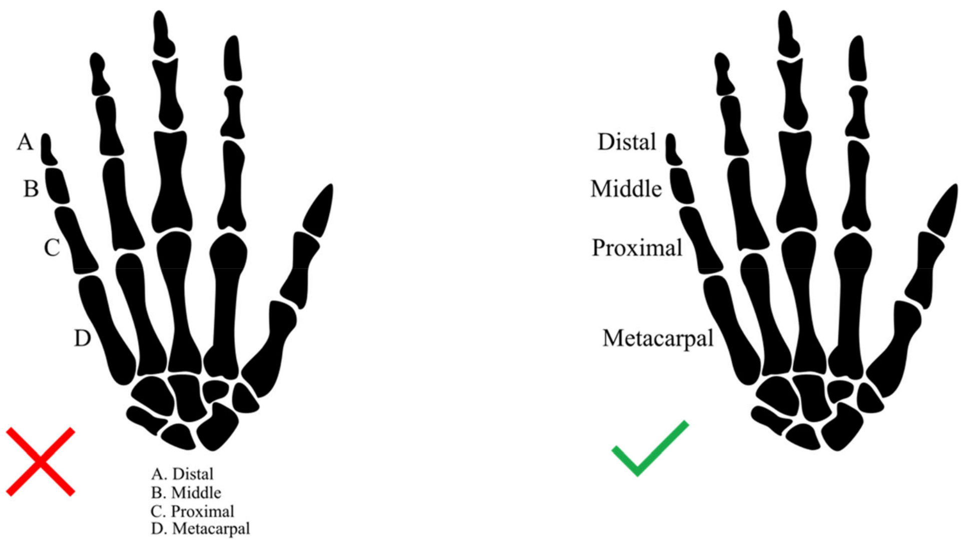

FIGURE 1 Example of non-integrated and integrated (split attention compliant) anatomy diagram. This figure illustrates how a non-integrated diagram (left) results in split-attention, while the integrated diagram (right), which places the label next to the item it describes, reduces split attention.

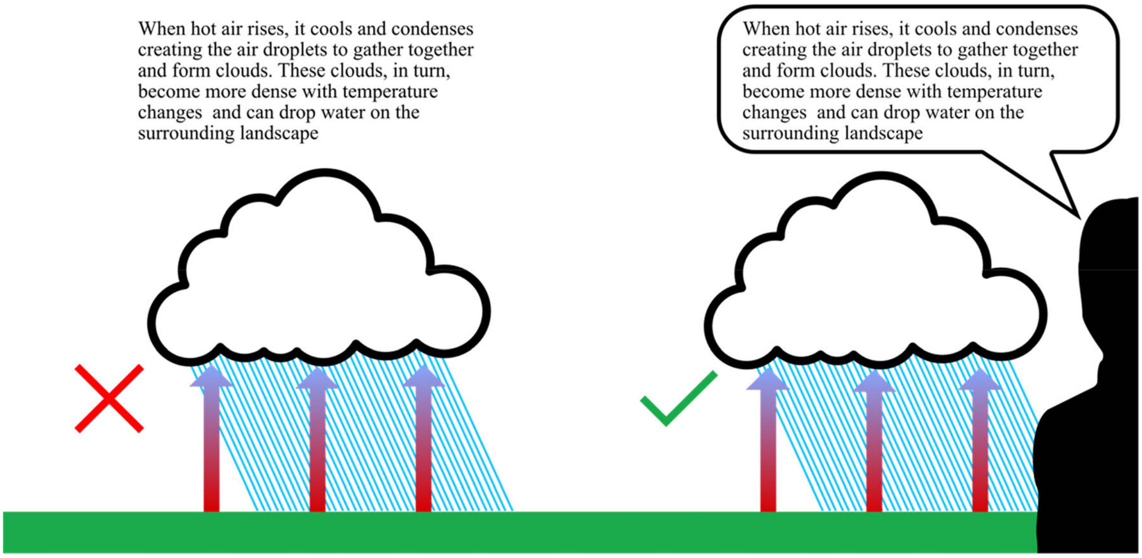

FIGURE 2 Example of single-modality and dual-modality weather systems diagrams. This figure illustrates how a verbal (auditory) explanation of a diagram from an instructor (right) can replace a text explanation (left) to enhance students' learning.

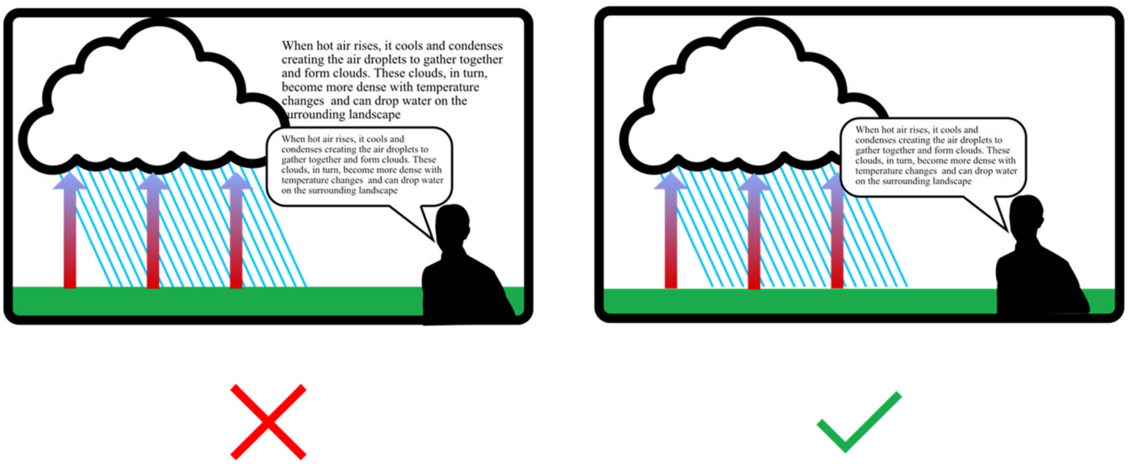

FIGURE 3 Example of redundant and non-redundant weather systems video lessons. This figure illustrates how the verbal repetition of on-screen text (left) results in a redundancy effect and therefore hampers students' learning, while the verbal description of a diagram without text (right) does not.

materials in the 'integrated format' in visual or multimedia formats. Kalyuga et al. (2004) found that when students were engaged with learning materials consisting of identical on-screen text and audio explanations, they achieved lower test scores compared to those who engaged with auditory materials alone (see Figure 3).

de Koning et al. (2017) found similar results in that on-screen labels became redundant and detrimental to learning when presented with accompanying video animations, suggesting that these labels did not augment or add to the animated content, but simply reiterated information already presented. The authors suggested that this identical information required additional cognitive resources to integrate and reconcile. This redundancy effect (Kalyuga & Sweller, 2014; Sweller et al., 2011) essentially imposed an extraneous cognitive load due to the requirement to process similar and competing information in working memory, resulting in lower learning outcomes. While similar, Mayer's redundancy principle (see Mayer, 2020) more specifically refers to on-screen text and audio narration or explanation, whereas the CLT redundancy effect can be applied more generally to repetitiously presented information of any kind.

Evidence supporting the redundancy strategy has been reported in various learning fields, such as Science, Technology, Engineering and Mathematics learning (STEM; see Kalyuga et al., 1999, 2004; Leslie et al., 2012), language learning (Yeung et al., 1998), and even the learning of procedural information (de Koning et al., 2017). In these studies, participants represented many age groups, including primary, secondary, university, and vocational education.

Implications for the redundancy effect in the design of learning materials are numerous. First, self-explanatory diagrams may not need explanatory text added, with the opposite also being true—a passage of text that may not need any accompanying diagrams. By presenting redundant text and diagrams together, students need to focus on both and mentally reconcile and compare them. By omitting the redundant information, this frees cognitive resources for learning (Chandler & Sweller, 1991; Sweller & Chandler, 1994).

Second, when teachers present or provide recordings that use slides, simply reading the text presented on each slide aloud should be avoided because this is considered as redundant information (i.e. auditory explanation is identical to text on slides). Instead, replacing the written text with a diagram and providing a supplemental (but not redundant) auditory explanation can support learning in alignment with the modality effect.

Third, the findings of Rop et al. (2018) suggest that learners engaging in multimedia lessons may be able to ignore task-irrelevant, redundant or conflicting information as they gain more experience with a task, which may be particularly relevant for online tutorials and self-paced lessons. While this suggests that students may be able to adapt when confronted with irrelevant information, it is always better to remove extraneous information in the initial design to avoid redundancy when possible.

3.4 | Include visual signals or cues

When learning materials are complex, it can sometimes be challenging for students to focus on and process new information as they progress through a lesson. The signalling (or cueing) strategy supports student learning by guiding their attention with visual cues that highlight specific elements presented or the relationship between these elements (see de Koning et al., 2009; Mayer & Fiorella, 2014; van Gog, 2014; see also Castro-Alonso, de Koning, et al., 2021). Signals and cues can take many forms and can direct learners to focus on the right elements at the right time (see Figure 4).

Moreno and Abercrombie (2010) found that highlighting key terms in red in a written case study about diversity in education led to higher learning outcomes for students, as opposed to no highlighted terms. A similar study by Tabbers et al. (2004) also found that using red text to bring attention to elements in a diagram when accompanying information was presented with written or spoken text led to increased retention, however, this did not extend to benefit problem-solving.

Additionally, highlighting or shading key areas of explanation in a text or multimedia lesson has also been found to benefit learners. Studies by Jamet et al. (2008), Ozcelik et al. (2010), and de Koning et al. (2007, 2010) all found that when key areas of a diagram were shaded in while an audio explanation was played during a multimedia lesson, learners demonstrated increased retention and transfer of skills when compared to materials without shading. Further, Kalyuga et al. (1999) explored interactive learning materials that allowed learners to click on a text explanation, causing the text and corresponding portion of a diagram to appear in the same colour. This design, when compared to non-interactive materials, also led to increased test performance. Similarly, when other non-interactive learning materials were displayed as a full paragraph with multiple text passages and their corresponding portions of a diagram shaded the same colour, learners processed this information at a faster rate as measured by eye tracking technologies (Folker et al., 2005) when compared to materials shown in a single colour.

Overall, when designing digital learning materials, instructors should add visual signals or cues, as the presence of these elements can guide learners' attention to key elements, as well as increase their understanding of the relationships between elements. Cues, in this way, reduce extraneous cognitive load as learners do not need to visually search for related items (de Koning et al., 2009).

3.5 | Chunk or segment videos to reduce transient information

The transient information effect describes the impacts on learning from a video or animation when visual elements, such as text and pictures, appear and disappear on the screen as the lesson progresses (see Castro-Alonso et al., 2014; Castro-Alonso et al., 2019; Castro-Alonso, de Koning, et al., 2021; Ng et al., 2013). This constant, and sometimes fast, substitution of available visual information requires

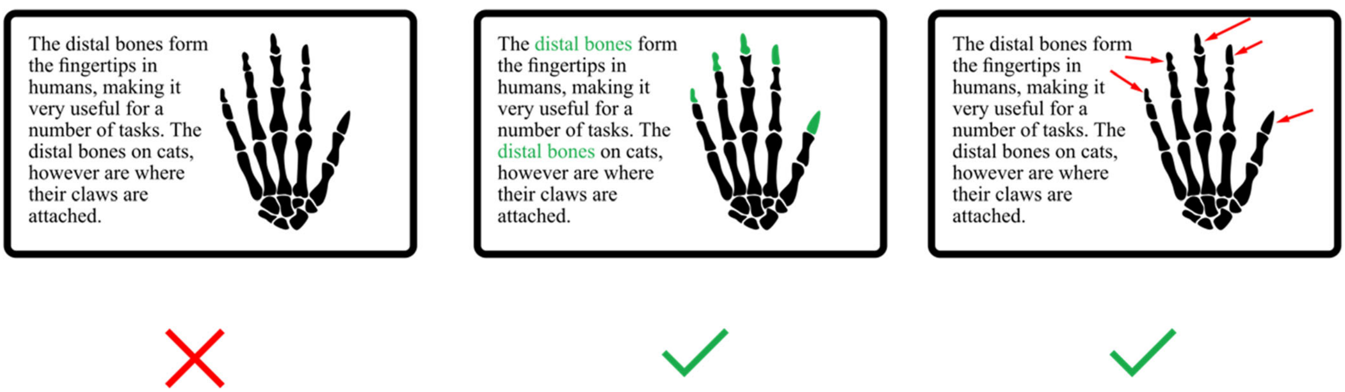

FIGURE 4 Examples of non-cued and cued learning materials. This figure illustrates how variations of cueing in the form of colour cues (centre) or arrows (right) could direct attention and improve students' learning when compared to a diagram with no cues presented (left).

students to attend to and process new information in working memory under time constraints. In these circumstances, students may not have the necessary cognitive resources available to store and process this information before it disappears, which can reduce the effectiveness of these materials for learning. This effect is expected to be more pronounced as more information is presented and processed, leading to a further reduction in the effectiveness of these learning materials (e.g. Castro-Alonso et al., 2018; Wong et al., 2020).

A solution to avoid the transient information effect is to provide shorter 'chunked' or 'segmented' videos or animations, which include interspaced breaks that allow cognitive resources to be replenished before new information is shown on the screen (see Chen et al., 2018a; Leahy & Sweller, 2019). A meta-analysis (Rey et al., 2019) and several studies (e.g. Biard et al., 2018; Hasler et al., 2007; Mayer & Chandler, 2001), which included different age groups and learning areas, have supported this solution of 'segmenting' materials as opposed to presenting longer, uninterrupted videos or animations.

Another solution to avoid the transient information effect is to allow students to control the playback and speed of these videos and animations through presented buttons or play bars/scrollers. Playback can then be tailored to the needs of the individual student, allowing them to reduce the speed of elements entering and leaving the screen as needed, so there is more time to process this information. The technique, which is known as 'pace-control', has also been supported in the meta-analysis by Rey et al. (2019) and in several studies (e.g. Hatsidimitris & Kalyuga, 2013; Höffler & Schwartz, 2011; Merkt et al., 2011; Stiller et al., 2009) in which multimedia containing features to control its pace were more effective than multimedia without these features. Generally, as long as students are able to process information in segments or chunks, this will reduce extraneous cognitive processing and support learning.

3.6 | Make the instructor visible

As more teachers use video and online lectures to present learning materials, a key consideration in the design of these materials is whether and when the instructor presenting the information should be visible to learners. This question is a focal point in recent instructional video research (e.g. Fiorella et al., 2019), but has also been addressed in the context of adding people or animated human-like characters (also known as avatars or agents, see Castro-Alonso, Wong, et al., 2021) to other forms of technology-enhanced learning such as animations (e.g. Linek et al., 2011) and computer-based learning environments (e.g. Kim & Wei, 2011).

From a CLT perspective, one could argue that showing an instructor on the screen elicits a specific case of split attention (see above), forcing learners to divide their attention between the instructor and the learning materials being presented. Although instructors indeed draw a lot of attention (e.g. van Wermeskerken & van Gog, 2017), some studies reported no test performance differences between an instructor visible condition and a condition that does not show the instructor at all (e.g. Hoogerheide et al., 2014a; Kizilcec et al., 2015; van Wermeskerken et al., 2018), while others report a learning benefit favouring a visible instructor or animated character (e.g. Castro-Alonso, Wong, et al., 2021; Pi et al., 2020; van Gog et al., 2014; Wang et al., 2020). Considering these differing results, however, there is little to no evidence that showing an instructor on the screen would actually impair students' learning (for an exception, see Wilson et al., 2018), so there would be no negative implications of showing one.

Whether including a visible instructor enhances learning depends on what the instructor does in the presented material. To ensure that students learn, instructors may help learners to focus on the right materials at the right time, such as through gesturing or looking at the material at key moments (e.g. Pi et al., 2020; see also Mayer & Fiorella, 2014; Mayer et al., 2020; see also the above section on signalling). From a CLT perspective, attending to the right material at the right time reduces the student's need to search for information on the screen, and therefore reduces extraneous cognitive load (see Figure 5). Consequently, if instructors just look at the audience and do not interact with the materials, their presence is not required for students to learn (e.g. 'talking heads'; Kizilcec et al., 2015; Wilson et al., 2018).

Another perspective to consider, however, is that a visible instructor provides learners with important social cues, which help them feel connected to and be aware of other people in online settings

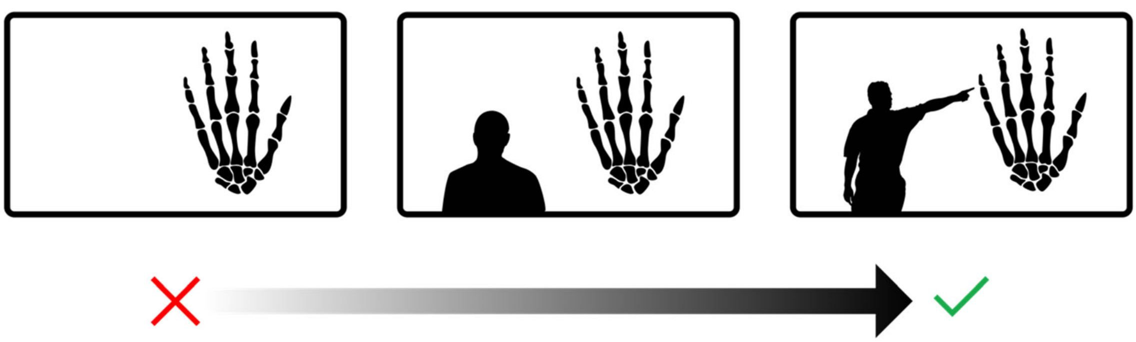

FIGURE 5 Example of video lessons demonstrating levels of instructor presence. This figure illustrates how levels of instructor presence may support learning through the inclusion of an instructor or animated character (centre) and one in which the instructor / character gestures to key parts of a diagram (right) to direct attention.

(i.e. social presence; Short et al., 1976). Online learning research has shown that in online environments, social presence is positively linked to improved satisfaction, participation, and learning outcomes (Borup et al., 2013; Gunawardena & Zittle, 1997; Russo & Benson, 2005). From this perspective, it is recommended that instructors regularly show themselves, particularly at the start of the lesson or lecture.

3.7 | Encourage human movements

Although online teaching and learning often takes place at a desk with minimal physical engagement in the learning process, research from classroom settings has suggested that human movement plays a supporting role in learning (e.g. Goldin-Meadow, 2009; Goldin-Meadow et al., 2009, 2012). The human movement effect suggests that when students are learning specific tasks requiring manipulation by human hands, that learning from animations or videos is more effective than from static images. An initial study found that when studying origami, learners who were engaged with animations of the paper folding from a first-person perspective performed better than those who engaged with static images (Wong et al., 2009). A subsequent study by Ayres et al. (2009) found that learners who observed videos showing knot-tying or solving puzzle rings with hands included were more accurate in replicating these tasks.

As a result, when teaching in domains related to health sciences or trades/polytechnical contexts, videos that demonstrate performance of tasks should be recorded from a first-person perspective, showing hands when possible. When hands are not required to learn a task or solve a problem, traditional materials such as text and images will suffice. The human movement effect has since expanded to explore how the performance of gestures by students can support learning (see the section about tracing below). Paas and Sweller (2012) theorized that the observation and performance of human movements may not impose a cognitive load due to evolutionary factors and can therefore support learning in certain contexts without any negative effects (see Sepp et al., 2020).

3.8 | Record (demonstration) videos in the first-person perspective

The first-person perspective effect is similar in origin to the human movement effect but refers to the finding that "people learn better from narrated video of a manual demonstration when it is filmed from a first-person perspective rather than a third-person perspective" (Mayer et al., 2020, p. 846). In the seminal study by Fiorella et al. (2017), university students learned how to assemble an eight-component electrical circuit from a demonstration video showing an instructor's hand and a circuit, recorded from the instructor's first-person perspective or from the opposite third-person view. Students who watched a first-person video were better (and somewhat faster) at rebuilding a complex circuit than third-person perspective students. This effect was found across a lab in the Netherlands and a lab in the USA.

A likely explanation is that having to convert third-person information into one's own first-person perspective places a heavy additional burden on the limited working memory resources (Fiorella et al., 2017). From a CLT perspective, it is likely that this burden increases extraneous cognitive load, impairing memorisation and therefore performance on a later test. In line with this explanation, Fiorella and colleagues only found the perspective effect when the electrical circuit was complex (placing heavy demands on working memory) and not when the circuit was relatively easy (less demanding, leaving ample working memory 'space' for processing the incoming third-person information). Another possible contributing factor is that seeing the demonstration video from the perspective of the instructor could prime a social response by making learners feel more like they are building the materials themselves, which from an embodied learning perspective could foster memorisation (see Fiorella et al., 2020; Leopold et al., 2019).

The first-person perspective effect has important implications for online teaching through instructional video (and other types of multimedia, such as animations). All demonstration videos that show a sequence of actions such as construction tasks (e.g. assembling furniture), cooking tasks (e.g. cutting an apple), repairing tasks (e.g. repairing a flat tire), and medical procedures (e.g. how to suture a wound; see Boucheix et al., 2018) should likely be shown from the perspective of the person performing the task (see Figure 6). This perspective principle also applies to live demonstrations in synchronous online settings, such as when instructors give a demonstration via online video conferencing platforms.

4 | INSTRUCTIONAL STRATEGIES TO SUPPORT LEARNING

After teachers have designed and created learning materials, students usually study these materials with the intention of retaining new information or learning a new skill. This section provides four tips focusing on what teachers can do to ensure that students learn more effectively from the online learning materials they provide.

4.1 | Use example-based learning

Learning new problem-solving skills is a common activity in many disciplines—particularly in STEM domains (van Gog et al., 2020)—and typically requires students to learn a series of actions to get from the problem state (e.g. an electrical circuit is broken) to the goal state (e.g. the circuit is repaired). Although many educators believe that novice learners (i.e. those with little to no knowledge of the topic) benefit more from repeatedly practicing to solve the problem without any instructional support, decades of research inspired by CLT has revealed that replacing all or a substantial number of practice problems with examples helps novices to acquire better performance on posttests, often with less effort and time investment than practice problem-solving only (see Hoogerheide & Roelle, 2020; Sweller

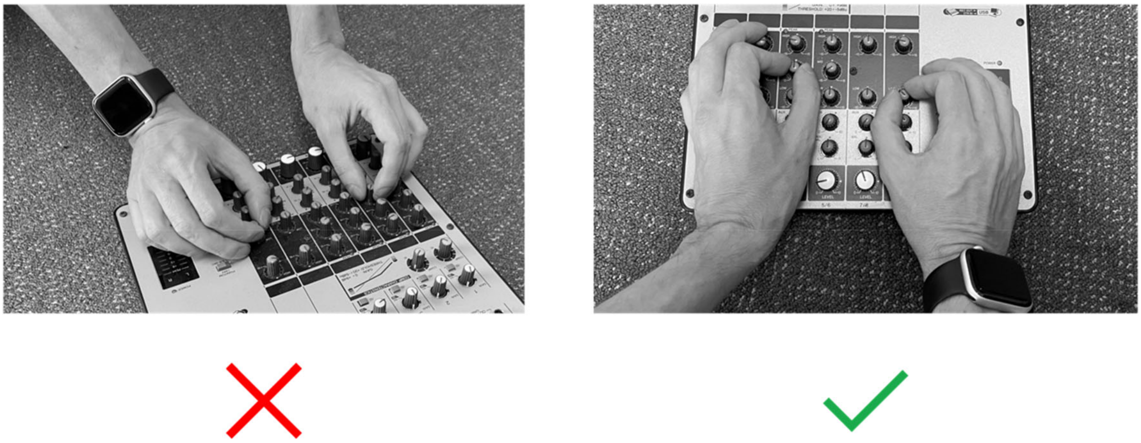

FIGURE 6 Example of video lessons demonstrating third-person and first-person perspectives. This figure illustrates how a first-person video (right) can help students learn more from demonstration videos relative to a third-person video (left).

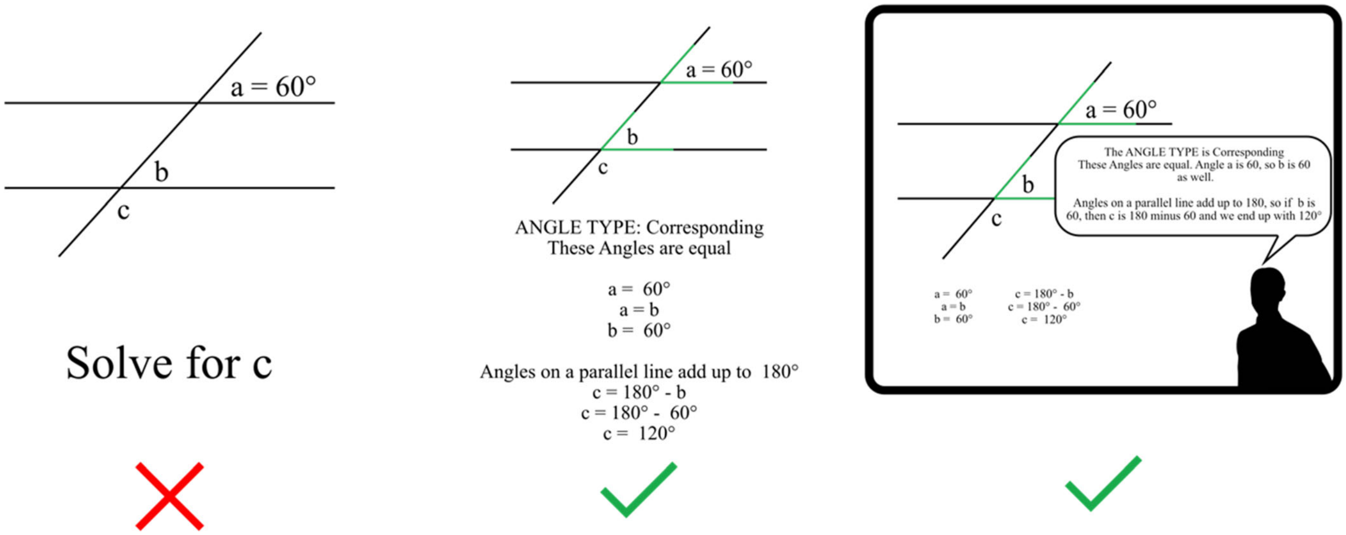

FIGURE 7 Examples of practice problem-solving, worked-out example, and video-based worked-out example with instructor audio explanations. This figure illustrates how written step-by-step examples of how to solve a problem (centre) or a video of someone demonstrating and explaining how to solve a problem (right) can help students acquire new problem-solving skills relative to a practice problem without such a solution procedure (left).

et al., 2011; van Gog et al., 2019). As shown in Figure 7, this example-based learning effect has been found with both worked examples (i.e. a written step-by-step explanation of a problem-solving procedure; e.g. Sweller & Cooper, 1985; van Gog et al., 2011) and video modelling examples (i.e. a video of someone demonstrating and explaining how to solve a problem; e.g. Kant et al., 2017; van Harsel et al., 2020).

The effectiveness of examples is commonly explained by CLT and more specifically by differences in cognitive load relative to problem-solving (e.g. Sweller et al., 2011). Practice problem-solving usually forces novices to use very poor problem-solving strategies (e.g. trial and error) that are time consuming and impose a heavy load on working memory (Sweller, 1988; Sweller & Levine, 1982). Studying examples avoids the use of weak problem-solving strategies and allows all available cognitive resources to be devoted to learning the steps involved in the procedure.

Recent research also suggests that examples have motivational benefits, as they enhance the confidence that novice learners have in their abilities compared to those who solved practice problems (i.e. self-efficacy; e.g. van Harsel et al., 2019, 2020). When teaching new problem-solving skills, teachers should therefore give their students the opportunity to study multiple worked examples or video modelling examples first (with or without alternated practice problem-solving).

It is important to note that as students acquire a better understanding of the task, example-based study may lose its benefits or may even start to hamper learning relative to problem-solving practice (i.e. expertise-reversal effect; Kalyuga et al., 2003; Kalyuga et al., 2001), because more advanced learners do not need the instructional support (scaffolding) provided by the examples anymore. To ensure a smooth transition between example study and practice problem-solving, one could have students work on completion problems, which require students to generate the answer to some (but not all) of the problem-solving steps (Renkl et al., 2002; van Merriënboer, 1990; see also fading-guidance effect, Sweller et al., 2011). In an online environment, this may take the form of videos with embedded quizzes for some of the steps, or quizzes following videos.

This combination of examples, completion problems, and practice problems afford learners a gradual decrease in instructional support during learning, especially when the completion problems also gradually increase the number of steps that students must solve. Lastly, a great strategy for enhancing the effectiveness of examples is to prompt students to explain the underlying principles of the worked-out solution step to themselves (e.g. Atkinson et al., 2003; Chi et al., 1989) or to an imaginary other student (e.g. Hoogerheide et al., 2019; see section below on generative learning).

4.2 | Encourage tracing

Building upon the human movement effect described above, several studies by Ginns, Hu, and colleagues found that when studying health sciences and mathematics diagrams on paper (see Figure 8), participants who touched or traced along key elements performed better on post-tests compared to those who did not (Ginns et al., 2016; Hu et al., 2015; Macken & Ginns, 2014). Despite the increase in test scores, a recent study has suggested that subjective ratings of cognitive load were not significantly affected (Ginns et al., 2020).

These findings can be framed through both empirical and theoretical perspectives. First Abrams et al. (2008) found that whenever hands are presented within the visual field, attention is prioritized near the hands, which would suggest that any visual materials that a

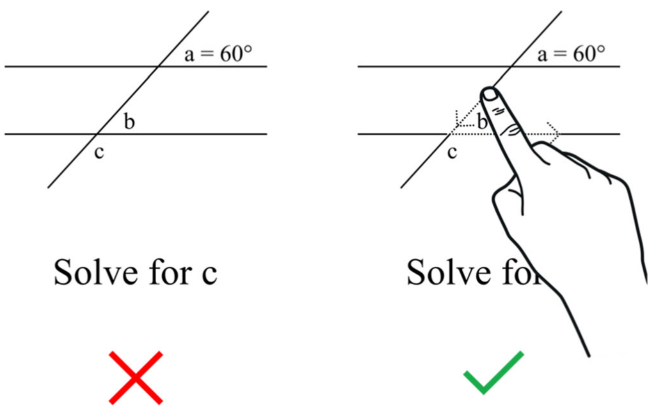

FIGURE 8 Example of static materials and materials traced upon to reinforce visuospatial concepts. This figure illustrates how tracing along an example geometry problem (right) leads to better learning outcomes than not tracing along (left) when learning novel visuospatial concepts.

student may trace on would be prioritized and thus given more scrutiny as they are studied. Further, Geary (2008) suggested that knowledge could be conceptually grouped into two different types. Primary knowledge is knowledge that humans are evolutionarily predisposed to learn without the need for formal education, including the use and observation of gestures, the understanding of social cues, and other information. Secondary knowledge on the other hand, is anything we learn that requires formal schooling such as mathematics, science, and literature. Paas and Sweller (2012) subsequently suggested that the activation of primary knowledge in memory may not require many cognitive resources, meaning that the performance and observation of gestures could be used to support learning of secondary knowledge with little cognitive load imposed. This theoretical advancement may also help to explain other effects discussed in this paper, namely the instructor visible, human movement, and first-person perspective effects.

Taking both the prioritization of attention around the hands and the use of gestures to support the learning of more abstract concepts such as mathematics and biology into account, for many learners, this strategy may be an effective means to learn from visual materials. In an online learning context, instructors may wish to encourage their students to trace along or point at key features when learning from complex diagrams and other visualizations if they find it beneficial for their own learning.

4.3 | Space out lessons and study sessions

When students study new materials or revisit them for major assessments such as exams, they often do so in a single sitting by 'cramming' for a long time before a major assessment task, such as an exam. Some teachers recommend that students avoid this study method and space out their learning experiences.

In educational settings, this strategy is said to follow the spacing effect (see Figure 9), which shows that learning activities with spaced-out breaks are more effective than activities without these breaks (e.g. Gluckman et al., 2014). It is thought that these breaks, and the resulting reduction of cognitive activity associated with them, allow depleted working memory resources to be replenished, though there is still ongoing discussion on this reasoning. In two experiments with primary school children learning math, Chen et al. (2018a) measured performance in working memory and learning tasks. Results showed that students who were allowed a full day break between learning tasks, outperformed those who were not allowed a break.

Andersen et al. (2016) investigated medical students training with a surgical simulator under two different conditions. Students in the no breaks group performed six pairs of simulator sessions, for a total of 12 on the same day. Students in the spaced group performed each of the six pairs of sessions separated by 3 days (two sessions per day). Results showed that the reaction time for those in the spaced group was significantly lower than in the no breaks group.

In the context of online learning, teachers may wish to avoid asking students to participate in prolonged periods of study in front of a

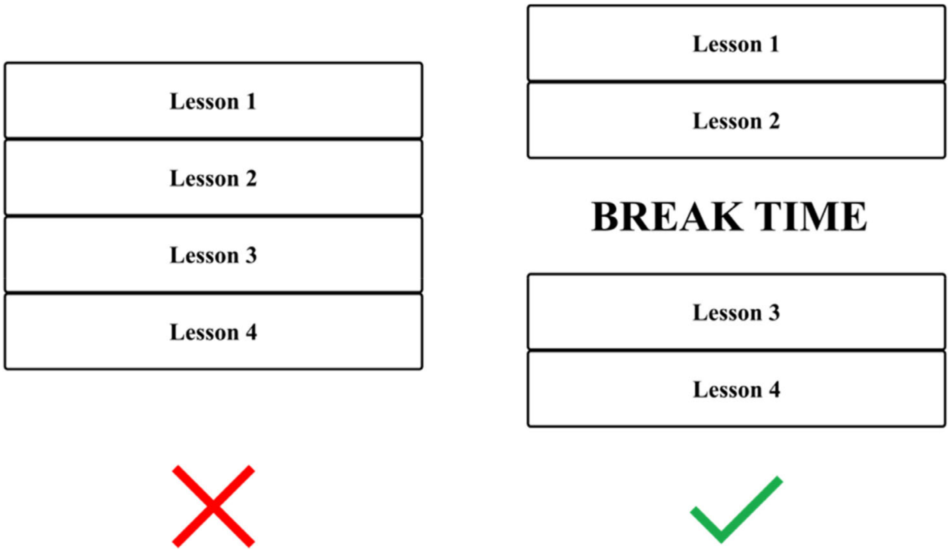

FIGURE 9 Example of non-spaced lesson, and spaced lesson including breaks in study. This figure illustrates a lesson plan in which lessons are not spaced (left), and a plan that includes breaks (right) which can support learning by avoiding the depletion of working memory resources.

computer, whether studying self-paced materials or by engaging in long online web-based video lectures. If the latter is necessary, teachers can include spaced off-line or asynchronous online tasks (e.g. forums, chats, formative quizzes, etc.), so students can step away from their computers and have a break, while still engaging in their learning. Alternatively, if teachers have the option to break up their teaching across multiple days, or at different times in the same day, this will also benefit learners as evidenced through the spacing strategy.

4.4 | Use generative learning strategies

A great way to further enhance learners' memory and understanding of material is to instruct them to engage in generative learning strategies, which is an umbrella term for strategies that stimulate students to actively engage with material, such as summarizing, explaining to oneself, teaching others, concept mapping, drawing, and practice testing (Brod, 2020; Dunlosky et al., 2013; Fiorella & Mayer, 2016; see also Castro-Alonso, de Koning, et al., 2021). From a CLT perspective, these strategies are considered to elicit intrinsic load, the type of cognitive load devoted to learning and integration of new information, by stimulating cognitive processes that contribute to learning (Kalyuga, 2011; Paas et al., 2003). More specifically, generative learning helps learners to select relevant information (e.g. words and/or pictures), to organize the selected information in a sensible narrative, and to integrate this newly acquired knowledge with existing prior knowledge (Fiorella & Mayer, 2016).

One of the most robust generative strategy is practice testing (cf. retrieval practice or testing effect; for reviews, see Adesope et al., 2017; Fiorella & Mayer, 2016; Rowland, 2014). Taking a practice test is a great strategy for remembering more of the learning materials and has been found to work with different materials at all educational levels. The memory benefits of practice testing are particularly pronounced when learners already have some knowledge to be retrieved from long-term memory and are given feedback on their answers, when there is delay between the practice test and the final test, and when the materials are not overly complex (e.g. word-pairs, prose passages; see Chen et al., 2018b; van Gog & Sweller, 2015).

Another great generative strategy that helps learners to understand complex material (e.g. longer texts with a lot of interacting information) is to explain the content of material to oneself (i.e. self-explaining; e.g. Chi et al., 1989; Lachner, Jacob, & Hoogerheide, 2021; see Rittle-Johnson & Loehr, 2017) or to teach the material to an imagined audience by recording a video that explains the novel concepts contained in the learning materials (e.g. Fiorella & Mayer, 2014; Hoogerheide et al., 2014b; Hoogerheide et al., 2019; for a review, see Lachner, Hoogerheide, et al., 2021). The benefits of explaining these new concepts seem most pronounced when students create high quality explanations (e.g. complete and accurate explanations that contain elaborations; Roscoe & Chi, 2007), generate oral explanations (Hoogerheide et al., 2016; Lachner et al., 2018), and are provided with an additional study opportunity to fill any found knowledge gaps (Lachner et al., 2020).

Generative learning strategies are best used after learners have acquired a basic understanding of the learning material, such as by studying the material or an instructional video prior to engaging in generative learning (e.g. practice testing or self-explaining). Generative strategies are generally very effortful to use as they place high demands on working memory, therefore it is important to ensure that sufficient working memory resources are available to deal with the demands of these strategies. Importantly, even (some) learners with sufficient prior knowledge will struggle to reap the benefits of generative learning strategies, because generative strategies are not always easy to use. For instance, complex activities such as drawing, explaining, and concept mapping may fail to improve understanding if learners are unable to generate a high-quality product (Fiorella & Mayer, 2016). Therefore, these complex strategies may not be as effective with younger samples. That said, there is a rich body of literature on how to support learners across different age groups as they engage in generative learning (e.g. Brod, 2020; see also Castro-Alonso, de Koning, et al., 2021). An effective way to help learners in online settings is to "train" them to use these generative strategies prior to engaging in them (e.g. explaining how to produce high quality self-explanations/summaries) or to provide feedback afterwards (e.g. feedback on the quality of the self-explanations/summaries or the answers given on a practice test).

5 | DISCUSSION

In this article, we have presented 12 tips for supporting effective teaching and learning in an online environment, based upon contemporary findings from CLT, educational psychology, and other related areas of research (see Table 1). For those new to online teaching, these tips can provide an informative and actionable resource as they design and adapt their learning materials and teaching practices to this context.

Several issues are important to consider if these tips are to be implemented in practice. Firstly, while learning is the primary goal in educational settings, teachers well know other processes and issues to consider that will influence how students learn when engaging online. These processes and issues may include assessment and engagement strategies, technology proficiency, digital and information literacy, social and emotional connection, equity and privacy, social presence (see Gunawardena & Zittle, 1997), motivation, and self-regulated learning (SRL) (see Artino & Stephens, 2009).

For instance, SRL is a well-established area of research that explores how learners monitor and regulate their own cognitive and affective processes. SRL is particularly important for online learning as attrition rates are typically higher than equivalent face-to-face classes due to the lack of immediate instructional support and the feelings of social isolation (Cho & Shen, 2013; Muilenburg & Berge, 2005). As a result, online learners would not only be required to learn new concepts and skills, but also to self-regulate and monitor their own learning processes, which may be challenging for them in an online setting. Due to the support and social connections that online learning may lack, it may also be more challenging for students to ask teachers for assistance in larger online meetings, and concurrently more challenging for teachers to informally assess students' understanding through body language or facial expressions, further affecting the application of self-regulation. While SRL and CLT are historically two parallel lines of inquiry (Sweller & Paas, 2017), recent efforts have been made to share methods and create a link between the two areas of research (Castro-Alonso, de Koning, et al., 2021; Wirth et al., 2020). For more information, we kindly refer to the effort monitoring and regulation (EMR) framework proposed by de Bruin and colleagues (de Bruin et al., 2020; de Bruin & van Merriënboer, 2017; see also Eitel et al., 2020).

Secondly, we cannot say with absolute certainty that these 12 tips would *always* generalize across *all* different age groups, cognitive abilities, online settings, and materials. Although with the exception of the perspective principle, each tip is based on robust evidence (i.e. based on many years of research showing a mostly consistent pattern of results spanning multiple subject areas, languages, and cultures), many studies discussed in this article have been conducted in controlled, face-to-face environments such as research laboratories with university student samples and within a rather short timeframe. Moreover, not every tip has sufficiently been tested with different topics and material types as well as within online settings. Regarding the issue of online settings, it is important to note that these tips primarily focus on the effective design of visual materials and the use of specific learning strategies. Given that learners are exposed to visual information on screens (e.g. tablets, monitors, projectors, etc.) in both in-person classrooms and laboratories, it is reasonable to presume that these tips are also beneficial for online learning using personal screens at home.

More generally, based on the theoretical underpinnings of the effects, one would not expect a lot of variances in how well these tips work in practice across different online learning situations. These tips are informed by many years of original research, all based upon long-established foundations of human cognitive architecture and cognitive processing, namely: reducing extraneous cognitive load to eliminate unnecessary processing (e.g. split-attention, modality, redundancy); highlighting key information to guide attention (e.g. signalling, human movement, first-person perspective); managing cognitive processing load over time to ensure learning happens (e.g. transient information, spacing); and structuring the acquisition of new procedural skills to support problem-solving (e.g. example-based, generative). Hence, following these guidelines should in most cases help students learn (more) and rarely hamper students' learning. It is nevertheless important for future research to continue testing how generalizable these principles are.

6 | CONCLUSION

The 12 tips provided in this article contribute to a much-needed bridge between theory and practice. While each study and effect described contributes meaningful insights into the specific nature of cognition and learning in their own right, this collection of tips for instructors can provide succinct and actionable approaches to enhancing learning in an online environment. As many practicing teachers may not have the time or energy to pour through 30-plus years of research, considerations for teaching practice have been discussed to ensure that teachers can make the most effective choices in the application of these strategies.

Online learning in all its forms, including emergency remote teaching, can differ greatly across institutions, subject areas, and locations. For this reason, education systems in the post-COVID-19 world will continue to engage in these practices, presenting a unique opportunity for further research and inquiry. As teachers around the world learn and adapt to support their students in an ever-changing teaching and learning landscape, it is important to consider that students also come to online learning with much diversity and are simultaneously learning how to learn online, while also studying in their areas of interest. Teachers, therefore, will continue to be mindful and supportive of their students' individual differences and needs within their context when considering the adoption of these strategies.

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