
Multitasking, note-taking, and learning in technology-immersive learning environments

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Abstract: It is common to see students multitasking or switching between different tasks on the computer while also listening to a teacher’s lecture in a classroom. In today’s classrooms equipped with computers, mobile devices, and wireless connections, students have much greater control over how they use their time. It is important to understand how students learn with connected technologies. This chapter reviews literature on the dynamics between multitasking, note-taking, cognitive load, and learning in today’s technology-immersive classrooms.

Keywords: Cognition; learning; technology-immersive learning environment; note-taking

Multitasking activities can appear as doing several things at the same time or switching rapidly between different tasks. Educators are concerned about the impact of multitasking on students’ cognition and learning. With an increasing amount of technology in the learning environment, many educators are concerned that students are too distracted to learn what they are supposed to learn (Healy, 1999; Oppenheimer, 2003).
The present chapter discusses the impact of technology integrations on multitasking and learning. In particularly, it focuses on technology impact on learners’ cognitive load, note-taking abilities, study habits, and learning. The chapter will be organized as follows. We begin by looking at the benefits and drawbacks of technology-immersive learning environments. This brings forward discussions on different kinds of multitasking activities, with some more compatible while others more distracting to the intended learning. The compatibility of various activities is related to working memory, cognitive load, and multimedia design in learning. We highlight note-taking as a likely compatible multitasking activity in our discussions on working memory, cognitive load and multimedia design. We conclude the chapter by discussing future studies to better understand the dynamics between multitasking, note-taking, and learning in today’s technology-immersive classrooms.

Media multitasking and technology-immersive learning environments

The rapid development of new media and technologies places pressure on schools and teachers to integrate them in classrooms. From computers in the classroom to one-to-one computing and laptop initiatives, there has been a rise of connected technologies in the classroom. Such connectivity has created new promises as well as challenges for learning.

The new learning opportunities range from self-directed learning to collaborative work afforded by the new media and technologies. With new technologies, students can use their social media and mobile devices to solve problems on their own or together with peers more easily. Instead of waiting for a teacher to provide the information or the answer, students can conduct their own searches online and find answers to problems. As a result, teachers may use the class time more effectively by discussing problem-solving skills
instead of providing answers or drill-and-practice, as advocated by the Khan Academy (https://www.khanacademy.org/).

New technologies are advocated as a way to motivate students to learn (Prensky, 2001; 2012; Tapscott, 2009). For instance, young kids are often attracted to the gestural interface of an iPad. Recent Horizon Reports highlighted gesture-based computing as a promising learning technology (Johnson et. al, 2011; 2012; 2013). Gesture-based systems, for example, the Apple iPhone, iPad, Microsoft Kinect and Nintendo Wii, are creating new opportunities for students to engage with information and learning materials through gestures such as touching, tapping or swiping screens, jumping or moving their bodies. By incorporating physical movements into learning environments, gesture-based technologies are helping to bridge educational theory and practice, and incorporate grounded cognition and embodied learning theories into teaching and learning practice.

Newer technologies are making significant gains in learning in the most fundamental ways. These advancements are occurring in the area of recursive content. That is, the technology-based activities and engagements not only help the learner obtain the content, but the activities also create a deeper understanding of the esoteric content in the process because of the new technologies. To put it simply, the “how” becomes the “what,” and the “what” becomes the “how.” The discussions between which is more important – the message or the medium (McLuhan, 1994), or between which are more important for students to learn – the knowledge or the way to obtain knowledge, may become irrelevant in near future.

Technology applications have an intrinsic potentiality to provide the learner with reinforcing activities that demonstrate the conceptual framework of the content, because
they can be designed from the ground up with these learning connections in mind. An example of what is meant by this in practice: A four year old is encouraged to trace the letters of the alphabet into an iPad application to learn his/her letters. By tracing the letters with fingers and changing colors to the letters traced, the child is learning to write the letters through more motivating practices. From a constructivist point of view, the selection of the required activities for the learner must always accomplish at least two things at once; it must convey the content (the what) using only the unique skill (the how) being taught. These “design for learning” vectors must be moving in the same direction. Further, the iterative nature of the collective tasks, and the variety of the methods of engagements, convey a body of knowledge that collectively further demonstrate the learner’s appropriated knowledge. Since most of these learning applications are often repeated, the learner’s repeated exposures afford discernment of the nuanced differences required in each individual task (what’s required to write an “E” versus an “F” for example). Taken collectively the recursion is complete when the activities or employed methods, applied consecutively, complete the body of knowledge to be conveyed. While the design of the content and tasks might be undertaken linearly, the engagement of the learner can be linear or global, depending on the desired learning outcome. Technology applications in their basic designs can choose whether conceptualization precedes visualization, whether visualization precedes conceptualization, or whether they arise simultaneously in the design (Davydov, 1990).

However, new technology opportunities come with new challenges. One of the challenges of new technologies in the classroom is the increased level of multitasking or distraction. When learning is distributed and diverse, and when students are allowed to
explore freely, some students will be distracted, or be attracted towards things that are 
different from what the teacher intends for them to do. Even in a structured lecture or 
learning activity, it is not uncommon to find students texting friends on their phones or 
updating their Facebook pages while sitting in a lecture (Rosen, Carrier, Cheever, 2013). 
Students can be seen to switch between computer programs and Internet browsers 
constantly when they are working on the computer. Instead of reading a story in a linear 
format, students often follow the hyperlinks and never seem to be able to complete one 
story in its completion anymore. In fact, students are on their phones or on their social 
media sites throughout the day whenever they are allowed to have access to their devices.

**Compatible versus non-compatible or distracting multitasking activities**

To simplify discussions, we will divide multitasking activities into two main groups. 
We name one group as “compatible multitasking activities” and the other as “non-
compatible or distracting multitasking activities.” By “compatible multitasking activities,” 
we refer to the multiple tasks involved that are heading towards the same directions or 
goals. We can see such compatible or concerted effort in activities such as playing piano or 
basketball. A skillful pianist must coordinate eyes, hands, feet, and mind towards the same 
goal with multiple tasks (e.g., reading the music, playing the keyboard, pressing the piano 
pedal) in order to play a musical piece well. By “non-compatible or distracting 
multitasking activities,” we refer to the activities that are not heading towards the same 
goal. For instance, checking postings on one’s Facebook page is usually not related or 
compatible to listening to a lecture in the classroom unless directed by the lecturer to do so; 
as such, it serves as a distracting activity from the intended goal. Below, we will briefly
discuss the distracting multitasking activities, followed by the compatible multitasking activities.

**Non-compatible or distracting multitasking activities**

Research done on multitasking has mostly targeted the non-compatible multitasking activities. Studies show that our ability in multitasking is rather limited, if not impossible (Broadbent, 1957; Lang, 2001), that multitasking over different types of tasks reduces productivity (Just et al, 2001; Rubinstein, Meyer & Evans, 2001), and that our ability to perform concurrent mental operations is limited by the capacity of the brain’s central mechanism (Schweickert & Boggs, 1984). Burgess (2000) notes that three constructs support multitasking: retrospective memory, prospective memory, and planning. As such, the role of memory, expertise, and organization becomes critical. Klingberg and Roland (1997) observed that when people conduct two tasks that activate overlapping parts of the cortex, they experienced significant interference and increased reaction time to the tasks. Scholars believe that switching between tasks wastes precious time because the brain is compelled to restart and refocus (Meyer and Kieras, 1997; Just et al., 2001). According to Meyer and Kieras (1997), each time one has this alternation, there is a period in which one will make no progress on either task. The result is that it takes longer to finish any one chore, and that people do not do their task nearly as well as they would, if they had given their full attention to the task at hand. A study by Ophir, Nass, and Wagner (2009) reported that heavy media multitaskers (HMMs) performed worse on task switching than light media multitaskers (LMMs), likely due to HMMs’ reduced ability to filter out interference from irrelevant stimuli and representations in memory.
Poldrack and Foerde (2007) found that people had a harder time learning new things when their brains were distracted by another activity. The Functional Magnetic Resonance Images (fMRIs) used by researchers showed that when people learned without distraction, an area of the brain known as the hippocampus was involved. This region of the brain is critical to the processing and storing of information. However, the hippocampus was not engaged when people learned while multitasking. Instead, the region of the brain called the striatum was activated. The striatum is activated by stimuli associated with reward or by stimuli associated with aversive, novel, unexpected or intense experiences (Schultz, 2010). Results indicated that learning while distracted or multitasking would alter the brain’s learning processes and change the way people learn (Poldrack & Foerde, 2007). Foerde, Knowlton, and Poldrack (2006) found that learning new things is dependent on working memory whereas habit learning is not as sensitive to working memory. Some tasks such as learning new skills may require high cognitive loads, while other familiar and automatic tasks may require lower cognitive loads. Studies on the impact of media multitasking on attention, cognitive load and expertise (Lin, Robertson, & Lee, 2009; Lee, Lin, & Robertson, 2011) found that students were able to understand their reading materials well in the silence and non-obtrusive background environments but they did poorly in the demanding multitasking environment. These results confirmed that working memory and cognitive load play an important role in determining how much information is retained when students perform more than one task at a time.

There have been claims that children who have grown up in environments rich in dual-task experiences can perform at higher levels in these situations than adults (Prensky, 2001). If the cognitive load for a task can shift toward the striatum (Schultz, 2010) because
of practice forming habit learned performances, then it might be possible that children have
greater exposure to opportunities for dual-tasking and therefore develop greater habit
learning (Poldrack & Foerde, 2007). However, studies looking at age differences related to
dual-task coordination have returned differing results. For instance, Carrier, et al., (2009)
investigated whether technological changes have resulted in changes in multitasking skills
in younger generation. They found that the younger generation exhibited similar mental
limitations in multitasking as the older generation did, although members of the younger
generation reported more multitasking activities. The studies conducted by Hartley and
Maquestiaux (2007) and Hartley, Jonides, & Sylvester (2011) using fMRI showed no
evidence that the management of central processing of dual tasks is qualitatively different
in older adults than it is in younger adults. At the same time, we are seeing an increasing
amount of psychological and cognitive issues that seem to be connected to the immersive
use of new media and technologies and connected to media multitasking, ranging from
stress, anxiety, to various disorders (Rosen, 2012; Rosen, Carrier, & Cheever, 2011; 2013;

Compatible multitasking activities

Compatible multitasking activities refer to the multiple tasks carried out together to
help advance the intended goal. For instance, if the goal is to learn, then the compatible
multiple tasks involved need to facilitate the learning process. Background music, note-
taking, and real-time group work may belong to the set of compatible multitasking
activities. In a study that was published in 2012 (Lin, Robertson, & Lee, 2012), we
investigated undergraduate students’ reading comprehension with different intentions and
in different multitasking situations. We found that the addition of an unobtrusive video did
not inhibit the processing of the primary reading task and that some participants actually benefited from the addition of the background video. We concluded that the unobtrusive video might have served as something to prevent the participants from daydreaming when they were completing their reading tasks. An analogy to this can be seen in people who prefer to study in a noisy café to a quiet library because the very quiet library may make them feel sleepy or mind-drifting. A study conducted by Andrade (2010) showed a similar result of the beneficial effect of a secondary task (doodling) on a primary task. According to Andrade, the act of doodling as the secondary task facilitated the primary task by reducing daydreaming. Such effect may also be due to the fact that people perform better in an environment where they have more control and flexibility, or are more comfortable or familiar for them (Lin, 2009). In this case, the multitasking activity or habit may be part of the individual comfort or control for their learning.

Another potentially compatible multitasking activity might be the back-channeling. Back-channeling has been enabled by the multiple converging technologies. For instance, it can occur when an attendee at a conference takes notes and immediately publishes their notes through social media such as Twitter or Facebook, making related comments about the presentation that is unfolding in real time. In this case, the back-channeling attendee is multitasking and works almost as a reporter. Other participants, onsite or offsite, read the comments of the “reporter” and offer their input. As a result, there may be a group of multitaskers sharing, communicating, and discussing the related topic while they are listening to the presentation at the same time. Obviously, the back-channeling attendees may take similar or opposing positions, may explain the topic with their own interpretations, and may point out unspoken aspects or undercurrents related to the topic at
hand. What is interesting is that the back-channeling occurs while the event is unfolding. While it has the potential to sway the topic in a direction that is different from what was intended by the original speaker, it also has the potential to take advantage of multiple points of view and add to the richness of the topic.

Perhaps one of the most compatible multitasking activities in learning is taking notes while listening to a lecture. Note-taking, when defined broadly, may serve different purposes. For instance, drafting a shopping list is a note-taking activity just as jotting down notes while one is listening to a lecture. Below, we will focus on the kind of note-taking activity that takes place while one is listening to a lecture or reading a text. This particular kind of note-taking usually requires comprehension, selection of information, and written production processes in a limited time or in a time-demanding environment (Bui, Myerson, & Hale, 2013; Piolat, Olive, & Kellogg, 2005). As a result, it is similar to a dual-tasking or multitasking activity.

**Note-taking, multitasking and cognitive load in learning**

In general, the main functions of note-taking are to encode and to store information externally for later review (DiVesta & Gray, 1972). Research shows that effective note-taking usually includes a great quantity of notes and that it captures the main or most important ideas (Einsteirn, Morris, & Smith, 1985; Kiewra & Fletcher, 1984). As a review tool, note-taking can be used to improve recall and retention (Hartley & Davies, 1978). In addition, note-taking may help increase a learner’s attention when he or she is listening to a lecture or reading a text; as a result, it may help the learner integrate and elaborate upon what he or she hears, sees, or reads with prior knowledge.
Research on note-taking has produced mixed results. Some show that students improve their recollection of information when taking notes (Bligh, 2000; Howe, 1970; Johnstone & Su, 1994; Kiewra, et. al, 1988), while others indicate that there is no difference between taking notes and not taking notes (Kiewra, 1985). Some studies show that students fail to record the most important points when they take notes (Hartley & Cameron, 1967; Howe, 1970; Kiewra, 1985). Yet, in studies where note-taking-plus-review was compared to note-taking-only and no-notes, the note-taking-plus-review yielded better recall in general (Fisher & Harris, 1973; Richards & Friedman, 1978). Wittrock (1974; 1979) suggested that note-taking is beneficial when learners generate paraphrased notes which incorporate prior knowledge. Novellino (1985) compared note-taking on the computer to note-taking using pencil and paper in a lecture environment, and found that the participants who were poor typists did better with recall while taking notes using pencil and paper, and the skilled typists had better recall while taking notes on the computer.

Whether taking notes helps or not probably depends on the cognitive load that the students can handle in the note-taking process (Baddeley, Chincotta, & Adlam, 2001). Note-taking depends on the working memory (Baddeley, 2007). When taking notes, the learner needs to maintain a short-term memory in order to acquire, represent, select and understand the continuous flow of incoming new information, and to update and interact with prior knowledge (Piolat, Olive, & Kellogg, 2005). Studies show that learners who had greater working memory capacity benefited from note-taking while those who had less working memory capacity were impaired by taking notes (DiVesta & Gray, 1972).
Katayama and Robin (2000) argued that the primary obstacle of good-quality notes was the amount of cognitive overload experienced by the students.

Our own research has also documented the complex relationships between note-taking and learning. In one study (Lin & Bigenho, 2011), we investigated undergraduate students’ memory recalls in three different learning environments (no-distraction, auditory distraction, and auditory-visual distraction) and with three different note-taking options (no-note-taking, note-taking-on-paper, and note-taking-on-computer). We found significant interactions between the different learning environments and note-taking options. In the no-distraction environment, the participants had better word recall taking notes on paper than taking notes on the computer or not taking notes. However, in the auditory–visual-distraction environment, the participants had better word recall with no note-taking than taking notes on computer or taking notes on paper. The participants in the study indicated that when there was no distraction, note-taking, especially note-taking-on-paper, helped them remember and recall the words; however, when there were lots of distractions, note-taking served as another burden on their mental processing or recall.

In another study (Lin & Bigenho, 2013), we examined the extent to which high school students were capable of switching between different activities including watching a recorded lecture, taking notes, and chatting with a friend. We found that when chatting with friends, the students not only reduced the volume of notes by about 30% but also did worse in understanding or remembering the lecture. There were also interferences between notes and chat texts, resulting in mixed notes and chat messages in different places. Continued studies are being conducted to investigate interactions between different information delivery methods, patterns of notes and patterns of chat activities. Note-taking,
therefore, is a complicated process involving storing, comprehending and producing information (Kiewra & Benton, 1988). According to Kiewra and Benton (1988), the “effective note-taker uses working memory capacity to attend, store, and manipulate information selected from the lecture simultaneously, while also transcribing ideas just previously presented and processed” (p. 35). While note-taking can be considered germane to many learning activities, it is clearly a dual task which can add to cognitive load under and have a negative impact on the short-term recall. With note-taking being a surrogate form of memory, it is important to understand how it plays with different memory structures and functions.

**The relationships between note-taking, memory, cognitive load and learning**

If part of learning is the ability to place new information into long-term memory, then technology-immersed or multimedia learning must examine the process of adding to long-term memory. For the purposes of this chapter we will use Cowan’s (2008) definitions to define the types of memory, which includes long-term memory, short-term memory, and working memory.

Long-term memory refers to a large store of knowledge and a record of prior events. In general, a normal healthy person has a rich set of long-term memories. Short-term memory refers to a temporary storage of a limited and highly accessible amount of information (Cowan, 1993; 2008). One objective of learning is to encode memories worth recalling into the long-term store. This involves a transfer from the short-term store to the relatively permanent long-term store (Atkinson and Shiffrin, 1971).

Short-term memory is limited in both capacity and duration of store. Most people are limited to 4 to 7 items in short-term memory without employing strategies such as
chunking. Items in short-term memory rapidly decay with time making room for shifts in attention and perception (Atkinson and Shiffrin 1971; Baddeley, 1992; Cowan, 1993). Therefore, when making the distinction between long-term and short-term memory, we usually differentiate if the memory displays properties of memory decay and hits a chunk capacity limit (Cowan, 2008). If it exhibits these characteristics, we tend to categorize it as short-term.

While it is comparatively easy to differentiate the long-term memory from the short-term memory, it is a little more difficult to make the distinction between short-term and working memory. This is because they overlap (Baddeley & Hitch, 1974; Cowan, 2008). Baddeley and Hitch (1974), and Cowan (2008) found that working memory is made up of multiple components. Working memory is comprised of short-term storage components, activated memory, along with a focus of attention within it, and central executive processes that manipulate stored information. Both storage and processing are required to assess working memory capacity. Baddeley (1992) proposed a working memory model with three subcomponents composed of (1) the central executive, (2) the visuospatial sketchpad, and (3) the phonological loop. This model operates within the short-term memory system and requires “the concurrent storage and manipulation of information” (Baddeley, 1992, p. 556). The central executive serves as the attentional controller coordinating information from the visuospatial sketchpad and the phonological loop while the visuospatial sketchpad allows for cognitive manipulation of images. The phonological loop consists of a phonological store and an articulatory control. The phonological loop can be thought of as the region where self-talk takes place. Information entering the phonological loop comes from sensory receptors and long-term store where it
is integrated with additional information. The central executive controls where the individual focuses their attention. This becomes important for learning, as tests of memory over the short term tend to correlate significantly towards cognitive aptitude. These also point to the importance of the attentional system (focus) used for both processing and for storage.

There are a series of control processes operating within the short-term store that lead to either a response output or placement of the object in the long-term store. According to Atkinson and Shiffrin (1971), information follows in the process from sensory receptors to memory systems. That is, people acquire information through the process of environmental input, to sensory (visual, auditory, or haptic) registers, to short-term store/working memory (through rehearsal, coding, decisions, and retrieval strategies), and finally to long-term store or permanent memory. It is this process where our attention must focus if we are to understand how we can best use multimedia to increase learning outcomes. While there are distinct components to working memory, dual-task studies have demonstrated decreased performance under some conditions. Baddeley (1992) found “no disruption from the concurrent verbal task[s] but clear impairment from the tasks occupying the visuospatial sketch pad or the central executive” (p. 558). Baddeley (1992) also suggested it was possible to interfere with phonological coding of visual information, resulting in decreased ability to recall visual information.

Working memory is a complex process that exists at the junction of attention, perception and memory. It is the gateway to learning. Any interference with the process of working memory disrupts learning. As input to working memory increases, cognitive load also increases. Exceeding the capacity of working memory leads to poor coding in long-
term store. The phonological loop and the visuospatial sketchpad are the functional structures of working memory that allow a person to mentally manipulate visual representations of objects and memories, link phonological coding with visual coding and mentally rehearse through inner voice. While these are separate systems, one can introduce interference between the systems through dual-tasking. This interference can also exist within the structures.

Cognitive load plays an important role in both hindering performance as well as enhancing experience. Ang, Zaphiris, and Mahmood (2007) identified five different forms of cognitive overload related to playing massively multiplayer online role playing games (MMORPGs): (1) multiple game interactions, (2) multiple social interactions, (3) parallel game and social interactions, (4) interface overloads and (5) identity construction overloads. They report a relationship between cognitive level and capacity to handle tasks. Generally, high cognitive levels result in low capacities. When a player exceeds cognitive capacities his or her level of play decreases. However, “task[s] can be transferred from high to low level cognition by repetition” (Ang, Zaphiris, and Mahmood 2007, p. 171). This implies that practice can improve a player’s ability to work at higher cognitive levels. In fact, they reported that “expert users are almost immune to distractions” (Ang, Zaphiris, and Mahmood 2007, p. 171). One explanation could be that repetitive practice stimulated activity in the striatum resulting in habit learning and lower cognitive loads.

Cognitive load theory (Sweller, 1988) suggests that a learner carries three forms of cognitive processing load: intrinsic load, extraneous load, and germane load. Intrinsic load is imposed by the nature and difficulty level of the new information; extraneous load is imposed by the methods and materials in the learning process; and germane load is the
mental process of taking new information and integrating it with old information in order for the learning to occur. The total cognitive load of the three added together should not exceed the cognitive processing resources of the learner; otherwise, learning shuts down under excessive or over load. The intrinsic load tends to be fixed. Yet, the extraneous load and germane load can be manipulated through instructional design and note-taking strategies so as to maximize the cognitive resources available for the learner to process the intrinsic load and to improve learning outcomes (Kirschner, 2002).

**Effective multimedia design to reduce cognitive load and to improve learning**

Paivio presents a Two-Channel Theory (1986), which models information input to a learner as entering through two channels: a vocal channel (the processing of words) and an imagery channel (the processing of images). Paivio argues that it is easier for a learner to utilize attentive resources on two tasks differing in nature (one a word-task, the other an image-task) than on two similar tasks (two word-tasks or two image-tasks). Computer-based learning environments may incorporate text, video, and pictures to load the learner’s input channels in a complementary manner and enrich the learner’s experiences (Clark & Mayer, 2003). Yet, good multimedia design is necessary to minimize the extraneous cognitive load by filling multiple senses and channels of the learner with complementary information without redundancy, confusion, or an over-reliance on working memory (Miller, 1956; Sweller, 1988).

With the advent of netbooks and the iPad, along with the decreasing cost in computers, schools are moving fast in the direction of one-to-one computing, that is, a personal computer or laptop with the Internet and software for every student anytime and anywhere (Bebell & O’Dwyer, 2010). As a result, the technologies available to assist
learning in the classrooms are evolving. For instance, students are increasingly taking notes with their laptops instead of paper-and-pencil notebooks. When they take notes, they may multitask, switching between word documents, chat windows, and the Internet on their computers. These multitasking activities may be interconnected and create a synergy to facilitate learning; yet they can also compete for attention and distract students from the learning task that they need to focus on. It does not happen that the more technologies the better the learning. For effective learning to take place, it is necessary to integrate sound multimedia design with the learners’ active engagement (Kozma, 1994; Schnottz & Bannert, 2003; Lusk, et al, 2009).

Little research has been done to examine the relationship between working memory capacity as needed in note-taking and multimedia learning. Both working memory capacity and multimedia learning are influenced by attentional control (Mayer, 2001). Mayer (2001) describes multimedia learning as based on three essential processes requiring attentional control: selecting, organizing, and integrating relevant information. Note-taking requires similar processes of attentional control: the learner must attend to the goal and the available information, select and organize the relevant information, and integrate the working memory and long-term memory to achieve the learning goal. Given the potential overlap of the processes of multimedia learning and working memory required by note-taking, it is necessary to examine the effects of note-taking and learning in different media environments.

Multimedia environments present at least two different media concurrently. This is often visual and auditory but could also be haptic as well as multiple presentation of visual or auditory information. Care must be taken to assure that information assembled for
presentation does not greatly increase cognitive load or create competing interference within working memory. Game developers recognize that one can vary the level of cognitive load to manipulate levels of engagement in the game (Ang, Zaphiris, and Mahmood 2007). Games that are too easy or too difficult are seldom successful.

As designers work with multimedia, they can use cues to shift attention to relevant changes in the media environment. This could be an audio cue such as a chime, change in volume or music, or a change in pitch. Users can also be alerted to changes in the environment through visual cues such as change in color or location in the screen. The success of these alerts requires consistency in usage. Studies on flanker presentations illustrate the importance of location of presentation on a screen. Depending on the type of information and the task, poorly placed flankers can create unwanted increases in cognitive load leading to inefficiencies in working memory and therefore learning.

These techniques are very important when working with parallel games, simulations that require parallel experiences and social interactions (Ang, Zaphiris, and Mahmood, 2007). There is considerable interest in virtual world video game and Massively Multiplayer Online Role-Playing Game (MMORPG, such as the World of Warcraft) for learning. Cognitive overload may result from trying to keep track of multiple users in these multiplayer/multi-participant environments. Some environments use only visual cues of the avatar for identification while others mitigate these effects by allowing users to place the avatar name above the character (Ang, Zaphiris, and Mahmood, 2007). These names may be fictitious providing relative anonymity or real life references.

When designing multimedia systems for learning, there are several design principles related to cognitive theory that may be of assistance when trying to integrate
verbal and visual information: (1) dual coding visual and verbal information, (2) remain cognizant of the limited capacities of memory systems, and (3) use generative learning which requires the learner to “mentally select relevant information and build coherent connections” (Mayer et al. 1999, p. 639). Mayer (2001) suggested seven principles for the design of multimedia learning (p. 184):

1. Students learn better from words and pictures than from words alone.
2. Students learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen.
3. Students learn better when corresponding words and pictures are presented simultaneously rather than successively.
4. Students learn better when extraneous words, pictures, and sounds are excluded rather than included.
5. Students learn better from animation and narration than from animation and on-screen text.
6. Students learn better from animation and narration than from animation, narration, and on-screen text.
7. Design effects are stronger for low-knowledge learners than for high-knowledge learners and for high spatial learners rather than for low-spatial learners.

The principle at play here is that construction of knowledge is facilitated when a learner can hold visual and verbal representations in working memory while relevant connections are created. Cognitive load can be “a major impediment to constructivist learning” (Mayer et al. 1999, p. 639). For this reason, how one assembles the audio and
visual components is important. The designer needs to remain cognizant of other cognitive demands that are within the environment remembering that he or she may not have control over all aspects of the learner’s environment.

Mayer and colleagues (1999) found that learners were more effective at making referential connections associated with constructivist learning when visual and verbal presentations were constructed so that their respective representations were held in working memory concurrently. They reported that this effect was “maximized by concurrent presentation and … minimized by successive presentation” (p. 643) so long as the capacity of working memory was not exceeded. This illustrates the importance of minimizing cognitive load demands within constructivist multimedia learning environments. Munyofu and colleagues (2007) discovered that chunking strategies can be effective in reducing the cognitive load in animated instructional environment, but that students need to have prerequisite knowledge before benefiting from animated instructions. McLaughlin and colleagues (2007) underwent a different route examining the relationship between media and learning: they investigated the attributes of audio and video as instructional media and provided a basis for a taxonomy that would match the appropriate media to learning situations. They concluded that effective learning would not necessarily occur until there was an appropriate match between instructional media types and learning situations (McLaughlin et al, 2007).

However, it is not a simple task to control cognitive aspects or to match media with learning demands. It is important to keep in mind the intended audience as well as the expected outcomes. Every learner is different and some groups of learners require unique considerations. In a study looking at the use of color for attraction to relevant information
in attention-problem children, Zentall and Kruczek (1988) found that it was important to apply discriminating use of color. They reported that “active attention-problem children performed better with relevant color than with non-relevant color. The educational implications of these findings are that color for active attention-problem children should be used to draw attention to relevant discriminative stimuli within tasks.” (1988, p. 363). It is also possible that the use of color just to increase attractiveness of the task could actually disrupt performance for these children (Zentall & Kruczek, 1988). At the same time, color can be used to focus a learner’s attention on new or relevant information. This form of instructional cueing might reduce cognitive loads adding to the effectiveness of the multimedia lesson.

Finally, we must consider the nature of secondary interactions and secondary tasks performed during multimedia interactions. The literature on dual-tasking related to cellular phones and driving provides convincing evidence of the negative effect competing dual-tasks can have on performance outcomes. The more complex the learning environment, the greater the likelihood for there to be interference between tasks. Interactive lessons delivered through learning management systems must be designed to minimize cognitive interference. This interference can result from interactions with a poorly designed learning environment, competing auditory or visual tasks, or extraneous visual or auditory characteristics of the course or multimedia environment. However, not all learning environments will result in the same cognitive levels for all students. While background music might serve as a major distraction for some, others would find that music increases their attention (Langer, 1997).

Future research and conclusion
It is clear that technology will continue to permeate our society in ways that exceed our imaginations. Advances in wearable technology and an emphasis on reduction in size with increases in performance ensure we will see smaller, less obvious and externally intrusive forms of technology entering our classrooms. With a major limiting factor to speed being the interface between human and machine, we will continue to explore new ways to directly interact with our devices. These continuing advances make it important that we continue to explore active learning processes such as note-taking along with the various ways we interact with our technologies.

Future studies should explore the nature of note-taking compared to active dialogue with note-taking being considered a surrogate discussion during the act of listening to a lecture. This would help us to better understand the role of technology in the note-taking process. What affordances do our existing technologies provide for effectively engaging in the process of learning and what are the cognitive costs of these uses? While multitasking has been demonstrated to have a large impact on psychological and cognitive processes (Rosen, 2010; 2012), it is clearly a functional part of our society and there is a need to better understand acceptable costs and useful forms of multitasking in learning environments. While increasing uses of fMRI technologies will help us to better understand multitasking in learning environments at a functional level, we must continue to explore educational multitasking in situ.

Learning environments today contain complex interactions, constantly evolving in structure and function. Educators must understand how to design learning environments that take advantage of the new media and technologies while minimizing negative cognitive impact from competing dual-task scenarios often encountered in media rich
learning environments. Controlling cognitive loads will rise in importance as these environments become more complex. A basic understanding of working memory, dual-tasking or multitasking, and cognitive load will help educators improve the efficacy of their multimedia rich learning environments. The number of portable connective devices continues to increase in classrooms resulting in a need to understand the effects of using these devices while attending to lessons in the classroom.

References


Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our


