Mind, Brain and Education in the Digital Era: Applications for Online Learning

By

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We accept the thesis as conforming to the required standard

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Abstract

This research examines mind, brain and education theories applied to online instruction. Findings emphasize role of motivation and prior knowledge in multimedia learning. A sequential quantitative-qualitative mixed methods design was used to collect and analyze data through qualitative coding and statistical computations. Research participants (n= 26) randomly allocated to one of three groups completed three different versions of How Floods Work, a self-paced online course developed with multimedia design principles in mind. To measure subject matter knowledge prior to and after the course, participants completed pre- and post-assessments. Small-to-medium size effects were observed in comparisons of post-assessment performance between control and treatment groups (d= 0.58, d= 0.35). Semistructured interviews were conducted to interpret quantitative findings. Data analyzed for participants who completed the course (n= 17) showed statistically significant positive correlations between pre- and post-assessment scores (r= 0.64, p <0.01), and between motivation and post-assessment scores (r= 0.53, p <0.05).

Keywords: mind, brain, and education; neuroeducation; self-paced online learning; multimedia learning; instructional design; motivation; mixed methods research
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CHAPTER ONE: INTRODUCTION

Mind, brain, and education, or neuroeducation, as referred to herein for short, is an interdisciplinary field of study that aims to inform educational practice and policies by enabling effective collaboration between neuroscientists, psychologists, and educators. Conceived in the late 2000s, neuroeducation is still defining its own standards and scope of practice (Fischer, Immordino-Yang, Stern, Battro, & Koizumi, 2007; Jensen, 2008; Tokuhama-Espinosa, 2008). Thus, it is not surprising that there are many possibilities for research in this field. Reviewed literature confirms Battro and Fischer’s (2012) observation that there is a particular need in the digital era for research on the implications of neuroeducation that goes beyond the use of technology for learners with disabilities, a field that has received some attention in the last decade (Mangiatordi, 2012; Denham & Battro, 2012). It is also interesting to note that researchers historically have not been concerned to the same degree with studying the effects of instruction on learning—or rather, on the learner—as with studying learning per se, even though “teaching is the natural counterpart of successful learning” (Goswami, 2004, p. 2). On the contrary, a large percentage of both consumer and peer review-oriented, research-informed literature has focused on dispelling neuromyths (Bruer, 1997, 1998; Jensen, 2005; Hirsch-Pasek & Bruer, 2007; Medina, 2009; Willis, 2008; Gardner, 2008; Geake, 2008; Lindell & Kidd, 2011; Pasquinelli, 2012; Serpati & Loughan, 2012; Tardif, Doudin, & Meylan, 2015). Two examples of neuromyths that persist among educators are the hemispheric dominance and modality dominance myths (Tardif, Doudin, & Meylan, 2015). Hemispheric dominance, the belief that some people use one half of the brain more than the other, leading to pseudoscientific practices such as right-brain teaching, was debunked decades ago (Lindell & Kidd, 2011) and recently dismissed again with the help of magnetic resonance imaging (Nielsen, Zielinski, Ferguson,
Lainhart, & Anderson, 2013). The modality dominance myth is a distortion of a long tradition of research into learning styles: In spite of a lack of empirical evidence, educators have been led to believe by peers and education authorities that there are techniques to diagnose and match learners’ preferences for visual, auditory, or kinesthetic (VAK) presentations of material to effective pedagogical strategies (Coffield, Moseley, Hall, & Ecclestone, 2004; Sharp, Bowker, & Byrne, 2008; Pashler, McDaniel, Rohrer, & Bjork, 2008; Willingham, 2012; Kirschner & van Merriënboer, 2013).

It seemed possible, therefore, to make a meaningful, original contribution to the relatively unexplored area of neuroeducation and e-learning from the perspective of an educator—an important distinction that breaks away from the tradition of the positivist neuroscience-dominated discourse—as advocated by Fischer, Goswami, Geake, and The Task Force on the Future of Educational Neuroscience (2010). Historically dismissed by neuroscientists, due to their lack of scientific approach to empirical research, educators now find themselves in a unique position to help shape the neuroeducation research dialogue. With the postpositivist need for research methods that take into account the complex nature of social contexts, educators, with centuries-honed skills and practices, can contribute as equal participants within the interdisciplinary field of mind, brain, and education research. Therefore, in addition to contributions made to the field as a result of research findings, this study also expected to contribute to research process discussions by combining quantitative and qualitative methods of data collection and analysis.

**Theoretical Framework**

Supported by the rationale for a research orientation that simultaneously seeks explanations of reality while allowing for multiple interpretations of that same reality, general
research questions reflect two complimentary worldviews, postpositivist and interpretivist. On the one hand, this research expected to find correlations between applied theories of neuroeducation and learning as measured quantitatively—a postpositivist orientation. On the other hand, being aware of the inherent limitations of suggesting causal relationships in a real life context, the hope that the present research would elucidate quantitative findings by probing the overall experience, perceptions, opinions, motivations, judgments and emotions of research participants helped guide the study—an interpretivist orientation.

In addition to the aforementioned philosophical orientation, various theories of cognition guided the design of research methods and analysis of findings. Mayer’s (2009) cognitive theory of multimedia learning informed the design of core learning materials used in the research and also provided guidelines for the interpretation of results. Theories of sleep and cognition (e.g., Roth, Costa e Silva, & Chase, 2001) and theories of physical exercise and cognition (e.g., Kramer & Erickson, 2007) guided the design and analysis of the second of the research experiments. These theories of learning are in turn substantiated by theories of memory (e.g., Kandel and Squire, 2009) and theories of attention (e.g., Posner, 1980). Among theories of memory, Paivio’s (1991) dual coding theory helped design and interpret interview questions meant to understand the participant’s audio-visual experience. Similarly, Sweller, Ayres, and Kalyuga’s (2011) cognitive load and split attention theory assisted in the design of interview questions and the interpretation of the participants’ experience during the multimedia module.

Finally, theories of motivation, such as Maslow’s (1943) humanistic view or Deci, Vallerand, Pelletier, and Ryan’s (1991) self-determination theory, helped interpret an emerging trend first noticed during the interviews, whereby participants who put greater effort into
engaging with course content—that is initiating, directing, and sustaining behaviours aimed at improved academic performance—scored better in the transfer-of-learning assessment.

**General Research Questions**

This research was guided by a set of defined hypotheses derived from the general questions that motivated the research, that is, questions such as how online instructional design can benefit from recent advances in neuroeducation. For instance, in a hypothetical world, everything else being equal, would one online student who performs physical exercise outperform another who did not during the period of instruction? What if student A took a mid-day nap, a much needed break from instruction, while student B fought a bodily need to sleep during the day as most of us routinely do? What if student B attempted to multitask during a unit of instruction while student A attempted to focus solely on the instruction? The answers to these questions may be evident to anyone who has read some of neuroscience’s best-known and widely accepted theories, but education occurs in complex, empirical systems with heterogeneous populations, instructional materials that may or not be adequately designed, untested assessment tools, and an overall heavy reliance on the art, rather than science of teaching. Given the near-impossibility of adequately controlling for such a large number of naturally occurring variables in learning environments, resourceful research methods are needed that bring the context of learning into perspective while attempting to elucidate relations between theory and practice.

These general questions were then delimited by a narrower set of hypotheses to guide research design and analysis of findings.
Hypotheses

As demonstrated by literature reviewed, sleep and exercise influence cognitive functions (e.g., Medina, 2009) while memory and attention are conditions for learning (e.g., Sousa, 2006). Likewise, the interdisciplinary field of multimedia learning has formulated multiple applications of the integration of words and pictures with practical implications for instructional design in the form of principles (Mayer, 2009). In order to research the extent to which learning may be influenced by the integration of all of these variables through the design of instruction, two sets of hypotheses guided the research. First, the research sought to find out whether participants who completed a course that included a self-paced e-learning multimedia module designed based on cognitive theory of multimedia learning principles would be able to demonstrate deeper learning of the content than those who completed a similar course where only the multimedia module were different. The second question concerning the research was whether participants who, in addition to completing the same said theory-based multimedia module, slept and exercised in accordance with bodily needs would boost their cognitive performance even higher.

As explained in detail in the methods chapter, two experiments were designed to test research hypotheses. For the first of the experimental comparisons, the null hypothesis is denoted by the symbol $H_0$ and the alternative or experimental hypothesis is denoted by $H_1$:

$H_0$: Participants who complete a self-paced online course that integrates into its design principles of multimedia learning theory will not perform better in transfer-of-knowledge assessments than those who complete a course where the only design difference is a less rigorous application of multimedia learning principles.

$H_1$: Participants who complete a self-paced online course that integrates into its design principles of multimedia learning theory will perform better in transfer-of-knowledge
assessments than those who complete a course where the only design difference is a less rigorous application of multimedia learning principles.

For the second of the experimental comparisons, the null hypothesis is denoted by \( H_0 \) and the alternative hypothesis is denoted by \( H_2 \):

\( H_0 \): Participants who complete a self-paced online course that integrates into its design principles of multimedia learning theory combined with directions to boost cognitive performance through sleep and exercise will not perform better in transfer-of-knowledge assessments than those who complete a course with a less rigorous application of multimedia learning principles and no sleep or exercise instructions.

\( H_2 \): Participants who complete a self-paced online course that integrates into its design principles of multimedia learning theory combined with directions to boost cognitive performance through sleep and exercise will perform better in transfer-of-knowledge assessments than those who complete a course with a less rigorous application of multimedia learning principles and no sleep or exercise instructions.

Research Delimitations

In order to test research hypotheses, participants had to be able to do physical exercise, sleep normally, see and hear. Research population was sampled based on these pre-requisites. This research delimitation effectively excluded the application of theories of universal design for learning (e.g., Meyer, Rose, & Gordon, 2014), which aim to make education accessible to all people, including, especially, population excluded from the present research, such as people with visual or hearing impairments. Central to the present research is the premise that people learn better with words and pictures than with words alone. This idea, at the core of Mayer’s (2009) theory of multimedia learning, does not apply to anyone who has a visual impairment. Likewise,
the multimedia learning principle of redundancy, upon which much of the multimedia module designed for the present research was based, predicts people “learn more deeply from graphics and narration than from graphics, narration, and on-screen text” (Mayer & Fiorella, 2014, p. 279), which is only applicable to people who can both see and hear. This is not to say that multimedia learning clashes with universal design for learning principles: It addresses a different set of problems. For example, a multimedia passage designed on the basis of the multimedia learning redundancy principle would minimize or altogether eliminate on-screen text, while the same passage designed with universal design and accessibility guidelines in mind might need to adapt to multiple audiences, containing no on-screen text for visually- and hearing-abled people (consistent with multimedia learning theory), optional closed captions for people with hearing impairments, and a combination of described graphics and narrated text—effectively a single-media design—for people with visual impairments.

Summary

The interdisciplinary field of mind, brain, and education provides a forum for educators and neuroscientists to collaborate for the purpose of improving the quality of education. In the digital era, research is needed to understand the implications of instructional technologies on learning and teaching, and educators are uniquely positioned to contribute in a dual role as practitioners and researchers. The present research is in part guided by the general question of how neuroscience can positively inform instructional design at the present time. In order to further delimit the scope of the research two hypotheses were formulated. First, the research sought to study differences in learning outcomes between learners who complete a self-paced online course designed with principles of multimedia learning theory in mind, and those who complete a version of the course where the principles are applied less rigorously. Second, the
research sought to understand the participants’ experience, judgments, and motivations in completing the course. Research hypotheses required the study be delimited to a population of adults who can perform physical exercise, sleep normally and be able to see and hear. Concepts introduced in this chapter are further explored in the literature review chapter (see also Glossary).

**CHAPTER TWO: LITERATURE REVIEW**

Mind, brain and education is a field that has been under development for over a decade, and comprises multiple biological and behavioural principles, hypotheses and theories (Schwartz, 2015). It wasn’t that long ago when there were no recognized experts in the emerging interdisciplinary field of neuroeducation. Efforts by researchers such as Tokuhama-Espinosa (2008) have begun to identify the field’s thought leaders making it possible to set parameters for the selection of relevant and credible neuroeducation literature. That is not to say that the field is now well defined and established: if anything, far from it, as the ongoing debate about the usefulness of linking brain science to education reminds us (Bruer, 1997, 1998, 1999, 2002, 2006; Byrnes & Fox, 1998; Ansari & Coch, 2006; Goswami, 2006, 2012; Lee, 2006; Hirsch-Pasek & Bruer, 2007; Szücs & Goswami, 2007; Willingham & Lloyd, 2007; Geake, 2008; Jensen, 2008; Purdy, 2008; Varma, Mccandliss, & Schwartz, 2008; Willis, 2008; Coch & Ansari, 2009, 2012; Willingham, 2009; Della Sala, 2009; Howard-Jones, 2009; Christodoulou & Gaab, 2009; Cubelli, 2009; Tommerdahl, 2010; Summak, Summak, & Summak, 2010; Worden, Hinton, & Fischer, 2011; Hruby, 2012; Pasquinelli, 2013; Edelenbosch, Kupper, Krabbendam, & Broerse, 2015).
Literature Selection Parameters

In order to address the general research question of how the instructional design of online courses could benefit from recent advances in the interdisciplinary field of neuroeducation, the literature review has been divided into five parts. The first part is an overview of the past, present and future of the relatively new interdisciplinary field of mind, brain and education. The second part of the literature review is concerned with research into how various functions, such as attention, memory, sleep, physical exercise and the integration of multiple senses enables and influences learning. The third part explores the potential that theories of neuroeducation hold for application in the design of instruction. The fourth part of the literature review delves a little deeper into theories of multimedia learning, and in particular Mayer’s (2009) cognitive theory of multimedia learning, which, although could be classified as both an applied or multisensory integration theory, deserves a section of its own given its relative importance to this research. Finally, the fifth part of the literature review explores theories of motivation, which although not originally included in the overall study design, became more and more relevant as the analysis of qualitative findings progressed and ultimately became central to the research.

Past, Present and Future of Neuroeducation

The latest attempt to formalize the field of mind, brain, and education took place in the late 2000s through the creation of the International Mind, Brain, and Education Society (IMBES) and the launch of its Mind, Brain, and Education journal (Fischer, Daniel, Immordino-Yang, Stern, Battro, & Koizumi, 2007), as well as similar contemporary efforts (e.g., OECD, 2007). Later attempts to define the field’s tenets, principles, instructional guidelines, and standards (Tokuhama-Espinosa, 2008), as well as its research methods, models, and morality (Educational Stein & Fischer, 2011) have all contributed to further establish the collaboration between
neuroscience and pedagogy. At the same time, skeptics and critics have reminded us of the importance of avoiding dangerous misinterpretations of neuroscience under the pretense of brain-based learning (e.g., Bruer, 1997; Bransford, Brown, Cocking, & National Research Council, 1999). The history of neuroeducation, however, is also the no less controversial history of its parent disciplines. For instance, while Tokuhama-Espinosa (2008) pegged the beginnings of neuroeducation to Gardner’s research in the early 1980s, Geake (2008) argued in reference to Gardner’s multiple intelligences theory that he “has just recycled Plato.” Similarly, Lee (2006) pointed out that the picture superiority effect, a concept fundamental to this research, could be traced back to Cicero, in the first century BCE.

The future of neuroeducation depends largely on the ability of educators and neuroscientists to collaborate in (a) the establishment of research schools; (b) the training of a new generation of neuroeducators; (c) the creation of shared databases; and (d) the design of educational research informed by neuroscience and genetics; as well as a debate on neuroethics (Fischer, Goswami, Geake, & The Task Force on the Future of Educational Neuroscience, 2010).

Embracing neuroeducation’s invitation to focus research efforts towards developing a theory of teaching—an area historically ignored by neuroscientists, who have concerned themselves primarily with developing learning theory (Battro, 2010)—the present research embraces the dual function of research and practice to turn attention and efforts towards developing a theory of teaching that is informed by neuroscience.

**Mind, Brain, Body and Learning**

The second part of the literature review is concerned with research on how diverse human functions affect learning. In relation to the present research, this review of past research is driven by the search for potential applications of attention, memory, sleep, physical exercise and
multisensory integration applications to the design of instruction. First, the function of attention and memory functions as necessary conditions for learning is described. Second, the influence of physical exercise in learning is presented from a neurophysiological perspective. Third, the importance of sleep for learning is explained. Fourth, the effect that integrating multiple senses, such as vision and hearing, has on learning is explored.

**Attention + memory = learning.** Though the mechanisms through which attention improves memory consolidation, resulting in greater learning, are not fully understood, there exists ample evidence to suggest a strong link between attention and memory as pre-requisites for learning (Awh, Vogel, & Oh, 2006; Chun & Turk-Browne, 2007; Deco & Rolls, 2005; Sousa, 2006). The link between memory and attention in relation to learning is evident when analyzed from a pathological perspective: Learning does not occur, or is compromised, when either the memory or attention function is missing or malfunctioning due to brain damage (Dean, 2006). The myth of multi-tasking is a typical non-pathological example of how learning is compromised by lack of attention: Multi-tasking is in fact an attention-dividing act of switching tasks due to the brain’s inability to consciously focus on more than one non-automated task at the same time (Fernandes & Moscovitch, 2000; Lozito & Mulligan, 2006; Naveh-Benjamin, Guez, & Sorek, 2007).

**Attention.** According to Posner’s model (Posner, 1980; Posner, Snyder, & Davidson, 1980; Posner & Petersen, 1989), three attentional neural networks exist in the brain which are anatomically separated but work together: (a) the alerting or arousal network, responsible for intrinsic alertness (constant monitoring of the environment) and phasic alertness, i.e., transformation of intrinsic into specific alertness triggered by stimuli that require attention (e.g., a lurking predator); (b) the orienting network, responsible for gathering information about
stimuli (e.g., turning head towards a predator to see or hear it better), and (c) the executive network, which controls our response to stimuli (e.g., running away from a predator).

Attentional networks can be shaped through training, as demonstrated by Posner, Sheese, Odludaș, and Tang (2006), who successfully improved executive function and selective visual attention during experiments with normal and pathological children. They explain,

Genes do not directly produce attention. They code for proteins that influence the efficiency with which modulators such as dopamine are produced and/or bind to their receptors. These modulators are in turn related to individual difference in the efficiency of the attention networks. (p. 1427)

To arrive at their conclusions on the role of experience in altering attention, Posner, Sheese, Odludaș, and Tang (2006) first identified two candidate dopamine-related genes involved in the efficiency of executive attention by having 200 persons perform an attention test and then having them genotyped. To confirm genotype findings, they conducted a neuroimaging experiment in which persons with different alleles of these two genes completed the attention test while their brains were being imaged. Then, they developed a five-day training intervention that used computerized exercises, hoping to improve conflict resolution in trained children. Posner, Sheese, Odludaș, and Tang (2006) conclude, “Training altered the network for the resolution of conflict in the direction of being more like what is found in adults” (p. 1426). Posner and Rothbart (2005) opined that attention training could soon be used in schools as a pedagogical intervention for cognitive and moral development, as well as the promotion of children’s social adaptation by altering children’s individual attentional networks.

**Memory.** Milner, Kandel, and Squire (1998) summarized cognitive neuroscientists’ concerns with the study of memory over the second half of the twentieth century as belonging to
one of two major research strands. The systems problem of memory “is concerned with analyzing what memory is, where it is stored, and what brain systems are involved” (p. 446). The molecular problem of memory “is concerned with analyzing how memory is stored” (p. 446) [emphasis in original]. Thanks in large part to the five-decade long study of amnesic patient Henry Molaison—referred to as H.M. in scientific publications since 1957 until his death in 2008—, it became possible to hypothesize the neuroanatomy of declarative and non-declarative memory storage with great precision (Scoville & Milner, 1957; Squire, 2009b). Declarative memory is the conscious (explicit) recollection of information that can be potentially declared (e.g. events, facts, words, and faces) through verbal language or mental imagery while non-declarative—also referred to as procedural or implicit memory (Kandel, 2009)—refers to habituation, sensitization, and classical conditioning (Squire & Kandel, 2009). Declarative memory is further classified by its distinct operations of encoding, storage, retrieval, forgetting, and permanence relative to time, i.e., short-term (immediate and working) and long-term memory (Squire & Kandel, 2009).

Educators can benefit from applying long-term memory potentiation techniques to help students overcome Schacter’s (1999) seven sins of memory: transience, absentmindedness, blocking, misattribution, suggestibility, bias, and persistence. “Practice makes perfect”, simplify Squire and Kandel (2009) as they recall Ebbinghaus’s 19th century experiment to remember a long string of nonsensical syllables through repetition, a daily two-year long effort described as heroic by James (1890/1931, pp. 676–679). Similarly, Ericsson, Chase, and Faloon (1980) helped S. F., a college student, successfully increase his memory capacity from a normal capacity of about seven-digit strings (Miller, 1956), to a seventy-nine-digit string. S. F. achieved this feat by chunking information and associating it to information known to him (i.e., track and
field scores and dates). However, when the experiment was switched to letters instead of numbers, he was back to remembering only six consonants. Pointing out the significance of this and other experiments Cowan (2011) concludes, “A student’s existing knowledge can be used to overcome working memory limits in many situations” (p. 123).

Medina (2009) summarizes three characteristics of memory encoding that have applications to the design of instruction: (a) the more elaborate the encoding (multiple meaningful associations), the stronger the memory, (b) the brain seems to store memories in the same neural pathways initially used for encoding, and (c) memory retrieval improves by replicating conditions surrounding encoding. In other words, we remember, or learn best when information is meaningful, contextual, and elaborate.

**Physical exercise.** Moderate exercise has been shown to improve cognitive abilities. Evidence indicates executive functions may be selectively maintained or enhanced in humans with higher levels of fitness (Churchill et al., 2002). Exercise can increase levels of brain-derived neurotrophic factor (BDNF), a gene-secreted growth factor (protein) correlated with neuroplasticity, and more specifically with neurogenesis, neuroprotection and long-term potentiation (LTP), the latter a synaptic mechanism related to strengthening memory and learning (Cotman & Berchtold, 2002; van Praag, 2009). Aerobic fitness and exercise have also been shown to increase hippocampal volume and improve spatial memory performance (Colcombe et al. 2006; Erickson et al., 2009). Based on the review of three separate literatures—human observational studies, randomized clinical trials in humans, and cellular and molecular research in animals—that examined the influence of physical activity and exercise on cognition, Kramer and Erickson (2007) conclude, “Physical activity enhances cognitive and brain function, and protects against the development of neurodegenerative diseases” (p. 342).
**Sleep.** Sleep deprivation can hurt a lot more than just learning: it can be fatal. A meta-analysis revealed attention as the cognitive domain most strongly affected by short-term sleep deprivation (Lim & Dinges, 2010). There is now ample scientific evidence to suggest that ‘sleeping on it’ goes a long way into gaining insight on a problem and improving overall alertness and cognitive performance (Rosekind, Gander, Connell, & Co, 2001; Roth, Costa e Silva, & Chase, 2001; Nelson, 2004; Wagner, Gais, Haider, Verleger, & Born, 2004). In addition to a good night’s sleep, it has been demonstrated that a short daytime nap—20 minutes to 1 hour, depending on the study—has positive effects on subjective and objective cognitive performance, as well as mood and relaxed wakefulness (Dinges, 1992; Hayashi & Hori, 1998; Ficca, Axelsson, Mollicone, Muto, & Vitiello, 2010). In the same regard, naps are also deemed superior to daytime short rest periods of the same lengths of time (Hayashi & Chikazawa, 2004). Medina (2009) summarizes, “Sleep has been shown to enhance tasks that involve visual texture discrimination, motor adaptations, and motor sequencing” (p. 153).

**Multisensory integration.** Multisensory integration describes a process by which vision, hearing, touch, taste, and smell signals are combined in the brain to “influence perception, decisions, and overt behavior” (Stein, Stanford, and Rowland, 2009, p. 4). For example, “foods are appreciated according to their appearance, smell, taste and texture” (Sperdin, Cappe, Murray, 2010, p. 9). In regards to the specific type of sensory crosstalk that will be tested in the present research, sound and vision are integrated in the brain to “form a single representation of space that involves both auditory and visual stimuli” (Goldstein, 2011, p. 312).

**Applications of Neuroscience to Instructional Design**

Unlike literature reviewed thus far, where authors are primarily neuroscientists who may not have explicit interest in applied research for education practice, this third section of the
literature review will introduce more of the work of researchers and practitioners concerned with applications of neuroscience for education. The importance of this section of the literature review to this research is the potential that applied neuroscience research holds for design of instruction that leads to meaningful learning outcomes. According to Tokuhama-Espinosa (2008), “The ultimate purpose of neuroeducation is to maximize every person’s individual learning potential specifically within classroom contexts” (p. 22). As seen in literature reviewed thus far, there are several actual and potential applications of memory, attention, sleep, exercise, and multi-sensory integration for the design of online courses. In this context, it is important to note there are three recurring assumptions prevalent in much of the literature reviewed in this study: (a) that there is a teacher involved in the delivery of instruction, (b) that instruction takes place in a classroom, and (c) that the recipients of instruction are children (e.g., Willis, 2006, 2007). This is not surprising given the fact that many of the recognized achievements of neuroeducation are in areas such as reading and dyslexia (e.g., Goswami, 2006; McCandliss & Noble, 2003), and mathematics and dyscalculia (e.g., Ansari, 2008; Price, Holloway, Räsänen, Vesterinen, & Ansari, 2007). It was necessary, therefore, to discern research applicable only to children from that which is also applicable to adults, based on the reviewed literature’s explicit or implicit limitations on the generalizability of findings.

Roediger III, Finn, and Weinstein (2011, p. 128) propose five cognitive psychology findings that can have applications for classroom delivery and individual study and are also suitable for self-paced online learning: (a) retrieval practice through testing; (b) spaced periods of study; (c) interleaving of different topics of study; (d) teaching students metacognitive self-monitoring; and (e) facilitating transfer of learning to novel situations. Of these findings with practical application to the design of instruction, the transfer of learning to novel situations is a
concept that was central to the method used to measure learning outcomes in the present research. Along similar lines, Mayer (2009) and collaborators define meaningful learning as characterized by good memory retention and good transfer performance—as opposed to rote learning (characterized by good retention but poor transfer) and no learning (poor retention and poor transfer), the other two possible learning outcomes.

The next and final section of the literature review delves deeper into the discipline of multimedia learning, and more specifically into applications of Mayer’s (2009) cognitive theory of multimedia learning, which guided, to a large extent, methods in the present research and has already been applied by instructional designers such as Dirksen (2012).

**Multimedia Learning**

The core multimedia principle is that people learn more effectively with words and pictures than words alone (Mayer, 2009). Drawing on dual coding theory (Paivio, 1991; Clark & Paivio, 1991), cognitive load and split-attention theory (Sweller, Ayres, & Kalyuga, 2011), and the mechanics of working memory (Baddeley, 1992), among other theories, multimedia learning researchers (e.g., Mayer, 2009; Paas & Sweller, 2014; Schnotz, 2014) have been developing, over the last three decades, the theoretical and empirical base of what is now the coherent discipline of multimedia learning; see Mayer (2014d), for a comprehensive overview of the discipline. Merging basic and applied research, multimedia learning researchers aim to “derive principles of multimedia design that are both grounded in cognitive theory and supported by empirical evidence” (Mayer, 2009, p. 3).

Koumi’s (2013) critique of Mayer’s (2009) cognitive theory of multimedia learning—among other multimedia learning theories—argues the difficulty of informing practice with controlled laboratory experiments. Analyzing Mayer’s principles of multimedia design from the
perspective of a practitioner who designs complex multimedia packages, Koumi (2013) points out, “Researchers typically make laboratory comparisons of multimedia presentations that differ in a single treatment variable and that are much shorter and simpler than real-life learning packages, hence sacrificing ecological validity through being so restrictive” (p. 111).

Figure 1 represents Mayer’s (2009) model of cognitive processing of visual and verbal information in a multimedia message, which is essential to understanding how the design of multimedia messages affects a learner’s capacity to process visual and verbal information when the two channels compete for attention. The processing of pictures starts with the storage of images in sensory memory, an event over which the learner has no control. The learner then plays a more active role in selecting images or fragments of images to store in working memory through attentional network processing. Next, images are organized to form a pictorial model, which the learner integrates the coherent visual representation with prior knowledge, resulting in the integrated learning outcome, represented by a circle in the figure. The processing of spoken words begins with the temporary storage of sound in the sensory memory. Then, words the to which the learner paid attention (actively processed) are stored as sound fragments in the working memory where they are organized to form a coherent verbal model. Finally, the learner actively integrates the verbal model with prior knowledge, resulting in an integrated learning outcome. The processing of printed words involves the storage of words as images in the sensory memory, followed by the active selection of images to store in working memory. Once in the working memory, words imported into the visual base are associated to their corresponding sounds in the audio base, organized into a coherent verbal model, and then actively integrated with prior knowledge resulting in the integrated learning outcome. Finally, Figure 1 also shows the connection between the sound and visual bases in working memory, where one base can
influence the other not only during the processing of printed words but also during the processing of spoken words or pictures.

Conducting repeated randomized experiments over the years, multimedia learning researchers have tested various multimedia designs and consistently measured the effect size of their experimental findings in order to discern between results with statistical significance from those with practical significance: Where an experiment that has been replicated multiple times
consistently yields an effect size of medium or higher significance, as measured using Cohen’s (1988) coefficient and interpretation guidelines (d = 0.5 or higher), findings are formulated as a principle of multimedia learning design with practical applications for the design of instruction (Mayer, 2009, p. 54). Adhering to these research methods, over twenty principles of multimedia learning have been formulated, and many of the principles with similar applications have been grouped under three categories: principles for reducing extraneous processing, principles for managing essential processing, and principles based on social cues.

**Principles for reducing extraneous processing in multimedia learning.** Research into techniques to reduce extraneous processing goes back to the beginnings of multimedia learning research by Mayer and collaborators (Mayer, 2009; Mayer & Fiorella, 2014). Extraneous materials in a multimedia message are images or words (spoken or printed) that are not essential to meeting the learning objective. Processing of extraneous materials competes with processing of essential materials. The five principles for reducing extraneous processing described below prescribe techniques that have significant empirical evidence of their ability to influence learning outcomes positively.

**Coherence principle.** Supported in 23 out of 23 experiments yielding a median effect size of d= 0.80 (Mayer & Fiorella, 2014), the coherence principle predicts “people learn more deeply from a multimedia message when extraneous material is excluded rather than included” (p. 279). For example, in a presentation designed to teach how floods work, the designer might be tempted to add interesting (but irrelevant) information about notorious hundred-year floods and their economic and social impact, but such information would distract the learner from essential materials, potentially resulting in extraneous processing overload and compromising expected learning outcomes. As Mayer (2009) points out, the coherence principle is therefore a
straightforward technique to deal with extraneous materials: extraneous materials are excluded altogether. It is not possible, however, to always exclude extraneous materials. Other principles can help designers incorporate necessary extraneous materials effectively.

**Signaling principle.** Supported in 24 out of 28 experiments yielding a median effect size of $d = 0.41$ (Mayer & Fiorella, 2014), the signaling principle predicts “people learn more deeply from a multimedia message when cues are added that highlight the organization of the essential material” (p. 279). Examples of verbal signaling include an outline of what will be covered at the beginning of the lesson, the use of headings, vocal emphasis on key concepts, and pointer words (Mayer, 2009, table 5.1). Examples of visual signaling include arrows, distinctive colouring, flashing, pointing gestures, and graying out (Mayer, 2009, table 5.3).

**Redundancy principle.** Supported in 16 out of 16 experiments yielding a median effect size of $d = 0.86$ (Mayer & Fiorella, 2014), the redundancy principle predicts “people learn more deeply from graphics and narration than from graphics, narration, and on-screen text” (p. 279).

**Spatial contiguity principle.** Supported in 22 out of 22 experiments yielding a median effect size of $d = 1.10$ (Mayer & Fiorella, 2014), the spatial contiguity principle predicts “people learn more deeply from a multimedia message when corresponding words and pictures are presented near rather than far from each other on the page or screen” (p.279).

**Temporal contiguity principle.** Supported in 9 out of 9 experiments yielding a median effect size of $d = 1.22$ (Mayer & Fiorella, 2014), the temporal contiguity principle predicts “people learn more deeply from a multimedia message when corresponding animation and narration are presented simultaneously rather than successively” (p. 280).

**Principles for managing essential processing in multimedia learning.** Principles outlined thus far deal with reducing extraneous processing to minimize the potential for
extraneous overload caused by cognitive processing of non-essential materials competing for attention with processing of essential materials. In this category, principles prescribe techniques to manage processing of essential materials. “When a concise multimedia lesson containing complicated material is presented at a fast rate, the result can be a form of cognitive overload called essential overload” (Mayer & Pilegard, 2014). Three principles for managing essential processing are defined below.

**Segmenting principle.** Supported in 10 out of 10 experiments yielding a median effect size of $d=0.79$ (Mayer & Pilegard, 2014), the segmenting principle predicts “people learn more deeply when a multimedia message is presented in learner-paced segments rather than as a continuous unit” (p. 316).

**Pre-training principle.** Supported in 13 out of 16 experiments yielding a median effect size of $d=0.75$ (Mayer & Pilegard, 2014), the pre-training principle predicts “people learn more deeply from a multimedia message when they know the names and characteristics of the main concepts” (p. 316).

**Modality principle.** Supported in 53 out of 61 experiments yielding a median effect size of $d=0.76$ (Mayer & Pilegard, 2014), the modality principle predicts “people learn more deeply from a multimedia message when the words are spoken rather than printed” (p. 316).

**Principles based on social cues.** Social cues are multimedia design features such as using a human voice for audio narration, speaking in a conversational style, or having an animated agent with humanlike gestures guide the learner through the material (Mayer, 2009; Mayer, 2014c). Principles based on social cues are effective in fostering generative processing: They are intended to encourage the learner to work harder at organizing incoming (sensory) material into coherent structures and integrating these structures with prior knowledge (Mayer,
Personalization principle. Supported in 14 out of 17 experiments yielding a median effect size of \( d = 0.79 \), the personalization principle predicts “people learn more deeply when the words in a multimedia presentation are in conversational style rather than in formal style” (Mayer, 2014c, p. 345).

Voice principle. Supported in 5 out of 6 experiments yielding a median effect size of \( d = 0.74 \), the voice principle predicts “people learn more deeply when the words in a multimedia message are spoken in a human voice rather than in a machine voice” (Mayer, 2014c, p. 345).

Image principle. The image principle predicts “people do not necessarily learn more deeply from a multimedia presentation when the speaker’s image is on the screen rather than not on the screen”, as demonstrated in 14 experiments that produced negative or negligible effects, yielding a median effect size of \( d = 0.20 \) (Mayer, 2014c, p. 345).

Embodiment principle. Supported in 11 out of 11 experiments yielding a median effect size of \( d = 0.36 \), the embodiment principle predicts people “learn more deeply when on-screen agents display humanlike gesturing, movement, eye contact, and facial expressions” (Mayer, 2014c, p. 345).

Motivation

The study of motivation in Western tradition traces back over 2,300 years to Aristotle, who initiated the longstanding nature-nurture controversy (Petri, 1996, p. 16) still prevalent today in psychology. There is no unified theory of motivation; rather, the concept has been studied from perspectives as diverse as philosophy, physiology, and psychology, giving birth to hundreds of theories of motivation. Defined as “the concept we use when we describe the forces acting on, or within an organism to initiate and direct behavior” (Petri, 1996, p. 3), motivation is
also used to explain the intensity and direction of behaviour. To summarize the last 100 years of research, Petri (p. 21) classifies theories of motivation into three main approaches, biological, behavioural and cognitive.

Classified by Petri (1996) as a cognitive approach to the study of motivation, Maslow’s (1943) humanistic theory of self-actualization and hierarchy of needs, among other theories of human motivation, may help in understanding the results of the current study. According to Maslow (1943), people’s motivation is gradually directed first towards meeting physiological needs, then safety needs, next belonging, and after esteem, before entering the fifth stage, self-actualization, that is “the desire to become more and more what one is, to become everything one is capable of becoming” (p. 382).

Summarizing a longstanding tradition of research into implications of motivation for education (e.g., Ames & Ames, 1989; Deci, Vallerand, Pelletier, & Ryan, 1991; Brophy, 2010), Bonk and Khoo (2014) classify ideas about “academic motivation”, as Mayer (2014b) calls a student’s motivation to study, as belonging to one of four major theoretical areas: (a) behaviourism, (b) cognitivism, (c) constructivism, and (d) sociocultural theory.

Summary

The literature review was divided into five parts. First, the past, present and future of neuroeducation were discussed. By embracing the dual function of research and education practice, the present research aims to contribute to the integration of neuroeducation theory and practice. The second part was concerned with the role that attention, memory, sleep, physical exercise and the integration of multiple senses (in particular hearing and vision) play in learning, with the objective of identifying potential applications of these functions to the design of instruction. The third part explored the potential that applied theories of neuroeducation hold for
application in the design of instruction. The fourth part of the literature review delved deeper into theories of multimedia learning, and in particular Mayer’s (2009) cognitive theory of multimedia learning—which guided research methods to a great extent—and included an overview of principles for reducing extraneous processing, managing essential processing and fostering generative processing. The fifth and final part provided an overview of theories of motivation relevant to the interpretation of findings that emerged during the research.

The next chapter demonstrates how theories reviewed guided the methods chosen to test research hypotheses, and determined how data was collected, reported and analyzed.

**CHAPTER THREE: METHODS**

A mixed methods approach was chosen to test research hypotheses given the complex nature of variables under study and the realistic context in which they were to be studied. Quantitative and qualitative approaches to data collection and analysis were integrated to simultaneously ensure the statistical sensitivity and validity of the research (Lipsey & Hurley, 2009), as well as assist in the understanding of contextual processes that have led to research outcomes (Maxwell, 2009). The quantitative strand consisted of a randomized trial with pre- and post- knowledge assessments and was followed by a semistructured interview, a design known as a sequential (quantitative-qualitative) mixed methods implementation (Tashakkori & Teddlie, 2009, p. 288). The qualitative strand was designed to help confirm (or un-confirm) quantitative findings (Table 9.1).

The research was conducted over a period of six weeks. Following a social media recruitment campaign (Appendix A), the first participants were enrolled on February 9th, 2015 and the last interview was completed March 17th, 2015.
Population and Sampling

Given the inherent limitation of the non-generalizability of the findings to the target population (i.e. non-visually impaired adults), research methods were expected to require qualitative weight to provide meaning to a statistically underpowered trial. Thus, research participants were recruited using non-probability sampling techniques (Sheppard, 2004, p. 93). Participants were recruited through convenience sampling (p. 94), from within a close circle of acquaintances, which included co-workers, classmates, relatives other than immediate family members, as well as their own acquaintances (i.e., snowball sampling; p. 95). Adults aged 18 and over, of any gender and place of origin, were eligible to participate in the research insofar as they met the following criteria (see Appendix B): (a) were legally able to freely provide informed consent, (b) were neither visually impaired, nor legally blind, (c) could read, write, and speak English fluently enough to successfully participate in a high school-level course, and (d) had mastered essential computer skills such as participating in an online forum, using the playback controls in a multimedia player, and uploading files to a website.

Table 1 summarizes the sample’s demographics. 70% of participants (n= 12) identified as female and 30% (n= 5) as male (no one chose not to identify as either). The mean age for all participants was 44 years. 12% of participants (n= 2) described their level of fluency in English as intermediate and 88% (n= 15) as advanced.
Table 1

Demographics

<table>
<thead>
<tr>
<th>Group</th>
<th>Female</th>
<th>Male</th>
<th>Age</th>
<th>Advanced</th>
<th>Intermediate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control\textsuperscript{a}</td>
<td>4</td>
<td>1</td>
<td>43</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Treatment 1 \textsuperscript{b}</td>
<td>2</td>
<td>3</td>
<td>40</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Treatment 2 \textsuperscript{c}</td>
<td>6</td>
<td>1</td>
<td>48</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

\textbf{Note.} All participants identified as either male or female. Age is calculated as the average for the group rounded to the nearest integer. Fluency in English was self-reported (see Appendix B for eligibility questionnaire).

\textsuperscript{a} n= 5. \textsuperscript{b} n= 5. \textsuperscript{c} n= 7.

Sampling: Threat to Validity?

Was the fact that the researcher knew all but two of the final 17 research participants a potential threat to the validity of research findings? During the interviews, participants were asked about their motivation to participate in the research. 82\% of participants (n= 14) who completed the study acknowledged being motivated to participate because of their relationship with the researcher. However, 65\% of participants (n= 11) also indicated a general interest in the advancement of knowledge as a motivator to enroll in the research. During qualitative data analysis the code \textit{motivation at outset} was applied to analyze the impact of convenience sampling on research findings.

Regardless of relationship to researcher, relatives, friends, acquaintances and unknown participants’ results were scattered in terms of engagement, pre- and post-assessment scores, as well as completion or withdrawal from the research. Research results suggest instead that initial motivation, or the driver behind participants’ decision to participate in the research, was not a
determinant factor in the participants’ level of engagement with the course, intensity or direction of behaviour, during the research period. Therefore, results show no obvious evidence of compromises to validity due to sampling technique.

**Quantitative Strand: ‘How Floods Work’ Moodle Course**

This section describes the quantitative strand of the research, which consisted of a self-paced online course called *How Floods Work*, hosted in Moodle, an open course learning management system.

Figure 2 shows 26 participants were assessed for eligibility to participate in the research (see Appendix B for consent form and eligibility questionnaire) and randomly assigned to a control group or one of two treatment groups (herein referred to as treatment groups 1 and 2, respectively). Participants were randomized for the trial on a first-come-first-serve basis and enrolled in the course immediately after being recruited, which meant all participants would be at different stages in the research at any given time. Based on the possibility of insufficient volunteer recruitment, only two groups were initially created for the research, control and treatment 1. When each of these two groups reached 8 participants, the third group (treatment 2) was opened to enroll new participants. All 26 initial participants were enrolled in one of three courses—one course per group administered through Moodle (v. 2.9), an open-source learning management system. Participants were blinded to knowledge of their part in one of three separate groups in the research by adjusting Moodle settings to hide participants from one another and eliminate all forms of communication among participants through the platform. Hence, courses were effectively self-paced and individual.
Participants in each of the three groups complete a unit of instruction consisting of pre-assessment, multimedia module, and post-assessment, albeit with differences between the groups (see Figure 3 for a screenshot of the course). The subject matter of the course (natural floods) was selected based on Mayer’s (2009) observation that applied multimedia learning principles are in general more effective when teaching subject matter that allow for mechanical
representation of steps such as how machines or natural hazards work. After considering a few topics, the subject of how natural floods work and how humans influence flooding, appeared to be appropriate for the research given the relatively short duration of the course (approximately 30 minutes). The Kemp model of instructional design (Morrison, Ross, Kalman, & Kemp, 2013) was used to guide the development of the unit of instruction, and the Quality Matters (2009) standards of online course design were used to assess the quality of the unit of instruction against an internationally accepted set of standards (see Appendix C for course syllabus).

Participants in all groups completed a pre-assessment to measure prior knowledge of the subject matter. Participants were asked two questions in relation to flooding as a natural hazard (see Appendix D for pre-assessment questions and scoring rubrics). The first question asked
participants to recall the steps of the hydrologic cycle, which was identified as prerequisite knowledge for the topic of flooding as a natural hazard. The second question asked participants to explain their understanding of flooding, its causes, control methods, and aggravating and mitigating factors.

Next, participants completed a multimedia module that contained all the course content. Participants in the two treatment groups were exposed to identical multimedia presentations that were designed on selected principles of multimedia learning (Mayer & Fiorella, 2014; Mayer & Pilegard, 2014), while control group participants experienced a multimedia module where theory principles were not applied to the visual aspect of the presentation, though audio tracks were identical for all groups.

Table 2
Comparison of Sample Frames from Two Versions of the Multimedia Presentation How Floods Work

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experiment Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Control Group Frame" /></td>
<td><img src="image2.png" alt="Experiment Groups Frame" /></td>
</tr>
</tbody>
</table>

The photo credit caption under the image is extraneous material requiring extraneous processing and potentially causing extraneous overload.

Applying the principle of coherence, the photo credit is excluded to reduce extraneous processing and minimize the risk of extraneous overload.
On-screen text during the hydrologic cycle animation results in redundant information as it follows very closely the narrated audio track, resulting in extraneous processing.

On-screen text is removed to reduce extraneous processing in accordance with redundancy principle.

Labels and image caption are removed to reduce extraneous processing. Signaling, spatial contiguity and temporal contiguity principles are applied to animate the frame. For example, a red line appeared over the image to highlight the perimeter of the floodplain, and a dotted line with bidirectional arrows and the label 11 km appeared later on screen to indicate the largest width of the floodplain at the same time as the corresponding segment in the narration, and on the area of the image that corresponded to the largest width of the floodplain.

Example of a frame with a static image containing extraneous material such as labels and an image caption, requiring extraneous processing and potentially resulting in extraneous overload.
The concepts of infiltration and runoff are explained consecutively in the narration while the screen displays the images corresponding to both concepts simultaneously, potentially resulting in extraneous overload.

Static images and numbered captions may force the learner to split attention between different areas of the screen while simultaneously listening to the narration.

The principles of signaling and temporal contiguity are applied to zoom in to the image that corresponds to the concept being narrated while it is being narrated, to reduce extraneous processing.

Signaling, redundancy, spatial contiguity and temporal contiguity principles are applied to reduce extraneous processing by synchronizing narration with the gradual appearance of corresponding images and eliminating captions that are separated in space from the images they label.

Table 2 contrasts and annotates sample screenshots from the two different versions of the multimedia module used in the research, highlighting how principles of multimedia learning were applied to the design of the module administered to the treatment groups.
The multimedia module was designed with Articulate Storyline 2 and images were edited with Adobe Photoshop CS6. The narration (audio track) was scripted, recorded with a Blue Snowball microphone and processed with Audacity (v. 2.0.6). Flash and HTML5 files were rendered and integrated in Moodle using the SCORM 1.2 standard. A NASA hydrologic cycle animation was remixed under a public domain license, and the core of the course content was sourced from the University of Kentucky’s Department of Earth and Environmental Sciences (n.d.) module on how floods work. All images used in the course were sourced through Creative Commons licenses (via Wikimedia), public domain licenses (NASA), or non-attribution stock (via Pixabay), or were original creations. All sources of content were acknowledged in the multimedia module, either in the notes section (treatment 1 and treatment 2 groups) or in the notes section and on the slides themselves (control group). The narration was recorded using a female voice with a native Canadian (Southern Ontario) accent to minimize the possibility of language accent misunderstandings.

Control and treatment 1 participants were provided identical instructions on how to complete the unit of instruction, which did not include directions on sleep or exercise (Appendix A). Instructions included reading the course syllabus first, then completing the pre-assessment, multimedia module and post-assessment, and finally arranging for the interview with researcher, in this sequence of events. The course design further supported instructions in two different ways. On the one hand, course activities were setup so that they would remain locked (unavailable to participants) until certain conditions of completion of the previous activity were met. On the other hand, course activities contained further instructions, such as how to answer questions or how to complete the activity to ensure it was marked as complete.
Treatment 2 participants were given identical directions on how to complete the multimedia module and post-assessment, as well as additional directions to sleep and exercise meant to boost cognitive performance (Appendix A). The course setup, including restrictions on the release of activities, was identical to that of the other two groups. Where instructions differed significantly from those provided to Treatment 1 and Control participants was in the timing to complete different activities. Treatment 2 participants were asked to complete the course over two days. On the first day, they were instructed to read the syllabus, complete the pre-assessment and multimedia and preview—but not complete—the post-assessment. On the second day, they were instructed to review the multimedia presentation and complete the post-assessment. Between the two days, Treatment 2 participants were asked to ensure they would get a normal amount of sleep, take a twenty-minute nap in the middle of the day if completing the post-assessment in the afternoon or evening, and do some physical exercise just before completing the post-assessment.

In order to quantify their knowledge of the subject matter taught in the unit of instruction and compare it to prior knowledge, the post-assessment participants were asked to complete was designed to measure transfer of learning through a problem-based scenario (see Appendix F for the post-assessment question and scoring rubric). A computer-graded quiz consisting of 4 questions was administered as part of the multimedia presentation to capture short-term memory recall and measure rote learning (see Appendix E for quiz questions and design).

Of the 26 initial participants, 20 completed the trial. None of the 6 participants who were lost to follow-up during the trial offered reasons for their withdrawal: they stopped participating and did not respond to follow-up emails. Of the 20 participants who completed the trial, 2 did not respond to the interview request.
Qualitative Strand: Semistructured Interview

Following the trial, semistructured interviews were conducted with the remaining 18 participants to further probe individual, perceptions, motivations, and judgments (Sheppard, 2004, p 141), as well as to contextualize results. To expedite the interviewing process, a pre-interview questionnaire (Appendix G) was administered to participants via FluidSurveys. The semistructured interview (Appendix H) was designed to explore in-depth participant experience during the trial in the following areas: (a) participant’s overall experience; (b) temporal-physical context in which course was completed; (c) how multimedia module was completed, including information about number of views (memory), whether there were distractions or interruptions (attention) and whether the participant simultaneously viewed images and listened to audio (dual channel theory), among other details; (d) experience, thoughts and opinions concerning pre- and post-assessments, as well as the quiz; (e) physical activity; (f) overnight sleep and nap patterns; (g) motivation to join and complete study; and (h) final comments.

Interview questions were drafted based on the theoretical framework. Questions seeking to explore the overall experience of the participant while completing the trial were framed by the postpositivist-interpretivist research orientation. Probing questions made use of quantitative findings such as quiz scores and time spent on tasks, in order to explore the participant’s emotions, judgments, and own interpretation of their experience. Questions designed to understand the participant’s experience while completing the multimedia module were framed based on attention and memory theories such as dual coding (Paivio, 1991) and split-attention (Sweller, Ayres, & Kalyuga, 2011), as well as Mayer’s (2009) comprehensive cognitive theory of multimedia learning. Questions about physical activity and sleep were framed by theories of sleep and cognition (e.g., Roth, Costa e Silva, & Chase, 2001) and theories of physical exercise.
and cognition (e.g., Kramer & Erickson, 2007) and were meant to determine the level of normality of—or compliance with recommendations in regards to—these activities to assist in the interpretation of quantitative findings. Questions about motivation to join and complete the research were framed as part of the overall postpositivist-interpretivist orientation, as at this point in the research, motivation theories had not yet been considered a distinct element of the theoretical framework.

During the interviews, the interviewer referred to the participant’s course logs in Moodle (i.e., timestamps), quiz score (pre- and post- scores were not known to participants), as well as pre-interview questionnaire responses, in order to quantify data such as number of multimedia module views, time on task, amount of sleep and exercise, among other quantifiable variables with participant’s help. Many of the semistructured interview categories became coding units or code families in the qualitative analysis.

Coding was completed over two cycles following Saldaña’s (2009) guidelines. Interview transcripts were imported into Dedoose (v. 6.1.9) where 48 codes had been prepopulated and classified into 13 categories and various subcategories with up to three levels of depth. By the end of the first coding cycle, a total of 128 codes had been applied to 373 excerpts with new codes being created using a combination of grammatical, elemental, and exploratory coding methods (Saldaña, 2009): magnitude coding (called weighted codes in Dedoose) where quantification was desirable (p. 58); structural coding where the coded excerpt was directly related to research hypotheses (p. 66); emotion coding (p. 87); as well as a few instances of in vivo coding where the participant’s exact words best captured the essence of the code (p. 74). Prior to starting the second coding cycle, one of the original codes was deleted as it was never applied. Henceforth, the focus was on “themeing the data” (Saldaña, 2009, pp. 139–145). The
second coding cycle was conducted with the aim of grouping codes by reorganizing and reanalyzing data, with the secondary goal of reducing the total number of codes and code families to facilitate analysis and data visualization. The main coding methods used in the second cycle coding were pattern, focused and axial coding (pp. 152–163), whereby codes were merged, renamed, re-classified, and quantified. Figure 4 is a visualization of the final codebook, which consisted of 66 codes organized in 10 code families: (a) context, (b) motivation, (c) multimedia, (d) physical activity, (e) pre-post, (f) sentiment, (g) sleep, (h) study design, (i) time on task, and (j) quotes (reserved to capture direct quotes from participants). In addition to the codes, the 50

*Figure 4. Code pack word cloud showing second coding cycle results. Each phrase corresponds to an individual code. The size of the code phrase is relative to frequency of applications and the sum of sub-code count and applications. Exported from Dedoose (v. 6.1.9).*
memos created during the interview and coding cycles further supported data triangulation.

**Data Collection and Analysis Methods**

Data was analyzed for 17 of the 18 participants who completed both the quantitative and qualitative strands of the research. Data from one participant was excluded from analysis because during the interview the participant revealed having completed the unit of instruction in a manner that strayed too far from directions provided. All data was collected directly from participants and further confirmed with them using a variety of instruments. An online questionnaire and consent form was used to screen candidates for their suitability to participate, to provide a research background, and to inform them of their rights as participants and collect consent (Appendix B). Participants then took a pre-test to assess their knowledge of how floods work, the subject matter of the unit of instruction, that is, the core component of the randomized trial (Appendix D). During the multimedia module, students completed a computer-graded quiz meant to measure rote memory recall of multimedia content (Appendix E). Upon completion of the multimedia module, including the quiz, participants completed an open-ended, problem-based post-assessment to measure their understanding of the course’s subject matter at an applied level (Appendix F). Finally, a pre-interview questionnaire was administered (Appendix G) and a semistructured interview was conducted to contextualize trial findings (Appendix H).

Using a deductive approach, quantitative data was analyzed using statistical methods in an attempt to identify correlations that might point in the direction of improved knowledge for participants in the treatment groups when compared to the control group (see Appendix I for individual participants’ pre- and post-assessment results used to compute statistical significance and effect size statistics). To triangulate quantitative and qualitative research strands findings, qualitative data was coded, memoed and analyzed inductively in an attempt to confirm or un-
confirm quantitative data results, as well as reveal relations not readily apparent in the quantitative strand findings (see Appendix J for the final codebook).

Quantitative data were analyzed using Microsoft® Excel® for Mac 2011 (v. 14.5.2), StatPlus:mac (v. 5.9) and the Lenhard and Lenhard (2015) effect size calculators. Qualitative analysis was done on Dedoose (v. 6.1.9), a web-based Computer Assisted Qualitative Data Analysis (CADQAS) application that allows for importing the quantitative data to conduct mixed methods analysis.

**Ethical Considerations**

The nature of the research required that participants be deceived regarding the true nature of the research. Participants were made aware only of the general purpose of the research but were unaware of research methods. The blind trial required participants to not be aware about the differences between or the existence of other groups.

Participants were made aware of their right to withdraw from the research or to refuse to complete any part of it, at any point, with no prejudice or negative consequence to them.

The research presented minimal risk to participants, as defined in the Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, & Social Sciences and Humanities Research Council of Canada (2010, p. 23).

To further protect the anonymity of participants, names were coded using a P000 naming convention. Only the researcher was aware of participant identity. All participant information collected was kept confidential. Data has been aggregated for the purpose of reporting research findings. Where direct quotes are used, the anonymity of the participant has been secured by ensuring quoting the participant reveals no identifying information. All research data will be destroyed one year after thesis completion.
To protect participants’ privacy, the domain that was purchased for the research (mberesarch.net) and used to install Moodle and deploy the three versions of How Floods Work, was hosted on Canadian servers (hostupon.ca) and therefore not subject to the United States’ Patriot Act. Electronic forms (consent form and eligibility questionnaire and pre-interview questionnaire) were also hosted on Canadian servers at fluidsurveys.com.

Electronic files containing participants’ information were stored in a password-protected computer with a File Vault-encrypted hard drive. Interviews were conducted by telephone and recorded using an audio-recording application in the researcher’s password-protected mobile phone. All participants provided verbal consent prior to beginning the interview to the audio file being potentially stored in United States’ servers and hence subject to the Patriot Act and potential loss of confidentiality.

Participants were not paid for their participation in the research or otherwise compensated. Royal Roads University’s Research Ethics Board approved the research proposal.

Summary

In order to test research hypotheses, a sequential mixed methods research was designed to collect quantitative and qualitative data concerning the experience of participants completing How Floods Work, a self-paced online learning environment. The quantitative strand consisted of an experiment and the qualitative of a semi-structured interview. A total of 26 participants were randomly allocated to one of three groups, control, treatment 1 or treatment 2. Each of the groups completed a different version of How Floods Work. Treatment 2 and treatment 2 participants received identical multimedia presentations, different from the control group’s presentation, but only treatment 2 participants were instructed to sleep, exercise, and review the multimedia module more than once in order to boost cognitive performance. The design of the multimedia
module was based on principles of multimedia learning theory. Participants were recruited through convenience sampling techniques from within a close circle of the researcher’s relatives, acquaintances and friends. Taking a preliminary look at research results in regards to participants’ motivation to enroll in, engage with, and complete the research, the concern that invalidity was introduced through sampling was mitigated. A total of 8 participants were lost to follow-up at different stages throughout the research. Data from one participant was excluded from analysis. Therefore, data was analyzed for the 17 participants who completed both the trial and interview and whose data was not excluded from the findings.

The next chapter presents findings based on data collected during the quantitative and qualitative strands of the research, with deeper data analysis reserved for the following chapter.

CHAPTER FOUR: FINDINGS

Research findings are presented following the sequential quantitative-qualitative research design. That is, quantitative findings are presented first, followed by qualitative findings. Quantitative findings are based on data collected during the trial, and through the pre-interview questionnaire and interviews. Qualitative findings are based on data collected through the pre-interview questionnaire and interviews.

Quantitative Findings

Quantitative data collected as part of the trial include pre-assessment, quiz, and post-assessment scores. In addition, various Moodle logs were used to estimate participants’ time on task, calculate the number of times course activities were accessed, and the dates on which all events took place. Moodle-generated data and information provided by participants in the pre-interview questionnaire were used during the interviews to clarify, refine and reconcile times and dates estimates and calculations with the assistance of participants.
Table 3
Pre-Assessment, Quiz and Post-Assessment Scores by Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre (/13) M</th>
<th>SD</th>
<th>Quiz (/4) M</th>
<th>SD</th>
<th>Post (/12) M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control a</td>
<td>7.0</td>
<td>2.9</td>
<td>3.0</td>
<td>0.7</td>
<td>4.0</td>
<td>3.9</td>
</tr>
<tr>
<td>Treatment 1 b</td>
<td>8.6</td>
<td>2.1</td>
<td>2.6</td>
<td>1.1</td>
<td>6.0</td>
<td>2.8</td>
</tr>
<tr>
<td>Treatment 2 c</td>
<td>9.6</td>
<td>1.6</td>
<td>2.8</td>
<td>0.7</td>
<td>5.4</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Note. M= Mean. SD= Standard Deviation. Pre-assessments were graded out of 13 maximum possible points, quizzes out of 4, and post-assessments out of 12. All numbers rounded to one decimal.

a n= 5. b n= 5. c n= 7

Table 3 tabulates pre-assessment, quiz and post-assessment scores as arithmetic means and standard deviations for each of the groups. Pre- and post-assessments consisted of different questions and were graded by the researcher using different rubrics and scales. During the pre-assessment (Appendix D), participants answered questions regarding their level of knowledge of the hydrologic cycle (identified as pre-requisite knowledge) and of how floods work (the core subject matter of the course). The post-assessment included a single problem-based question designed to measure knowledge transfer or deep learning (Appendix F). The multimedia module included a computer-graded quiz consisting of four questions (Appendix E) designed to measure retention of information or rote memory learning immediately following the multimedia presentation.
Table 4

*Quantitative and Quantified Measurements of Engagement by Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Control (^a)</th>
<th>Treatment 1 (^b)</th>
<th>Treatment 2 (^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time on task</td>
<td>Minutes</td>
<td>43</td>
<td>53</td>
<td>48</td>
</tr>
<tr>
<td>Interruptions to reinforce concepts</td>
<td>Count</td>
<td>2.0</td>
<td>5.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total multimedia views</td>
<td>Count</td>
<td>1.3</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Views prior to quiz</td>
<td>Count</td>
<td>1.3</td>
<td>1.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Views after quiz, before post</td>
<td>Count</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Effort vs. credit course</td>
<td>Weighted /10</td>
<td>3.5</td>
<td>6.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Interest in topic</td>
<td>Weighted /10</td>
<td>5.3</td>
<td>6.0</td>
<td>7.6</td>
</tr>
<tr>
<td>Engagement</td>
<td>Weighted /5</td>
<td>2.6</td>
<td>4.0</td>
<td>3.9</td>
</tr>
</tbody>
</table>

*Note.* All figures are reported as arithmetic mean for the group. Time on task is reported in minutes rounded to the nearest integer. Count units are average sums of events recorded in LMS logs, reported in the pre-interview questionnaire, and confirmed with participants during the interview. Weighted units are quantified qualitative codes on a scale of 1 to 10 or 1 to 5 (engagement score), where the maximum score represents highest self-reported effort, most interest in subject matter, or highest overall level of engagement. Except for time on task, all figures are rounded to one decimal.

\(^a\) \(n=5\). \(^b\) \(n=5\). \(^c\) \(n=7\)

As seen in table 4, in addition to assessment scores, a number of other variables were quantified to measure participants’ *engagement* with the course and the multimedia module. For the purpose of this research, participant engagement is “the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education” (“Student Engagement”, 2015). Initially, data such as the number of times a participant viewed the multimedia module (as well as the reasons for doing so), or how often someone purposefully paused the multimedia (e.g., to look up a term in the dictionary), or was interrupted by someone
else while completing it, were recorded in an attempt to contextualize findings in relation to attention and memory. However, as qualitative coding progressed and learner motivation emerged as a major theme, these same variables became measurements of learner engagement in addition to other qualitative variables outlined in the qualitative findings section.

Table 5

*Elapsed Time Between Research Milestones*

<table>
<thead>
<tr>
<th>Group</th>
<th>Multimedia – Post</th>
<th>Post – Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.6</td>
<td>7.6</td>
</tr>
<tr>
<td>Treatment 1 b</td>
<td>0.4</td>
<td>9.6</td>
</tr>
<tr>
<td>Treatment 2 c</td>
<td>1.9</td>
<td>2.3</td>
</tr>
</tbody>
</table>

*Note.* Average elapsed time by group, in days, rounded to one decimal.

\(^{a} n=5\).  \(^{b} n=5\).  \(^{c} n=7\).

As shown in Table 5, the dates on which key events took place were also recorded due to the concern that letting too much time go by between events could lead to memory loss. Concerns in this regard were twofold. On the one hand, participants who let too much time go by between completing the multimedia module and the post-assessment could have negatively affected their performance on the latter, compared to participants who completed both the multimedia module and post-assessment one after the other on the same day. On the other hand, participants who let too much time pass between completing the post-assessment and interviewing could forget details about their experience completing the multimedia module. It is important to note that Treatment 2 participants were instructed to complete the post-assessment the day after completing the multimedia module, and to review the multimedia module right before completing the post-assessment on the second day.
Qualitative Findings

A total of 128 codes were applied to interview transcript excerpts during the first coding cycle and later reduced to 66 during the second and final coding cycle. 47 codes were derived from the theoretical framework and prepopulated in the qualitative analysis application prior to beginning the first of the two coding cycles. The rest of codes were created as coding progressed, using a combination of grammatical, elemental, and exploratory coding methods, namely magnitude, structural, emotion, and in vivo coding (Saldaña, 2009). Altogether, nine themes were identified by the end of the second coding cycle: (a) context, (b) motivation, (c) multimedia, (d) physical activity, (e) pre-post, (f) sentiment, (g) sleep, (h) study design, and (i) time on task. Findings for each of these themes are discussed separately.

Context theme. Participants were asked to report on the circumstances under which they completed the course. Summarized in Figure 5, most participants completed the How Floods Work under typical time and space conditions, that is, in a typical physical environment in which they would normally study and on a day and time of day they would normally do so. 82% of participants (n= 14) reported completing the Moodle course in a typical space and 76% (n= 13) said they completed the course at a typical time of the day and a typical day of the week. Four different participants spoke about their own children as a determinant factor on the choice of place and time to study. One participant spoke about issues at work in relation to her immigration status and connected those issues to her poor performance on the post-assessment due to an overall lack of motivation, and another mentioned having heard that learning is boosted when the brain is rested and therefore completed How Floods Work early in the morning. Of the participants who reported having completed the course under atypical circumstances, two mentioned the short length of the course as a factor for choosing to complete it during a lunch
break at work rather than at home where they would normally study for more intensive programmes.

**Motivation theme.** Not considered initially in the research design or included in the literature review, motivation first emerged as a theme during interviews. Multiple codes and subcodes were applied to explore the theme thoroughly. First, motivation was divided into two codes, motivation to enroll in the research and motivation to complete it. The former was labeled **motivation at outset** and the latter was called **engagement.** During the second coding cycle, engagement was quantified for each participant by considering factors such as time spent on task; perceived and self-reported effort; whether the participant had consulted external sources to make sense of course material; taken notes to aid memory; the number of times they viewed the
Engagement was then quantified on a scale of 1 to 5, where 1 = very low (i.e., minimal evidence of effort), 2 = low (i.e., less effort than average), 3 = average (i.e., did as expected for the most part), 4 = high (i.e., engaged with course content beyond expectations), and 5 = very high (i.e., consulted websites and people in addition to completing all course material).

In relation to motivation at the outset of the research, 82% of participants (n = 14) acknowledged being motivated to participate because of their relationship with the researcher, and 65% of participants (n = 11) indicated a general interest in the advancement of knowledge as a motivator to enroll in the research.

During the interview, participants were asked about how much effort they had put into the course compared to the effort they would have put into completing a course with implications on their personal, academic or professional life. The example used was a for-credit course at university or college, and if needed, other examples such as continuing education or at-work training were used. The ratings assigned to participants’ responses were reported in Table 4 as groups’ averages.

Interest in topic, another indicator of motivation, was weighted on a scale of 1 to 10. Averaged results for interest are reported in Table 4.
Altogether, 16 codes were applied within the theme of motivation, including motivation itself as the parent code. Under engagement, 11 codes were applied. Figure 6 shows motivation code and sub-code frequency of applications for 13 of the 16 codes (3 levels of depth in the hierarchy). The missing codes (*consulted people, consulted websites, and looked up terms*) are all under the category of additional research (abbreviated as “additional” in the co-occurrence table).

**Multimedia theme.** The largest theme in the research by code count and number of code applications, multimedia is the family of codes under which participants’ experience completing the multimedia module was coded. Figure 7 shows 14 out of the 17 codes themed under
motivation (three levels deep). Multimedia findings highlight the complexities of conducting an experiment with a self-paced multimedia course in a realistic setting. During the interview participants were asked how attentive they had been to the multimedia presentation. Using phrases such as “one hundred percent attention” and “full undivided attention”, 76% of participants (n= 13) reported having completed the multimedia module uninterrupted. However, since various participants completed the multimedia module more than once (particularly those in the Treatment 2 group who were explicitly asked to review the module before attempting the post-assessment), 41% of participants (n= 7) also reported interruptions. For example, P029
reported having interrupted the presentation multiple times to research the topic on day 1, but completing it uninterrupted on day 2 before answering the post-assessment question. Participants were also asked whether they had watched the multimedia images at the same as listening to the narration. To further clarify participants’ interaction with the presentation, probing questions included whether they had at any time turned their head away from the screen to concentrate on the audio track or turned off the volume to focus on the images. Of the fourteen participants who recalled details of their interaction, only one participant inadvertently completed the multimedia presentation with the volume off, thinking there was no audio (coded as dual channel: visual only). Findings for the remaining thirteen participants were coded as dual channel: both. Under the memory code and subcodes the number of multimedia module views were quantified (see Table 4) as well as memories triggered by the course in relation to course content. Though some participants (n= 3) had personally experienced major floods (e.g., Alberta floods, Katrina) no one of reported traumatic associations between course content and their personal experience. The quiz code was applied anytime this particular assessment, included at the end of the multimedia module, was brought up during the interview. The multimedia module also included a full script of the narration, accessible through a tab on the multimedia player. Only one participant reported having noticed the script only to ignore it in order to focus on the presentation.

Three of the four missing codes in Figure 7 (interruptions to reinforce concepts, views prior to quiz, and views after quiz and before post-assessment) are reported in Table 4, under quantitative findings: all three were quantified for the purpose of measuring engagement. The other missing code (external interruptions) was applied when participants said others had interrupted them (e.g., children or co-workers) as opposed to pausing the presentation themselves.
**Physical activity and sleep themes.** Data on physical activity and sleep was first collected through the pre-interview online questionnaire and further probed during the interview. Figure 8 summarizes findings for both themes. Findings revealed Treatment 2 participants were non-compliant with research instructions, presented as suggestions to sleep well overnight, nap during the day, and exercise before completing the boast-assessment in order to boost cognitive performance. 88% of participants reported typical physical activity during completion of the course. Of the two participants who reported unusual physical activity, one from the Treatment 1 group reported having had alcoholic drinks with friends prior to completing the post-assessment, resulting in a “big headache” as a consequence of the alcohol consumption compounded by the mental effort required in answering the problem-based question in the post-assessment. The only

![Figure 8. Code co-occurrence table of physical activity and sleep themes.](image)
other participant who reported unusual physical activity did not exercise the morning she completed the post-assessment whereas she routinely exercises; she was part of the Treatment 2 group.

As part of the probe into sleep data, participants were asked in pre-interview questions whether they routinely take naps and whether they took a nap while completing the research. 94% of participants (n= 16) reported not taking naps routinely and 100% said they did not take a nap during the course (not shown in Figure 8). Upon further probing during interviews, one participant was not sure whether an early morning sleep, shortly after waking up, constituted a nap. The nap code was used to capture such unusual scenarios as well as participants’ perceptions of naps. Altogether, 82% of participants (n= 14) reported typical a sleep pattern at the time of completing the course (the night before or the night or nights in between views). However, the typicality of sleep does not imply healthy sleep patterns: When asked about the number of hours of sleep needed per day to feel rested and the number of hours participants slept during the research, 41% of participants (n= 7) reported getting less hours of sleep than needed to feel rested. Upon further probing during the interview, 12% of participants (n= 2) spoke of sleep patterns that appear to be signs of chronic sleep deprivation, with one participant reporting having been diagnosed with insomnia. 18% of participants (n= 3) said they were rested while completing the course.

Pre-post, study design, and sentiment themes. Compared to other themes, these themes are characterized by a higher level of co-occurrence among themselves as well as with other themes since they were meant to assist in the contextualization of findings by associating, for example, sentiments to particular course components, or recording participants comments about the study itself or the course. Therefore, Figure 9 summarizes findings for these three themes
together. The pre-post theme is a family of codes designed to capture participants’ experience completing the pre- and post-assessments, their opinions and judgments, and frequently, their feelings too (co-coded with the sentiment code). The study design theme, which included participants’ comments and perceptions about the overall design and purpose of the research, was applied 29 times to interview excerpts from 100% of participants (n= 17). 57 comments from 100% of participants (n= 17) on the design of multimedia module or the layout of the course in Moodle were coded as course design. For example, in one case, a participant suggested for better coding and improved compatibility with mobile devices. Coded as barriers, 12% of participants (n= 2) reported technical difficulties while trying to upload an image on the post-assessment, and expressed frustration as a result.

Figure 9. Code co-occurrence table of pre-post, sentiment and study design themes.
During the first coding cycle participants’ emotions were coded under the category of emotional state. In every instance, emotion codes were co-coded in context. For example, when a participant experienced frustration with the multimedia quiz, the frustrated code was applied together with the quiz code (from the multimedia codes family), and when participants expressed disappointment at their own performance on the quiz (the only score known to participants), the emotion and quiz were co-coded accordingly. Thus, during the first coding cycle, emotions were coded in-vivo to capture feelings in the participants’ own words. However, to facilitate analysis, all emotion codes were quantified during the second coding cycle, merged under the sentiment code and assigned a score from 1 to 5, where 1 = negative sentiment (e.g., P027: “annoyed”), 2 = somewhat negative sentiment (e.g., P023: “disappointed”), 3 = neutral sentiment (e.g., P005: “no emotional reactions”), 4 = somewhat positive sentiment (e.g., P004: “satisfied”), and 5 = positive sentiment (e.g., P022: “amazing”). Figure 10 shows the full range of emotions coded in vivo by the end of the first coding cycle.

Figure 10. Code pack word cloud showing first coding cycle emotions before being quantified as a sentiment score.
**Time on task theme.** As shown in Table 6, these codes were used to quantify the amount of time participants purposefully invested in completing the course in and out of the learning management system, including the number of days they accessed the course and the number of sittings over which they completed the course. Time on task, reported also in Table 4, is the total sum of time (in minutes) participants invested on the course.

Table 6
*Time on Task in Days and Number of Sittings*

<table>
<thead>
<tr>
<th></th>
<th>Control (^a)</th>
<th>Treatment 1 (^b)</th>
<th>Treatment 2 (^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One day, one sitting</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Two days, two sittings</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Two days, multiple sittings</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>More than two days</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total time on task (in minutes)</strong></td>
<td><strong>43</strong></td>
<td><strong>53</strong></td>
<td><strong>48</strong></td>
</tr>
</tbody>
</table>

*Note.* Figures represent number of participants per group. Total time on task is reported (in minutes) as the mean for the group.

\(^a\) \(n=5\). \(^b\) \(n=5\). \(^c\) \(n=7\).

Three techniques were used to calculate time on task: (a) Moodle learning management system (LMS) reports, (b) pre-interview questionnaire, and (c) time confirmation check done during the interview to ensure recorded time matched total minutes participants invested in the course, including time spent outside of the LMS. Therefore, time on task data represents the total time spent on online tasks such as reading the syllabus, completing the pre-assessment, multimedia module, post-assessment plus the total time invested in the course offline consulting with others for their expertise, searching the internet for additional information on course subject matter, and preparing the post-assessment submission.
Summary

Quantitative findings included assessments as well as quantified qualitative codes such as engagement. Qualitative findings were the result of two cycles of coding, themed under the banners of (a) context, (b) motivation, (c) multimedia, (d) physical activity, (e) pre-post, (f) sentiment, (g) sleep, (h) study design, and (i) time on task.

The next chapter is concerned with the analysis of quantitative and qualitative findings and the relations among them.

CHAPTER FIVE: ANALYSIS

The first of the study’s hypotheses expected treatment 1 participants to perform better than control in knowledge-transfer assessments due to the improved multimedia presentation they received. The second hypothesis expected treatment 2 participants to perform even better than control due to the additional directions they were given to boost cognitive processing through sleep and exercise. In addition, treatment 2 participants received the same improved version of the multimedia presentation as treatment 1, were told to complete the study in two phases over two different days, and view the multimedia presentation twice (once before post-assessment) to improve memory retention.

Compared to control, both treatment groups performed better on the post-assessment, on average, than control. The first comparison (treatment 1 vs. control) yielded a medium effect size of $d=0.58$ and the second (treatment 2 vs. control) a small effect size of 0.353.

However, treatment 2 participants did not comply with instructions to exercise and take a nap before the post-assessment, viewed the multimedia presentation 1.9 times on average, and 43% of them (3 out of 7) completed the course in a single sitting in spite of being asked to
complete it in two sittings over two separate days. The overall engagement score for treatment 2 was 3.9 (out of 5).

Treatment 1 participants, by contrast, viewed the multimedia presentation 2.3 times on average, and 40% of them (2 out of 5) completed the course over two sittings in two separate days, even though not explicitly to do so. The overall engagement score for treatment 1 was 4.0 (out of 5).

The experience of participants in both treatment groups was therefore very similar for analysis purposes.

Control group participants viewed the multimedia presentation 1.3 times on average, and 40% of them (2 out of 5) completed the course over two separate days in two or more sittings, even though not asked to do so. The overall engagement score for control was 2.6 (out of 5).

**Analysis Themes**

Following a similar organization as the methods and findings chapters, quantitative findings are analyzed first using statistical methods; qualitative findings are analyzed next by grouping codes into themes; and finally, quantitative computations and selected quantified qualitative themes are triangulated using statistical methods. The analysis of findings is organized by the major themes that dictated the study as well as those that emerged during the analysis itself. Thus the analysis of findings is split into six distinct sections. First, the participants’ knowledge of the subject matter prior to and after completing the unit of instruction will be analyzed in the pre-post analysis section. Second, the extent to which participants’ intrinsic motivation influenced study outcomes is analyzed through the lens of theories of motivation. Third, the analysis focuses on the participants’ experience completing the multimedia module with particular emphasis on how attention and memory variables may have
affected study findings. Fourth, participants’ sleep and exercise routines while completing the study are analyzed to assist in drawing conclusions on whether they influenced study outcomes. Fifth, the context in which participants completed the unit of instruction is analyzed by probing into the temporal-physical conditions under which they chose to engage with course content. Finally, to bring together significant research findings obtained through mixed quantitative and qualitative data collection methods, a mixed methods analysis section is dedicated to the triangulation of study themes identified to have influenced course outcomes.

Pre-Post Analysis

Data collected during the study’s pre- and post-assessments were measured using two different rubrics (see Appendices D and F for the rubrics used in pre- and post-assessments). Therefore, a statistical method that contrasts results between two different scales was needed. Cohen’s d, a scale-free statistical calculation method was chosen to analyze effect sizes in standardized terms (Ellis, 2010). Cohen’s d was calculated for each of the two study comparisons (treatment 1 vs. control and treatment 2 vs. control) by subtracting the means of the two groups being compared and dividing the result by the pooled standard deviation. The resulting effect size represents the difference between the groups in terms of their common standard deviation. However, Cohen’s d, as described, is best used when sample sizes are identical (Lenhard & Lenhard, 2015). Hedges’g, an adaptation of Cohen’s d that corrects for different sample sizes (Lenhard & Lenhard, 2015) was computed, to provide a more accurate representation of the findings in the comparison where samples sizes were different (treatment 2 vs. control). However, the difference between Hedges’g and Cohen’s d results was 0.002, insignificant enough to warrant reporting effect sizes using Cohen’s d, a popular (Ellis, 2010) and therefore more readily recognizable measure of effect size. Where control and treatment group have the
same sample size (treatment 1 vs. control), Hedges’s $g$ is identical to Cohen’s $d$ (see Appendix I for the complete dataset used to calculate the effect size). According to Cohen (1988, p. 40), a general guideline to interpret the practical significance of effect sizes is that a coefficient under 0.2 is insignificant, small over 0.2, medium over 0.5, and large over 0.8.

Table 7 shows effect sizes of pre- and post-assessment scores for the two study comparisons, treatment 1 vs. control (trial 1) and treatment 2 vs. control (trial 2). It is noteworthy that participants in both treatment groups had prior knowledge of the subject higher enough than control participants to register as medium and large effect sizes respectively. Differences among groups at the outset of the trial are preserved at the end, albeit with less pronounced effect sizes in both comparisons.

<table>
<thead>
<tr>
<th>Trials</th>
<th>Pre $d_{\text{Cohen}}$</th>
<th>Post $d_{\text{Cohen}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1*</td>
<td>0.629</td>
<td>0.583</td>
</tr>
<tr>
<td>Trial 2**</td>
<td>1.153</td>
<td>0.353</td>
</tr>
</tbody>
</table>

*Note. Trial 1= treatment 1 vs. control; Trial 2= treatment 2 vs. control.

* $n=17$
** $p > .05$.

Research hypotheses dictated that research findings be analyzed in terms of differences between research groups. However, to better understand the relationship between pre- and post-assessment performance, it was necessary to shift analysis from the trial group to the individual participant level.
Figure 11 is a visualization of the statistically significant positive correlation between pre- and post-assessment scores (r = 0.639; p < 0.1; see Table 8). However, having a higher prior knowledge only makes learning integration easier but does not automatically result in better post-assessment results. No matter how well designed a multimedia message may be, if the participant is not motivated to engage with it little learning can occur.

**Analysis of Motivation**

Early on during the interviews, it became evident that participants had engaged at different levels of intensity with course content: some had chosen to do the minimum of work necessary to complete the study, whereas others had gone beyond expectations to understand course materials at a deeper level and demonstrate their knowledge on the assessments. Initially just a code to capture participants’ drive to join the study, motivation grew into a significant qualitative theme, second only to the multimedia theme.
Figure 12 shows a relationship between engagement, sentiment and time on task that mimics the pattern observed in pre- and post-assessment scores. Is there a correlation participants’ motivation with assessment scores, and if so, how strong is it?

Could Maslow’s (1943) theory of motivation help explain, at least in part, the individual differences found in the level of engagement between participants in the study? For example, P026 is a foreign-trained graduate-level professional, a new immigrant overwhelmed with adjusting to life in the new country while dealing with the added stress of discrimination at work. Usually willing to donate time for research, P026 thought about withdrawing from the study, thinking it was not the best time in her life to participate in research and stated she could have

![Figure 12. Bubble plot showing engagement, sentiment, and time on task weighted codes by group. Time on task (horizontal axis) is the average time (in minutes) participants spent completing the course in and out of the learning management system. Sentiment (vertical axis) is the average of weighted sentiment codes on a scale of 1 to 5 (1= negative; 5= positive). Engagement (bubble size) is a thematic code weighted on a scale of 1 to 5 (1=low; 5= high).](image-url)
done a lot better on the post-assessment had it been a different time in her life. How well were P026’s basic needs met? In particular, were needs of safety and esteem sufficiently met in order for her to attain the next level of Maslow’s hierarchy and therefore be fully motivated to participate in the study without the distraction of basic needs requiring attention? Had basic needs been met, would the participant’s study results have shown better performance?

Motivation in this study was measured from a behaviourist perspective. That is, without making any inferences as to internal mechanisms that may have affected the participants’ choices, observable and measurable behaviours, such as time on task, the number of times a participant viewed the multimedia module, or the amount of external research conducted to better understand course materials were quantified and given an engagement score. According to the National Survey of Student Engagement (NSSE; n= 473,633 students), “Students who substantially exceeded their grade expectations spent more time studying compared to those who underperformed their expectations” (NSSE, 2014, p. 20; see also Carini, Kuh, & Klein, 2006).

Research participants were also queried as to the relative effort they put into the course compared, hypothetically, to the effort they would have put into completing a course for credit or with direct implications on their job (e.g., a university or college credit course as part of a program of studies or workplace training). Though an individual’s perception of their own performance in relation to a hypothetical scenario is not an objective measure, when participants’ answers were analyzed in conjunction with the rest of data, a fuller profile of the participants’ engagement in the course emerged. Time on task, additional research, and perception of own effort, were considered when weighing engagement together with self-perceived effort, additional research (consulting people, websites, and looking up terms), curiosity, taking notes,
passionate views on subject matter and other codes that make up the engagement and motivation code family.

**Analysis of Multimedia Learning, Attention and Memory**

During the interview all participants were asked to relay with great detail their experience on completing the multimedia module. Unsurprisingly, the pattern seen in Figure 10, where engagement, time on task, and sentiment are graphed together, is nearly identical when either time on task or sentiment are replaced with the number of multimedia views or any of the other measured behavioural manifestations of motivation. Once again, the data suggest that higher levels of engagement with course content results in better performance. On average, the multimedia module was viewed 1.3 times by control participants, 2.3 times by participants in the treatment 1 group, and 1.9 in treatment 2. It is important to note that only treatment 2 participants were encouraged to review the multimedia module twice, but no restrictions were set on how many times a participant, regardless of group, could view the module.

Participants were also asked how attentive they were to the multimedia module with questions such as whether they were able to give the presentation their undivided attention. They were asked to report on the frequency and nature of interruptions. Nearly 30% of participants (n=5) reported external interruptions by children, family members, or others. Interestingly, external interruptions are positively correlated with higher group performance, which suggests participants coped with the divided attention with no measurable detriment to their performance.

From the perspective of Paivio’s (1991) dual channel theory, 94% of participants experienced the multimedia module in a similar manner. Except for one participant (P023, treatment 2 group) who watched the multimedia module without audio on a mobile device, all other participants listened to the audio track at the same time as they viewed images on the
screen. In terms of the different design of multimedia modules for the control and treatment groups, control participants would have been exposed to more on-screen text than treatment groups participants, putting control participants at a disadvantage: spoken words compete with written words for cognitive processing (Mayer, 2009). The present trial, however, was conducted in a non-controlled environment, which means participants could use any number of tactics, such as viewing the multimedia module more than once and taking notes to aid memory, in order to compensate for multimedia design flaws or technical issues. For example, P023 heard no audio and did not know there was an audio track compensated by watching the multimedia module multiple times, stating during the interview, “So, the images obviously spoke for themselves; they worked even without the audio” (personal communication, March 10, 2015).

**Sleep and Exercise Analysis**

Only participants in the treatment 2 group were encouraged to sleep and perform physical activity as part of the study. However, no participant followed the suggested directions. As a result all participants in all groups reported typical exercise and sleep routines, and no conclusions can be drawn from participants’ physical activity and sleep. When asked about taking naps, no participant reported taking them during the study or routinely. When asked about taking naps at work, P017 echoed other participants’ thoughts: “Naps are frowned upon” (personal communication, February 24, 2015).

**Temporal-Physical Context Analysis**

One of the objectives of the study was to devise methods to conduct neuroeducation research in a realistic, un-controlled environment without the convenience a lab offers the researcher. After all, all theories that informed the study had already been extensively lab-tested. Participants were consequently asked to describe the circumstances under which they completed
the unit of instruction. 82% of participants (n= 14) reported completing the Moodle course in a
typical space, that is, where they would normally study, be it their home, office, a café or
elsewhere, as probed and clarified during the interview. 76% (n= 13) said they completed the
course at a typical time of the day. When adjusting for the length of the course, the typicality of
the context may be even greater: For example, P007 normally goes to a café to study, but since
the course was short, decided to complete it at home after the children went to sleep.

Triangulation of Findings

Consistent with Creswell and Plano Clark’s (2011) recommended approach for analysis
of sequential mixed methods data, qualitative and quantitative findings were triangulated
following independent analysis of the two strands. To measure the strength of linear relationships
between students’ engagement, pre-assessment, quiz, and post-assessment scores, Pearson
product-moment correlation coefficients—“the most common index of the relationship between
two variables” (Lane & Guerra, 2015)—were computed for all six possible combinations of the
four variables.

As shown in Table 8, calculations of correlation show two statistically significant
positive correlations. The strongest correlation is between participants’ pre- and post-assessment
scores (r = 0.639, t = 3.215, p < 0.01), and the second strongest is between engagement and post-
assessment scores (r = 0.533, t = 2.441, p < 0.05). These results mean that the higher a
participant’s knowledge of floods was at the outset of the trial, the higher the odds the participant
performed better in the transfer-of-knowledge assessment at the end of the trial. They also
indicate that the more a participant engaged with course content the higher the odds she or he
performed better in the post-assessment.
Table 8

Correlations Among Engagement and Assessments Scores

<table>
<thead>
<tr>
<th></th>
<th>Engagement</th>
<th>Pre Score</th>
<th>Quiz</th>
<th>Post Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engagement</strong></td>
<td>Pearson Correlation Coefficient r</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R Standard Error</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H₀ (5%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre Score</strong></td>
<td>Pearson Correlation Coefficient r</td>
<td>0.445</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R Standard Error</td>
<td>0.053</td>
<td>0.335</td>
<td></td>
</tr>
<tr>
<td></td>
<td>t</td>
<td>1.925</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>0.073</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H₀ (5%)</td>
<td>accepted</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Quiz</strong></td>
<td>Pearson Correlation Coefficient r</td>
<td>0.277</td>
<td>0.335</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>R Standard Error</td>
<td>0.062</td>
<td>0.059</td>
<td></td>
</tr>
<tr>
<td></td>
<td>t</td>
<td>1.116</td>
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<td></td>
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<tr>
<td></td>
<td>p-value</td>
<td>0.282</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>H₀ (5%)</td>
<td>accepted</td>
<td></td>
<td>accepted</td>
</tr>
<tr>
<td><strong>Post Score</strong></td>
<td>Pearson Correlation Coefficient r</td>
<td>0.533</td>
<td>0.639</td>
<td>0.289</td>
</tr>
<tr>
<td></td>
<td>R Standard Error</td>
<td>0.048</td>
<td>0.039</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td>t</td>
<td>2.441</td>
<td>3.215</td>
<td>1.170</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>0.028</td>
<td>0.006</td>
<td>0.260</td>
</tr>
<tr>
<td></td>
<td>H₀ (5%)</td>
<td>rejected</td>
<td>rejected</td>
<td>accepted</td>
</tr>
</tbody>
</table>

*Note.* n = 17.

The rest of correlations reported in Table 8, though not statistically significant, show, nevertheless an overall positive tendency, suggesting a positive relationship amongst motivation (engagement) and measurements of prior knowledge (pre-assessment), memory retention (quiz), and transfer of knowledge (post-assessment).

Figure 13 plots the relationships between engagement and the three assessment scores, showing positive trend lines for all comparisons, albeit a stronger trend line for the engagement and post-assessment relation than the engagement and pre-assessment relation or the engagement and quiz relations.
Quantitative and qualitative findings were first analyzed independently, organized by themes, and then triangulated. Mixed methods analyses revealed statistically significant correlations between engagement (the behavioural manifestation of motivation) and pre-assessment (prior knowledge) scores as well as between engagement and post-assessment (transfer of knowledge) performance.

The final chapter discusses conclusions drawn from the analysis of findings, research limitations, research implications, and opportunities for future research.

**CHAPTER SIX: CONCLUSIONS**

Though differences in post-assessment results may suggest course design positively influenced learning on a small to medium scale, an alternative explanation emerged during the mixed statistical and qualitative analysis of findings. Individual *motivation* as measured by

![Figure 13. Scatter plot with trend lines showing relationships between engagement and the three assessments administered during the trial, pre-assessment, quiz, and post-assessment.](image)
engagement and *prior knowledge* above all else may best explain the higher performance of treatment groups compared to control.

Are the null hypotheses accepted or rejected? They are accepted because of the strong likelihood that post-assessment outcomes are the product of chance in the random allocation of participants to trial groups rather than the result of differences in the design of the multimedia presentation. The significance of study results lies less in average differences between groups than measurements of correlation at the individual level.

To what extent did the design of the multimedia presentation affect learning outcomes? After all, treatment groups did perform better than control in post-assessment tests. Did the multimedia presentation not have a positive influence on study outcomes? Answers to these questions are less clear. Multiple principles of multimedia learning design—in particular those meant to reduce extraneous processing—were applied to ensure that the multimedia presentation received by the treatment groups was better designed than the version received by control group participants. All else ignored, it would appear the better design worked as expected. However, this was a complex study with many variables, conducted in a non-controlled environment, where participants had many more choices than the average participant does in a lab-based experiment. For example, participants were free to view the presentation multiple times and many used this recourse to their advantage. They were also free to do additional research prior to completing the post-assessment and several did so. It is therefore possible that multimedia design played a role in study outcomes, but as Mayer (2014a, p. 65) puts it succinctly, “In addition to being able to engage in appropriate cognitive processing during multimedia learning, successful learners must want to engage in appropriate cognitive processing (i.e., motivation) and know how to manage their cognitive processing (i.e., metacognition).” In other words, if a student is
not motivated to engage with the multimedia presentation in the first place, the quality of the design matters little.

This thought, namely that participants had put in different levels of effort in completing *How Floods Work*, greatly influenced the analysis of findings.

**Research Limitations**

There were many limitations to this research. Among the most significant limitations is the non-generalizability of findings. The present research is underpowered, meaning the statistical power levels are below the recommended level of 0.8 (Ellis, 2010; calculated with G*Power 3.1). Given an effect size of $d=0.58$ for the treatment 1 vs. control comparison, and sample sizes of $n=5$ and $n=5$ respectively, the two-tailed test of achieved statistical power for trial 1 is a very low 0.13 at a 95% confidence interval. Assuming the same means and standard deviations, a total sample size of 96 participants (48 in each group) would have been needed to achieve a 0.8 statistical power at the 95% confidence interval and report the findings as generalizable. At 0.08, the statistical power for trial 2 is even lower due to the higher pooled standard deviation and lower difference between the groups’ means. 254 participants (127 in each group) would have been needed in the comparison between treatment 2 and control for the statistical to reach 0.08 at a 95% confidence interval. In order to minimize the expected impact of low statistical power, the research was designed using a mix of quantitative and qualitative methods so that participants could effectively assist in the interpretation of results. For this reason, only data from participants who completed both the trial and interview was analyzed. A small compromise was made in terms of sample size for the purpose of maximizing analysis, the rationale being that if a participant who completed the course was not available to assist in the
interpretation of her or his own results, statistical analysis alone could compromise the integrity of the analysis.

Another significant limitation has much to do with the ongoing debate on the applications of mind, brain and education theories to the design of instruction. In the absence of proven neuroeducation instructional design models, designing a unit instruction that effectively applies principles and theories of neuroscience to instructional design posed one of the biggest challenges of the research. Often referred to as brain-based learning, the idea that neuroscience can, at the present time, inform teaching practices is very controversial and the source of extensive debate as exposed in the literature review. In the search for theories with applications for the design of instruction, Mayer’s (1999) cognitive theory of multimedia learning was chosen for this research because of its extensive empirical base. The theory’s principles informed the instructional design of the multimedia module used in the trial.

The fact How Floods Work was part of a research as opposed to a high stakes course (university or college credit course, or work training) appears to have been a study limitation. As seen in Table 4, when participants were asked to rate the level of effort they put into the course, the median was low to medium. On a scale of 1 to 10, where 1 equals lowest effort and 10 highest, control participants’ effort in relation to a for-credit course was rated on average 3.5, 6.2 for treatment 1, and 4.8 for treatment 2. Would participants have put more effort in completing the course and answering the post-assessment question had the course had a more pragmatic significance to their lives? Of all participants interviewed only P029 said resolutely she had treated the course like a credit course. P029 was the only participant to score 100% on the post-assessment test, scored 88% on the pre-assessment, and 75% on the quiz. P029 consulted someone else about floods, searched websites, and overall engaged with course at a seemingly
deeper level than anyone else in the research. Other participants sounded less confident when saying they had put a great effort and their behaviour showed otherwise. The majority admitted they would have taken notes, consulted external sources, or overall put more effort had the course had more serious implications to their lives. Though it is impossible to know for certain whether participants would have performed better had the course had implications to their lives, research findings support the view that “adults are motivated to learn after they experience a need in their life situation” (Knowles, Holton III, & Swanson, 2012, p. 299).

Interview questions were designed based on the theoretical framework and literature review but were not pilot-tested prior to being administered. This oversight may have compromised the validity of the questionnaire. It is recommended that future studies researching similar issues and using similar methods validate semi-structured questionnaires. For example, Creswell and Miller (2000) propose a validation model in which researchers collaborate with research participants to help write the questions.

**Research Implications**

Conducting a randomized trial in a realistic setting proved challenging. Without the convenience of a controlled environment, participants’ free will became a greater determinant factor of research outcomes. Treatment 2 participants did not exercise or sleep as directed, and all participants engaged with course content with various levels of intensity. Without the ability to observe, supervise and support participants while completing a multimedia module, there was a heavy reliance on the participants’ account of their experience, and when interviews were delayed, and took place days after the course had been completed, these limitations became compounded with the possibility of memory loss.
Nevertheless, the utility of mixed research methods for the study of online learning was demonstrated. Relying on quantitative analysis alone to make sense of results could have been misleading. The qualitative strand was instrumental in relating participants’ behaviour to evidence of learning outcomes. One of the objectives of this research was to devise methods to conduct research in a realistic setting, where heterogeneity is seldom the norm. But that is not to say methods cannot be improved upon.

Future similar studies could try to control for prior knowledge by ensuring that differences between groups are minimal at the outset of the research. For example, participants could be randomized after their baseline knowledge has been established so each of the groups is allocated a distribution that is more representative of the entire sample (and population). This means all participants would be enrolled in the trial at the same time. To minimize the effect of memory loss on reporting their experience, participants could be prompted to log their experience immediately after completing research milestones. For example, participants would be asked to report on the number of times they viewed individual multimedia module screens, whether they listened to the audio at the same time as viewing the images, and so on, by filling a short survey immediately following the multimedia module. In regards to sleep and exercise, a new method to entice participants to follow directions will be needed. In spite of being provided the rationale for such directions, participants disregarded the instructions, with one calling them “more appropriate for a Yoga course” than a unit dealing with “scientific” facts.

**Future Directions**

Research findings support Mayer’s (2014a, 2014b) call for more research on how learners can be motivated to learn more deeply through multimedia design. Several multimedia learning principles, such as those based on social cues (Mayer, 2014c), have yielded positive
results in fostering generative processing, that is, motivating learners to utilize more of their available cognitive processing capacity to select incoming input (images and words), form coherent verbal and pictorial models and integrate them more effectively with prior knowledge.

It is tempting to infer that higher prior knowledge always results in deeper learning when receiving a multimedia message. However, the multimedia learning expertise reversal principle predicts that, often, “design principles that are effective for novice learners may not be effective or even hinder learning for more knowledgeable learners” (Kalyuga, 2014). Similarly, boundary conditions for design principles such as coherence, segmenting, pre-training, and the multimedia principle, predict learners with low prior knowledge are more likely to benefit from multimedia messages than high-knowledge learner when these principles are applied (Mayer, 2009).

According to Kalyuga (2014), “an essential future research direction is that of identifying instructional designs and procedures that are optimal for different levels of learner expertise” (p. 592). “In conclusion,” Kalyuga continues, “adaptive multimedia systems that tailor instructional methods to levels of learner expertise have the best potential for optimizing cognitive load in multimedia learning.”

18 trends, challenges, and developments in the adoption of educational technology for higher education were analyzed in the 2015 edition of the NMC Horizon Report for higher education. Among topics analyzed, personalizing learning was identified as a challenge impeding the adoption of technology in higher education, a well-defined challenge for which solutions are elusive (Johnson, Adams Becker, Estrada, & Freeman, 2015). In search for solutions to this challenge, instructional design that draws from multimedia learning theories holds significant potential for the personalization of instruction through technology. Educators
and policy-makers would benefit from considering learner-centred—rather than technology-centred—multimedia designs consistent with the ways the human brain and mind work.
Glossary

*Cognitive capacity:* The amount of cognitive processing supported by memory at any one time (Mayer & Fiorella, 2014).

*Cognitive theory of multimedia learning:* “A theory of how people learn from words and pictures, based on the idea that people possess separate channels for processing verbal and visual material (dual-channel assumption), each channel can process only a small amount of material at a time (limited-capacity assumption), and meaningful learning involves engaging in appropriate cognitive processing during learning (active processing assumption)” (Mayer, 2014a, p. 67).

*Engagement:* For the purpose of this research, participant engagement is synonymous with *student engagement* as defined in the Glossary of Education Reform: “In education, student engagement refers to the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education” (“Student Engagement”, 2015).

*Essential processing:* Cognitive processing—such as selecting, organizing and integrating relevant words and images—required to understand essential instructional material (Mayer & Fiorella, 2014, p. 309).

*Extraneous processing:* “Cognitive processing that does not support the instructional goal and may occur when an instructional message contains too much detail, embellishment, or gratuitous information or when the layout of the material requires frequent switching of attention” (Mayer & Fiorella, 2014, p. 309).
Generative processing: “Cognitive processing aimed at making sense of the material and includes organizing the incoming material into coherent structures and integrating these structures with each other and with prior knowledge” (Mayer, 2009, p. 221).

Interpretivism: In the sense used in this paper, interpretivism is the idea that, ontologically, reality is defined by individuals’ interpretation of the world; epistemologically, the goal of research is to comprehend structures of meaning as constructed by individuals; and methodologically, the assumed interdependence between researcher and research participant call for qualitative inductive techniques that facilitate the emergence of knowledge through bidirectional, empathic dialogue (“Paradigms of Social Research”, 2003).

Learning Management System (LMS): “Learning management systems (LMS) integrate interactive learning environments and administration and facilitate customized online instructional materials. An LMS is a web-based software application using a database on which various types of information are stored” (Ifenthaler, 2012).

Moodle: Moodle is the open-source Learning Management System used to design, deploy, and manage How Floods Work, the course designed for the research.

Motivation: “The process of starting, directing, and maintaining physical and psychological activities; includes mechanisms involved in preferences for one activity over another and the vigor and persistence of responses” (“Motivation”, 2002).

Multimedia: “Combinations of visual representation and verbal information. Visual representations can take many forms, including photos, illustrations, animations, simulations and video. Verbal information can take the form of text (presented visually) or audio (presented orally)” (Butcher, 2014, p. 197).
Neuroplasticity: Neuroplasticity is the brain’s ability to modify itself due to experience, to create new synapses, change neural paths, and in limited parts of the brain, possibly create new neurons (i.e., neurogenesis) after birth: Neuroplasticity is the biological basis of learning (Bach-y-Rita, 2005; LeDoux, 2002; Kandel, 2009; Squire, 2009a; see Sheerin, 2008 for a video).

Neuromyths: This term denotes misconceptions, false beliefs, misinterpretations or distortions of scientific facts about the human brain and its functions.

Neuroscience: Neuroscience is an interdisciplinary scientific field dedicated to the study of the brain and nervous system that brings together professionals from backgrounds such as psychology, biology, and medicine (Kandel & Squire, 2001).

Postpositivism: In the sense used in this paper, postpositivism is the idea that reality, from an ontological stance, is knowable but only in a probabilistic and imperfect manner; from an epistemological viewpoint, reality can be explained by provisional laws open to revision; and methodologically, its study calls for deductive, quantitative, experimental methods that facilitate the detachment of researcher and research participant in their respective roles as the observer and the observed (“Paradigms of Social Research”, 2003).

Self-paced online learning (e-learning): A web-based learning environment in which learners complete a unit of instruction individually and at their own pace. As part of this research, participants were enrolled in the self-paced e-learning unit (alternatively called online course), How Floods Work, designed to be completed in approximately 30 minutes.
References


Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Should we be using learning styles? What research has to say to practice.* London, UK: Learning and Skills Research Centre


University of Kentucky, Department of Earth & Environmental Sciences. (n.d.). *Floods*. Retrieved from https://ees.as.uky.edu/sites/default/files/elearning/module12swf.swf


Appendix A

Recruitment and Follow-Up Communication

Social Media Recruitment Messages

Facebook MALAT group
Dear friends, I’d like to invite you to participate in research I’m conducting as part of my Master’s thesis. The total time commitment is 40-60 minutes, and includes the following steps: (1) sign consent, (2) complete a short online course, and (3) participate in an interview with me. http://fluidsurveys.com/surveys/felavid/mbstudy-questionnaire/

Twitter and Facebook wall (via Twitter)
Participate in my https://www.facebook.com/hashtag/research?source=feed_text&story_id=10155143159690405. (1) sign consent, (2) complete online course, and (3) participate in interview with me. http://t.co/fYyHlYLC

LinkedIn
Looking for participants for ‘Mind, Brain and Education' research. The total time commitment is 40-60 minutes, and includes the following steps: (1) sign consent, (2) complete a short online course, and (3) participate in an interview with researcher. https://lnkd.in/e5UxNUn

Facebook Status
Want to participate in my research? (1) sign consent, (2) complete online course, and (3) interview with me. http://t.co/fYyHlYLC

First Email to Control and Treatment 1 Group Participants

Subject: Welcome to MBE Research

Dear [name],

Thank you for accepting the invitation and consenting to participate in my study. Shortly, you will receive a system-generated email containing your username and password to access ‘How Floods Work’, the online course you will complete as part of the study. You can start the course right away, and complete it as soon as you can, as it is individual and self-paced.

Should you have any trouble accessing Moodle, the learning management system, for the first time, please watch this video for a step-by-step walkthrough. http://www.screencast.com/t/YYPE5QckKP

Thanks again and please let me know if you have any questions or require technical help. I will be in touch once you complete the course to set up the interview.

Felipe Villegas
First Email to Treatment 2 Group Participants

Email Subject: Welcome to MBE Research

Dear [name],

Thank you for accepting the invitation and consenting to participate in my study. Shortly, you will receive a system-generated email containing your username and password to access ‘How Floods Work’, the online course you will complete as part of the study. I will send you instructions on how to complete the course on a separate email.

Should you have any trouble accessing Moodle, the learning management system, for the first time, please watch this video for a step-by-step walkthrough.
http://www.screencast.com/t/YUYPE5QckKP

Thanks again and please let me know if you have any questions or require technical help. I will be in touch once you complete the course to set up the interview.

Felipe Villegas
Mobile: 1+ [phone number]
Email: [email]

Second Email Sent to Treatment 2 Group Participants

Subject: MBE Research Instructions

Dear [name],

How Floods Work is a self-paced, individual course, which you can start right away. However, I recommend you complete the course over two days as follows.

Day One

1. Read course syllabus
2. Complete pre-assessment
3. Complete multimedia presentation
4. Preview post-assessment: read the scenario, but do not answer at this time
Day Two

Complete the post-assessment, but first make sure you are rested and do some physical exercise to maximize your cognitive performance. Also take a moment to review the multimedia presentation to refresh your memory.

- Ensure you get as much overnight sleep as you normally need to feel rested the next day
- Take a nap the day you are completing the post-assessment; a 20-minute nap in the middle of a work day has shown to reduce the effects of the 'afternoon slump', increase productivity and improve overall cognitive performance (i.e. improved focus, concentration, attention and memory)
- If you already have an established exercise routine, such as walking, running, or weight-lifting, complete your exercise routine before completing the post-assessment; the closer to completing the post-assessment that you complete your established routine, the better your performance
- If you do not normally exercise, consider doing some physical exercise right before completing the post-assessment; it could be walking, or something more strenuous if you feel up to it and are medically cleared to do so, but it could also be doing some stretches right on your seat just before completing the post-assessment
- Finally, review the multimedia presentation before and/or while completing the post-assessment

These recommendations assume you will be completing the post-assessment towards the end of the day. However, there is no specific recommended time to sit for the post-assessment. If you complete it in the morning, taking a nap would not apply, but all other recommendations would. Likewise, if you work overnight and sleep during the day, you will have to adapt these recommendations to your specific schedule. When in doubt, contact me to brainstorm a course completion plan that works for you.

If you have any questions or require technical help, please contact me directly.

Thank you,

Felipe Villegas
Mobile: 1+ [phone number]
Email: [email]

Sample Individualized Reminder Email

Subject: MBE Research Participation

Dear [name],
I noticed you have not yet logged in to “How Floods Work”, the course you signed up to complete as part of my study. Please let me know if there’s anything I can do to help you complete the course and the study.

Your username is ____
You can find your password in an earlier system-generated email or reset it on the platform http://mberesearch.net/moodle

Thanks again for your help with my research.

Sincerely,

Felipe Villegas
Mobile: 1+ [phone number]
Email: [email]

Email to All Participants Upon Completion of Post-Assessment

Email Subject: MBE Interview

Dear [name],

Thank you for completing ‘How Floods Work.’ Please complete the interview questionnaire when you have a chance, and let me know what would be a good date and time to interview with me.
http://fluidsurveys.com/surveys/felavid/mbes-post-study-questionnaire

Thank you,

Felipe Villegas
Mobile: 1+ [phone number]
Email: [email]

Follow-up Email to Request Completion of Pre-Interview Questionnaire

Subject: MBE Research Interview

Dear [name],

I’d like to thank you once again for completing ‘How Floods Work.’ Please complete the interview questionnaire when you have a chance, and let me know what would be a good date and time to interview with me.
http://fluidsurveys.com/surveys/felavid/mbes-post-study-questionnaire
Thank you,

Felipe Villegas
Mobile: 1+ [phone number]
Email: [email]

**Personalized Final Week Email to Participants Still Completing Course**

Subject: MBE Research Final Week

Dear [name],

The data collection phase of my MBE Research project is coming to an end. I need to complete all interviews within a week in order to turn my attention to data analysis.

Please help me increase the significance of my findings by completing all remaining steps of your participation in the study.

To date, you have completed the following *[custom if applicable]*:
- *[null]*

You are missing *[custom list]*:
- Pre-assessment [2-5 min.]
- Multimedia module [10 min.]
- Post-assessment [10-15 min.]
- Interview questionnaire [3 min.]
- Interview [25 min.]

Please let me know if you need me to clarify any instructions, require any technical help or have any other questions about the study.

I have a very flexible schedule all week long, including the weekend, and should be able to accommodate a phone interview at your convenience.

Thank you for your participation in my thesis research.

Sincerely,

Felipe Villegas
Mobile: 1+ [phone number]
Email: [email]
‘Getting Started’ Announcement in Moodle News Forum

Dear MBE study participants,

*How Floods Work* is a self-paced, individual course, which you can start right away. All instructions can be found in the course. Please set aside 30 minutes to ensure you complete the course in one sitting. To protect everyone's anonymity, I have disabled all interaction among study participants.

To get started, please read the course syllabus. Then, complete the pre-assessment, multimedia module, and lastly, the post-assessment. Once you complete the course, please take a moment to answer the interview questions.

If you have any questions or require technical help, please contact me directly.

Thank you,

Felipe Villegas
Mobile: 1+ [phone number]
Email: [email]
Appendix B

Consent Form and Eligibility Questionnaire

MBE Pre-Study Questionnaire

Consent Form and Eligibility Questionnaire for research study conducted by Felipe Villegas (Royal Roads University).

Invitation to participate in study and consent decision
Please accept this invitation to participate in a study titled "Mind, Brain and Education in the Digital Era: Applications for Online Learning." The purpose of this study is to contribute to the general understanding of the applications of learning theories based on biology (neuroscience), human behaviour (psychology), and the practice of education (pedagogy), for online learning.

This study is being conducted by Felipe Villegas, a graduate student in the Master of Arts in Learning and Technology program at Royal Roads University. Only participants who meet the following criteria are eligible to participate in the study:

- Adults, aged 18 and over (of any gender and place of origin).
- Who are legally able to freely provide informed consent without the assistance of a third party.
- Who are able to see (not visually impaired; not legally blind).
- Who read, write, and speak English fluently enough to successfully participate in a high school-level course.
- Who have basic Internet skills: for example, understanding of link-based navigation and multimedia controls (back, forward, play, pause).

As a study participant, you will complete the following steps, should you choose to participate in the study until the end:

1. Consent to participate in the study and fill out the questionnaire below to confirm you meet the above criteria.
2. Complete a self-paced online course, consisting of a pre-assessment, a multimedia module, and a post-assessment. [20-30 minutes].
3. Complete a survey and participate in an interview with the researcher after completing the course. [20-30 minutes].

Some of the interview questions may be construed as of a sensitive nature because you will be asked to describe your thoughts about, and feelings towards the course, as well as your overall experience while completing it. You should not feel obliged to answer any questions that you find objectionable or that make you feel uncomfortable.

Your anonymity will be protected at all times during and after the study. Only the researcher will know your name and other identifying information. The researcher will use a pseudonym (e.g., p001) to refer to you in all communication with others, including the professor.
supervising the research project. The pseudonym will be your username for the online course, and your name will not be recorded in the course profile. Furthermore, the course and host platform have been customized so that participants not have access to one another's profiles.

**Your information will remain confidential at all times during and after the study.**
Information about you and your participation in the study will be recorded using a variety of tools. Your activity in the online course will be recorded electronically in a learning management system. The interview will be recorded using either a physical recorder (in-person interviews) or a digital application (remote interviews). You have the right to decline audio recording during the interview. In this case, the researcher will request your permission to use an alternative method of recording notes, such as pen and paper.

Locally stored digital information about you will be kept in a password-protected computer, in an encrypted hard drive using FileVault. The handheld digital recorder, notepad, or other physical tools containing your information, will be kept in a locked cabinet located at the researcher’s home office.

Additional steps have also been taken to protect your information from the U.S. Patriot Act. Both the online course platform (Moodle) and this electronic form are hosted on Canadian servers, managed by Host Upon and FluidSurveys respectively.

After the final thesis has been submitted, the researcher will store all information collected about you for a period of one year for the purpose of writing conference papers or making submissions to academic journals. All participants’ personal identifying information will be destroyed one year after the study.

**You should not feel obliged to participate in any part of the study that you find objectionable or that makes you feel uncomfortable.** There will be no adverse consequence of choosing not to participate in the study or withdraw from it at any point. **You may withdraw from the study at any time without prejudice against you.** If you withdraw prior to completing the study, all information about you, and your participation in the study, will be destroyed immediately and removed from the study.

The results of this research will be published in ProQuest, the Library and Archives Canada, and Royal Roads University’s digital archive. They may also be published in journals or presented at conferences, but such publications or presentations will report only aggregated findings, which in some instances may be illustrated by short, anonymous quotes carefully selected so as not to breach individual confidentiality. Should you be interested in receiving a copy of the study, the researcher will provide it to you upon request.

Questions about the study may be directed to Felippe Villegas at [email] or [phone number]. This study is being supervised by Dr. Martha Burkle, a professor affiliated with Yukon College. Please contact her directly should you wish to verify the authenticity of this research project or ask any questions about the researcher. You can reach Dr. Burkle by email at [email]. Additional references from individuals outside the research project will be provided upon request.
This study has been granted clearance according to the recommended principles of Canadian ethics guidelines, and Royal Roads University’s policies for research involving human subjects. There are no known risks associated with this study. The researcher does not intend to commercialize the study findings.

Thank you for your interest in this study. If you choose to participate in it, please consent below and fill out the rest of the questionnaire to confirm your eligibility.

**Consent Decision**

By selecting “yes” below you are freely consenting to participating in the study and further agree that you:

- Understand what is required based on reading the letter of invitation
- Understand that your participation is voluntary and you are free to withdraw at any time
- Understand the provisions for confidentiality and anonymity

Do you consent to participate in this study?

Yes  No

**Name**

Your real name will only be known to the researcher. You will be assigned a pseudonym throughout the study and this is how you will be identified to others, if needed.

**Email**

This will be the primary mean of communication throughout the study. Only the researcher will email you.

**Phone number**

You will be called by the researcher upon request only, and at an agreed upon time, e.g., for the interview or to provide technical support.

**Date of birth**

You must be at least 18 years old to participate in the study.

**With what gender do you identify mostly?**

Leave blank if answer is 'other' or you prefer not to identify.

- Female
- Male

**What's your vision like?**

The study has a multimedia component that requires you to be able to see.

- I am able to see
- I am legally blind or visually impaired
- Other, please specify...

Choose the option that best describes your ability to navigate the Internet and use web applications.
The study involves completing an online course, which requires participants to have a basic-to-intermediate knowledge of how to navigate the Internet and interact with common multimedia players (e.g., play/pause video on YouTube and use the slider to seek a specific frame).

- I know how to navigate the Internet and use common web applications. Example: you know what a link is and how to use it to open webpages; you know how to attach a file to an email; and you know how to play and pause web-based video.
- I have some familiarity with the Internet. Example: you know how to open webpages using links and/or how to attach a file to an email, but you are not confident you can interact with a web-based video.
- I have only a very basic familiarity with the Internet.
- Other, please specify

Choose the option that best describes your level of fluency in English.

- I have advanced fluency in English. Example: you can read and understand all sections of a major newspaper, or read and understand a novel, or listen to and understand an interview on the radio, without difficulty.
- I have intermediate fluency in English. Example: you can participate in an oral or written discussion with minimal difficulty, but may not be familiar with some informal expressions used by more advanced English speakers.
- I have basic fluency in English. Example: it is not easy to understand this questionnaire.
- If unsure, please specify (or enter IELTS or TOEFL score if available)

Comments or questions
Appendix C

*How Floods Work Syllabus*

**Summary**
Students will learn the essentials of the hydrologic cycle, the mechanics of flooding, some of the factors that influence floods, and flood control methods.

**Intended Audience**
This course was designed to conduct research intended to contribute to the field of instructional design. All course students are study participants who have consented to contributing as research subjects.

**Schedule**
This is a self-paced course, designed to be completed in about 30 minutes. The course will remain open until all participants have completed it or withdrawn from the study.

**Expected Learning Outcome**
By the end of the course, students will have demonstrated the ability to apply their knowledge of how floods work to a novel situation requiring problem-solving skills.

**Course Activities**
How Floods Work consists of three main activities:
1. A pre-assessment to establish a baseline of what the student already knows about the subject matter prior to beginning the course;
2. A multimedia module that covers the course topics; and
3. A post-assessment to establish the student's attainment of the expected learning outcome.

*Note.* To ensure that course activities be completed in sequence, students are subject to restrictions forcing one activity to be completed before the next one becomes available. These restrictions, however, do not always work as intended and can either reveal an activity prematurely or block it altogether. In the former case, students are encouraged to respect the sequence. In the latter case, students can contact the researcher for support.

**Assessment**
Though the assessment of the student's knowledge is an essential component of the study, no grade reports will be available on an individual basis. Assessment results will be aggregated and reported as part of the study findings.

**Technical Requirements**
For the best experience, please ensure you have the latest version of Firefox, Chrome or Safari installed. Internet Explorer failed to display various graphic elements correctly during testing.

**Support**
Please contact Felipe Villegas by phone, email, or text message, if you have any questions or require technical support.

- Mobile: [phone number] (call between 8:00AM and 10:00PM EST; text anytime)
- Email: [email] (preferred) or [email]
Appendix D

Pre-Assessment Questions and Rubric

Introduction

The pre-assessment consists of two open-ended, essay format questions. Feel free write in bullet points or paragraph format. Try to worry less about spelling and grammar, and more about demonstrating your knowledge of the content. Write as much or as little as you want. If you know nothing about the topic or question, simply write so (e.g., "I know nothing about this") so that an answer be recorded. If you know a lot about the content (e.g., you are a geologist), feel free to say so and perhaps just jot down some main points without feeling like you need to write a lengthy description.

Note. Please ignore the grades automatically assigned to each question (1 point) and the final score (0%).

Attempts allowed: 1

Question 1

Describe Earth's water's journey from the oceans to the atmosphere, to raining or snowing, and back to the ocean.

Question 1 Rubric [not available to participants]

<table>
<thead>
<tr>
<th>Q1 Criteria</th>
<th>0 Points</th>
<th>0.5 Points</th>
<th>1 Point</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation</td>
<td>No recall of concept</td>
<td>Partial recall of concept</td>
<td>Recalls concept</td>
<td></td>
</tr>
<tr>
<td>Condensation</td>
<td>No recall of concept</td>
<td>Partial recall of concept</td>
<td>Recalls concept</td>
<td></td>
</tr>
<tr>
<td>Precipitation</td>
<td>No recall of concept</td>
<td>Partial recall of concept</td>
<td>Recalls concept</td>
<td></td>
</tr>
<tr>
<td>Infiltration/Runoff</td>
<td>No recall of concept</td>
<td>Partial recall of concept</td>
<td>Recalls concept</td>
<td></td>
</tr>
<tr>
<td>Sequence</td>
<td>No recall or incorrect recall of</td>
<td>Partial recall of sequence (2-3</td>
<td>Recalls entire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sequence</td>
<td>steps)</td>
<td>correct sequence (4 steps)</td>
<td></td>
</tr>
</tbody>
</table>
Question 2

Describe how floods work. What are some of the causes of flooding? What factors influence the severity of a flood in a given area? What human-made or natural flood controls are you aware of?

**Question 2 Rubric** [not available to participants]

<table>
<thead>
<tr>
<th>Criteria</th>
<th>0 Points</th>
<th>1 Point</th>
<th>2 Points</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causes of Flooding</td>
<td>Does not recall any causes of flooding</td>
<td>Partial recall of one or more causes</td>
<td>Recalls one or more causes</td>
<td></td>
</tr>
<tr>
<td>Infiltration and Runoff Factors</td>
<td>Does not recall any factors that affect flooding</td>
<td>Partial recall of one or more factors</td>
<td>Recalls one or more factors</td>
<td></td>
</tr>
<tr>
<td>Flood Controls</td>
<td>Does not recall any flood controls</td>
<td>Partial recall of one or more controls</td>
<td>Recalls one or more controls</td>
<td></td>
</tr>
<tr>
<td>Concept Integration</td>
<td>Does not recall any concepts or integrates concepts into incoherent narrative</td>
<td>Integrates knowledge of flood causes, factors and controls into incomplete or weak narrative</td>
<td>Integrates knowledge of flood causes, factors and controls into complete and coherent narrative</td>
<td></td>
</tr>
</tbody>
</table>
Appendix E
Multimedia Module

Activity Introduction Text

The following topics are covered in this presentation:
- Water cycle
- Floodplains
- Infiltration and runoff
- Flood controls

To complete this activity you must answer all 4 quiz questions at the end of the presentation and receive a grade between 0 and 100%.

Number of attempts allowed: Unlimited
Number of attempts you have made: 1
Grade for attempt 1: 0%
Grading method: Highest attempt
Grade reported: 0%

Multimedia Module Quiz [identical for all groups]
Appendix F

Post-Assessment Question and Rubric

Imagine yourself on a mission to find a patch of land to build a small agricultural village for a hundred people or so. You find a suitable valley with a river large enough to sustain the village and the crops. After spending a full year watching the valley you get a sense of the river's typical behaviour. This is what you observe happens during the heaviest periods of rain: [http://mberesearch.net/floods/story.html](http://mberesearch.net/floods/story.html) [use the slider to control the animation]

Now you need to apply your knowledge of how flooding works to plan for the village's location in relation to the river and any flood controls or urban design that might be necessary for your plan. Your budget is virtually unlimited. Justify your answers and explain pros and cons of your approach.

*Tips.* Use cardinal points (North, South, West, East, SW, SE, etc.) and/or left-right, up-down directions to describe your plan. You can upload an image if you prefer to draw.

**Animation Screenshots**
### Post-Assessment Rubric [not available to participants]

<table>
<thead>
<tr>
<th>Criteria</th>
<th>0 Points</th>
<th>1 Point</th>
<th>2 Points</th>
<th>3 Points</th>
<th>4 Points</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infiltration and Runoff Factors</td>
<td>Does not recall any factors that affect flooding</td>
<td>Partial recall of one or more factors</td>
<td>Recalls one or more factors</td>
<td>Applies knowledge of one or more factors</td>
<td>Justifies or evaluates application</td>
<td></td>
</tr>
<tr>
<td>Flood Controls</td>
<td>Does not recall any flood controls</td>
<td>Partial recall of one or more controls</td>
<td>Recalls one or more controls</td>
<td>Applies knowledge of one or more controls</td>
<td>Justifies or evaluates application</td>
<td></td>
</tr>
<tr>
<td>Concept Integration</td>
<td>Does not recall any concepts or integrates concepts into incoherent narrative</td>
<td>Integrate knowledge of flood factors and controls into incomplete or weak narrative</td>
<td>Integrates knowledge of flood factors and controls into coherent narrative</td>
<td>Integrates knowledge of flood factors and controls into applicable, coherent narrative</td>
<td>Integrates knowledge of flood factors and controls into applicable, justified and highly coherent narrative</td>
<td></td>
</tr>
</tbody>
</table>
Appendix G
Pre-Interview Questionnaire

This questionnaire is intended only for participants who have already completed the online course "How Floods Work". The purpose of this questionnaire is to expedite the interview process by asking most questions in advance. Responses will be further probed during the interview.

Your Name

Course Experience
Did you complete 'How Floods Work' as directed?
Yes No

Did you consult any external sources during the course, e.g., websites or people?
Yes No

Did you review the multimedia presentation, or consult any external sources, while completing the test at the end of the course?
Yes No

Sleep
Have you ever been diagnosed with one or more of the following sleep disorders? Select all that apply.

- Sleep Apnea
- Narcolepsy
- Insomnia
- Other, please specify...
- Not applicable

How many hours of sleep a day do you need to feel rested?
Please ignore anything you may heard about ideal number of hours; answer based on your own experience with your body.
How many hours did you sleep the night before completing 'How Floods Work'? 
Note. Interpret 'night' as 'day' if, for example, you worked a night shift and slept during the day.

Do you routinely take naps? 
Only answer 'yes' if you take naps as part of your daily routine, everyday or during the work week (e.g., Monday to Friday). Answer 'no' if you only take the occasional nap or don't take any naps at all. 
Yes No

Did you take a nap the day you completed 'How Floods Work', BEFORE completing the course? 
Answer 'yes' if, for example, you took a nap at midday, during your lunch break, and completed the course at night. 
Yes No

Physical Activity
In which of the following activities have you routinely engaged over the last week, month or year? For each variable on the left, please indicate the longest applicable time you've engaged in it based on the choices provided in the drop-down menu.

- Sat at a desk for 7 hours or more per day, at least 5 days per week 
- Watched television/movies for 3 hours or more per day, at least 5 days per week 
- Walked for 30 minutes or more per day, at least 5 days per week 
- Ran for 30 minutes or more per day, at least 5 days per week 
- Did other type of physical exercise (e.g., weight-lifting, sports, etc.) for 30 minutes or more per day, at least 5 days per week

Was there anything unusual in your physical activity routine the day you completed 'How Floods Work'? 
Answer 'yes' if, for example, you do not normally exercise, but did exercise the day you completed the course. 
Yes No

In which of the following activities did you engage the day you completed 'How Floods Work', BEFORE completing the course?
- Sat at a desk for 7 hours or more
- Watched television for 3 hours or more
- Walked for 30 minutes or more
- Ran for 30 minutes or more
- Did other physical exercise (e.g., weight-lifting, sports, etc.)
- Other, please specify...
- Not applicable

Emotional State
Was there any event of significant emotional importance that took place while you were participating in the study?
Yes  No

Did the course trigger any memories or emotional reactions related to the course content?
Answer 'yes' if, for example, you have been personally affected by flooding and the course reminded you of your experience and triggered an emotional reaction due to the subject matter.
Yes  No

Were you stressed while completing the course?
APA defines stress as "a feeling of being overwhelmed, worried or run-down."
Yes  No
Appendix H

Semistructured Interview Guide

Participant:
Timestamp:
Duration:

Interviewer: “To record this interview I will use a web-based service that sets up for a three-way call between a server, your phone and mine. Unlike the online course and the two online questionnaires you have completed, which were hosted in Canadian servers to protect your privacy, it is my belief that this recording will be hosted in US servers, hence subject to the Patriot Act and the potential loss of privacy. Do you have any questions about what this means?”

[Answer questions as needed.]

“Do I have your consent to being recorded during the interview?”

[If yes: “Thank you. I will put you on hold for a moment while I set up the three-way call with the server.”]
[If no: May I take notes using pen and paper and/or my computer?]
[If yes: Thank you.]
[If no, explain that memory is unreliable and the participant’s data may need to be pulled from the study if the researcher cannot recall needed information. Try to obtain consent again and remind the participant of the confidentiality and anonymity provisions explained before in the consent form.]

START RECORDING

To be read verbatim:

“Thank you for consenting to being recorded. This call is now being recorded. For the record, please state your name.”

[Participant states name]

“I’d like to remind you that you should not feel obliged to answer any questions that you find objectionable or that make you feel uncomfortable. I’d also like to reaffirm my commitment to keeping your information confidential and your identity anonymous. Are you ready to start?”

Course Experience/Overall Reactions

Q: The first question is very general; feel free to say as much or as little as you want. How was your overall experience completing ‘How Floods Work’? [Alternative/probing questions: How did you feel towards the course content? How did you like the subject matter of the course?]
Q: Did your views on the subject change as a consequence of the course? How?
A:

Q: Did you find the course instructions in the unit of instruction easy or difficult to follow? [If difficult, what did you do to overcome these difficulties?]
A:

Q: [Probe on questionnaire answers to completing course as directed.]
A:

Q: How long did it take you to complete the course? How many views? Tries?
A:

Temporal-Physical Context/Environment
Q: Where do you normally study? Is this the same space where you completed the course? [Typical or not?]
A:

Q: Describe the environment/physical space(s) in which you completed the course.
A:

Q: How did the space(s) in which you completed the course affect your studies or understanding of the subject matter?
A:

Q: Why did you choose to complete the course in this/these space(s)?
A:

Q: What day and time of the week do you normally prefer to study? When did you complete the course? [Typical or not?]
A:
Multimedia: Attention and Memory

Q: [Probe on questionnaire answer to “Did you review the multimedia presentation, or consult any external sources, while completing the post-assessment at the end of the course?”]
A:

Q: How many times did you watch the multimedia presentation? Why? How much time went by between tries?
A:

Q: How was your concentration or attention to the unit of instruction affected by the environment in which you completed the course? Were there any environmental factors that affected your attention (e.g., phone rang, interrupted by someone, distracted by noise)?
A:

Multimedia Learning

Q: What did you think of the multimedia presentation?
A:

Q: How helpful to your learning did you find the audio and images?
A:

Q: Did you at any time turn off the audio to concentrate on the images? Look away from the screen to concentrate on the audio? [Confirm: At all times, you were looking at the images on the screen at the same time as listening to the narration?]
A:

Q: When the narration stopped on a slide, did you spend time going over the images or did you advance to the next screen right away?
A:

Q: Was there any particular part of the presentation you found more challenging to watch or listen? Why? [Probe on slide-by-slide experience: Intro, Water cycle, Floodplain, Flood factors, Flood control]
A:
Q: Did you refer to the notes (narration script and sources) on the side menu? How exactly did you use them? Did you read them at the same you listened to the presentation? Did you read them with the audio off?
A:

Q: Did you read on-screen text when available?
A:

Q: While taking the quiz, did you refer to the presentation or answer based on your recollection of the course material? Consult external sources? [Probe on answers to completing course as directed and consulting external sources.]
A:

Q: How did your quiz score make you feel? How did it affect you participation on the course?
A:

Pre-assessment and post-assessment
[Have both assessments ready to probe as needed.]
Q: Comparing what you knew about floods before with what you know now, would you say you learned anything new? [Probe if simple yes/no answer]
A:

Q: Describe your experience completing the post-assessment. How did you feel about it? How long did it take you to complete it? Why did you choose to write/draw your response? How did the format of the question affect your answer? (Essay, open-ended, justifications).
A:

Q: [Probe on sleep answers]
A:

Exercise
Q: [Probe on exercise answers]
A:

Emotional State and Stress
Q: [Probe on emotional state and stress answers]
A:

Motivation
Q: How did the fact that you were part of a research study and not taking a credit course affect your responses? Would you have done anything differently had this been a credit course?
A:

Q: Finally, what motivated you to participate in the study? To complete the course?
A:

Final Comments
Q: Is there anything else you would like to add about your experience completing ‘How Floods Work’?
A:
Appendix I

Pre- and Post-Assessment Scores Table

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Appendix J

Qualitative Analysis Codebook

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