Fall 12-16-2022

SYNCHRONOUS VIRTUAL K-12 TEACHERS' USE OF MULTIMEDIA PRINCIPLES IN ELECTRONIC SLIDE DESIGN

Lisa Beaulieu

SYNCHRONOUS ONLINE K-12 TEACHERS' USE OF MULTIMEDIA PRINCIPLES IN ELECTRONIC SLIDE DESIGN

A Dissertation

Submitted to the Instructional Technology and Leadership Program

Duquesne University

In partial fulfillment of the requirements for

the degree of Doctor of Education

By

Lisa Cartin Beaulieu

December 2022

SYNCHRONOUS VIRTUAL K-12 TEACHERS' USE OF MULTIMEDIA

PRINCIPLES IN ELECTRONIC SLIDE DESIGN

By

Lisa Cartin Beaulieu

Approved November 1, 2022

Joseph Kush
Professor, School of Education,
Instructional Technology and Leadership
(Committee Chair)

Nandini Bhowmick
Clinical Assistant Professor, School of
Education, Educational Foundations and
Leadership
(Committee Member)

Susan Ricke Poyo
Associate Professor of Education
(Committee Member)

ABSTRACT

SYNCHRONOUS VIRTUAL K-12 TEACHERS' USE OF MULTIMEDIA PRINCIPLES IN ELECTRONIC SLIDE DESIGN

By

Lisa Cartin Beaulieu

December 2022

Dissertation supervised by Dr. Joseph Kush

Hundreds of thousands of K-12 children in the United States are enrolled in online K-12 virtual schools that consistently report poor academic outcomes. There is a need to assess how well instructors in a synchronous online environment present new material to learners in a way that best aligns with how the brain manages and integrates new information into long-term memory. Online K-12 teachers use PowerPoint to design Electronic Slide Presentation (ESP) decks, which are used as their main form of instruction with their students during synchronous classes. The Cognitive Theory of Multimedia Learning (CTML) provides a set of principles which are proven to reduce extraneous cognitive processing, manage essential processing, and foster generative processing for learners. Yet many are concerned that teachers lack the skills and knowledge of best slide deck design practices required to create effective online learning environments.

This research examines online K-12 teachers' perceptions and practices related to designing ESP slides that mitigate extraneous cognitive load. This study establishes a base of knowledge previously unknown about online teacher practices to determine if there is a need for teacher education or professional development materials specific to improving synchronous K-12 virtual classroom learning outcomes in the context of ESP design.

The purpose of the study was to investigate to what extent virtual K-12 teachers design their lesson slides to reduce cognitive overload for their students. A questionnaire was used to measure perceptions and practices of teachers at a large K-12 academy encompassing three schools in the Midwest state of Ohio. A rubric was then used to evaluate sample ESP decks submitted by teachers to assess adherence to the CTML principles known to reduce extraneous cognitive load. Collected demographic information was analyzed with frequencies, means, and standard deviations. Group differences were examined using *t*-tests and Analyses of Variance (ANOVA) tests. Associations among variables were examined with correlation and multiple linear regression tests. Results of this research might be used to support teacher education and development programs.

DEDICATION

“Teaching is not a job; it is a vocation. To be a great one many qualities must be combined: love of truth, knowledge, reverence, loving concern for one's students, clarity and patience.”

– Dr. Alice von Hildebrand

I dedicate my teaching vocation to my lord Jesus Christ through Our Lady of Hope. Special thanks to all my “ministry and teacher saints” who have had my back: St. Madeleine Sophie Barat, St. Thomas Aquinas, St. Elizabeth Ann Seton, and St. John Bosco. Pray for me!

I dedicate this dissertation, the culmination of my studies at Duquesne, to my husband John and my beloved children: Andrew, Madeleine and Will, Cate and Grant, JohnPaul and Therese. Thank you for your sacrifice, patience, encouragement, and support. I love you all.

ACKNOWLEDGEMENT

I am extremely grateful for my committee members, who each taught and mentored me in different but powerful ways during my dissertation journey. Dr. Nandini Bhowmick, thank you for your time, encouragement, and statistical expertise. You helped me examine things in a different light. Dr. Susan Poyo, thank you for seeing something special in me, even before I entered this program. Your firm faith and constant friendship has deeply influenced my vocation as a teacher and my life as a faithful Catholic woman. Dr. Joe Kush, where do I start? You taught me so much more than how to design, conduct, and report research. I aspire to clearly and patiently guide my students as you have modeled for me. Thank you for your strong and gentle support. I am a better scholar and educator because of you.

TABLE OF CONTENTS

Page

Abstract ... iv

Dedication ... v

Acknowledgement ... vi

List of Tables ... viii

List of Figures ... ix

List of Abbreviations ... x

Chapter I Introduction ... 1

Framing the Problem ... 1

The Problem of Practice ... 2

Theoretical Framework ... 3

Significance ... 4

Purpose ... 4

Research Questions ... 5

Definitions of Terms ... 5

Research Questions ... 5

Assumptions ... 8

Delimitations ... 8

Summary ... 9

Chapter II Literature Review ... 13

Online Learning ... 13

Distance vs. Face-to-face ... 13

Transactional Distance 14
Who Succeeds in Online Learning? 15
K-12 Online Learning 16
K-12 Virtual Schools 17
K-12 Virtual School Delivery Formats 19
Asynchronous Delivery 19
Synchronous Delivery 20
Blended Delivery 20
Pedagogical Challenges in Virtual K-12 Classrooms 21
Online Synchronous K-12 Teaching 23
Online Synchronous K-12 Teaching Practices 24
PowerPoint in K-12 Virtual Classrooms 25
The Cognitive Theory of Multimedia Learning 27
Foundations and Evolution of the Cognitive Theory of Multimedia Learning 28
Assumption 1: Dual Channels 29
Assumption 2: Limited Working Memory and Cognitive Load 34
Assumption 3: Active Processing 38
Adherence to the CTML Principles 40
The CTML Principles 47
Principles to Foster Generative Processing 47
The Multimedia Principle 48
The Personalization Principle 50
The Voice Principle 52

The Embodiment Principle 53
The Generative Activity Principle 54
The Image Principle 55
The Immersion Principle..55
Principles to Manage Essential Processing 57
The Pretraining Principle 57
The Segmenting Principle..58
The Modality Principle 59
Principles to Reduce Extraneous Processing 60
The Coherence Principle..61
The Signaling Principle..66
The Contiguity Principle..70
The Redundancy Principle 75
Conclusion 79
Chapter III Method 81
Setting and Participants..81
Instrument 82
Adherence Rubric 83
Procedure 87
Rubric Scoring 89
Data Collection 89
Analysis...90
Chapter IV Results...93

Participants....93
Electronic Slide Presentation Creation....95
Class Sessions....102
Number of Students per Session....107
Boundary Issues Impacting CTML Principles....113
Reported Adherence to the Principles....114
Reported Principles in Practice Perception Scores....115
Observed Adherence to the Principles....121
Observed Presence of Extraneous Material....124
Observed Adherence to the Coherence Principle....129
Observed Adherence to the Signaling Principle....137
Observed Adherence to the Spatial Contiguity Principle....145
Observed Adherence to the Signaling Principle....152
Associations Among Variables....158
Predictor Variables....160
Summary....160
Chapter V Discussion....161
Descriptive Characteristics....162
ESP Slide Creation....163
Number of Attendees....164
Research Questions....165
Adherence to the CTML Principles....165
Coherence....166

Signaling 168
Spatial Contiguity 169
Redundancy....171
Associations Between Perception and Adherence....172
Group Differences in Adherence 173
Predictors of Adherence....175
Special Populations and Boundary Conditions....175
Summary....176
Significance of Study....177
Recommendations....178
Future Research 179
Replication and Expansion 179
Learning Environments....180
Efficacy of CTML in K-12 180
Physical Learning Spaces 181
Administrators and Policymakers....182
Teacher Preparation Programs....182
Conclusion 183
References....184
Appendices....216
Appendix A Formal Request of School District....216
Appendix B Request for School Principals to Distribute Email to Teachers 218
Appendix C Email Request to Teachers to Participate in Questionnaire 220

Appendix D Teacher Questionnaire..221

Appendix E Informed Consent 226

LIST OF TABLES

Page

Table 1 Dual Channel Input Approaches....................31

Table 2 Three Types of Cognitive Load Parallel Three Sets of Design Principles...........37

Table 3 Electronic Slideshow Presentation (ESP) Redesign Studies....................41

Table 4 Demographic Characteristics of Participants' Gender....................93

Table 5 Demographic Characteristics of Participants' Content Area....................94

Table 6 Demographic Characteristics of Participants' School Level....................94

Table 7 Demographic Characteristics of Participants' Education Level....................95

Table 8 Demographic Characteristics of Participants by Experience Level....................96

Table 9 Demographic Characteristics of ESP Creation....................97

Table 10 Demographic Characteristics of Presentation Software....................97

Table 11 ESP Creation by Gender....................98

Table 12 Demographic Characteristics of ESP Creation by Content Area....................98

Table 13 Demographic Characteristics of ESP Creation and School Level....................99

Table 14 ANOVA: ESP Creation by School Level....................99

Table 15 ANOVA Multiple Comparisons: ESP Creation by School Level....................100

Table 16 ESP Creation by Education Level....................100

Table 17 ANOVA: ESP Creation by Education Level....................101

Table 18 ESP Creation by Teaching Experience....................101

Table 19 ANOVA: ESP Creation by Teaching Experience....................102

Table 20 ANOVA Multiple Comparisons: ESP Creation and Teaching Experience......102

Table 21 ESP Creation by Virtual Experience....................103

Table 22 ANOVA: ESP Creation by Virtual Experience 103
Table 23 ANOVA Multiple Comparisons: ESP Creation and Years' Virtual 104
Table 24 Frequency of Class Sessions by Gender 105
Table 25 Frequency of Class Sessions and Content Area... 105
Table 26 Frequency of Class Sessions and School Level 105
Table 27 ANOVA: Frequency of Class Sessions and School Level 106
Table 28 Frequency of Class Sessions and Education Level.. 106
Table 29 ANOVA: Frequency of Class Sessions and Education Level 107
Table 30 Frequency of Class Sessions by Years' Teaching Experience 107
Table 31 ANOVA: Frequency of Class Sessions by Years' Teaching Experience 108
Table 32 Frequency of Class Sessions by Virtual Experience 108
Table 33 ANOVA: Frequency of Class Sessions by Virtual Experience 109
Table 34 Students per Session by Teacher Gender 109
Table 35 ANOVA: Students per Session and Gender 110
Table 36 Students per Session by Content Area 110
Table 37 Students per Session by School Level 111
Table 38 ANOVA: Students per Session and School Level 111
Table 39 ANOVA Multiple Comparisons: Students per Session and School Level 112
Table 40 Students per Session by Education Level 112
Table 41 ANOVA: Students per Session by Education Level 113
Table 42 Students per Session by Years' Teaching Experience 113
Table 43 ANOVA: Students by Years' Teaching Experience 114
Table 44 Students by Virtual Experience 114

Table 45 ANOVA: Students by Virtual Experience..115

Table 46 ANOVA Multiple Comparisons: Students by Virtual Experience..................116

Table 47 Reported Principles in Practice Perception Responses...................................118

Table 48 Reported Principles in Practice Perception by Gender...................................119

Table 49 Reported Principles in Practice Perception by Content Area 119

Table 50 Reported Principles in Practice Perception by School Level 120

Table 51 ANOVA: Reported Principles in Practice Perception by School Level..........120

Table 52 Reported Principles in Practice Perception by Education Level 121

Table 53 ANOVA: Reported Principles in Practice Perception by Education Level......121

Table 54 Reported Principles in Practice Perception by Teaching Experience..............122

Table 55 ANOVA: RPPP by Teaching Experience...122

Table 56 Reported Principles in Practice Perception by Virtual Experience 123

Table 57 ANOVA: RPPP Students per Session by Virtual Experience.........................123

Table 58 Submitted Slide Decks by Content Area 124

Table 59 Submitted Slide Decks by Education Level 125

Table 60 Submitted Slide Decks by Teaching Experience..125

Table 61 Submitted Slide Decks by Virtual Experience 126

Table 62 Submitted Slide Decks by Class Subject 127

Table 63 Observed Presence Extraneous Material 128

Table 64 Observed Reasons for Extraneous Material..128

Table 65 Observed Presence Extraneous by Gender 129

Table 66 Observed Presence Extraneous by Content Area 130

Table 67 Observed Coherence: Extraneous by School Level 130

Table 68 ANOVA: Extraneous by School Level 130

Table 69 Observed Coherence: Extraneous by Teaching Experience 131

Table 70 ANOVA: Observed Coherence: Extraneous by Teaching Experience 131

Table 71 Observed Coherence: Extraneous by Virtual Experience..............................132

Table 72 ANOVA: Observed Coherence: Extraneous by Virtual Experience 132

Table 73 Observed Coherence Adherence..134

Table 74 Observed Coherence by Gender 136

Table 75 Observed Coherence by Content Area...136

Table 76 Observed Coherence by School Level...137

Table 77 ANOVA: Observed Coherence and School Level 137

Table 78 Observed Coherence by Education Level..138

Table 79 ANOVA: Observed Coherence by Education Level 138

Table 80 Observed Coherence by Teaching Experience 139

Table 81 ANOVA: Observed Coherence by Teaching Experience...............................139

Table 82 Observed Coherence by Virtual Experience...140

Table 83 ANOVA: Observed Coherence by Virtual Experience 140

Table 84 Observed Signaling Adherence 142

Table 85 Observed Signaling by Gender 144

Table 86 Observed Coherence: Extraneous Material by Content Area..........................144

Table 87 Observed Signaling by School Level 145

Table 88 Analysis of Variance: Observed Signaling by School Level...........................145

Table 89 Observed Signaling by Education Level 145

Table 90 ANOVA: Observed Signaling by Education Level..146

Table 91 Observed Signaling by Teaching Experience 146

Table 92 ANOVA: Observed Signaling by Teaching Experience 147

Table 93 Multiple Comparisons: Observed Signaling by Teaching Experience 148

Table 94 Observed Signaling Score by Virtual Experience 148

Table 95 ANOVA: Observed Signaling Score by Virtual Experience 148

Table 96 Observed Spatial Contiguity Adherence..150

Table 97 Observed Spatial Contiguity by Gender 152

Table 98 Observed Spatial Contiguity: Extraneous Material by Content Area 152

Table 99 Observed Spatial Contiguity by School Level 153

Table 100 ANOVA: Observed Contiguity by School Level 153

Table 101 Observed Spatial Contiguity by Education Level...154

Table 102 Observed Spatial Contiguity by Teaching Experience 154

Table 103 ANOVA: Observed Spatial Contiguity by Teaching Experience 154

Table 104 Observed Spatial Contiguity by Virtual Experience.......................................155

Table 105 ANOVA: Observed Spatial Contiguity by Virtual Experience 155

Table 106 Observed Redundancy Adherence..156

Table 107 Observed Redundancy by Gender 158

Table 108 Observed Redundancy by Content Area...158

Table 109 Observed Redundancy by School Level 159

Table 110 ANOVA: Observed Redundancy by School Level 159

Table 111 Observed Redundancy by Education Level..160

Table 112 ANOVA: Observed Redundancy by Education Level 160

Table 113 Observed Redundancy by Teaching Experience 161

Table 114 ANOVA: Observed Redundancy by Teaching Experience............................161

Table 115 Observed Redundancy by Virtual Experience...162

Table 116 ANOVA: Observed Redundancy by Virtual Experience 162

Table 117 Reported Perceptions 163

LIST OF FIGURES

Page

Figure 1 Mayer's Cognitive Theory of Multimedia Learning 28

Figure 2 Coherence ESP Redesign...66

Figure 3 Signaling ESP Redesign...70

Figure 4 Spatial Contiguity ESP Redesign...74

Figure 5 Redundancy Spatial ESP Redesign..79

Figure 6 Coherency Adherence Rubric 84

Figure 7 Signaling Adherence Rubric 85

Figure 8 Spatial Contiguity Adherence Rubric: Labels 85

Figure 9 Spatial Contiguity Adherence Rubric: Text Explanations...........................86

Figure 10 Redundancy Adherence Rubric 87

Figure 11 Coherence ESP Submission Examples 132

Figure 12 Signaling ESP Submission Examples...140

Figure 13 Spatial Contiguity ESP Submission Examples 148

Figure 14 Redundancy Submission Examples 154

LIST OF ABBREVIATIONS

2D VR	Two-Dimensional Virtual Reality
3D VR	Three-Dimensional Virtual Reality
AOT	Asynchronous Online Teaching
BOT	Blended Online Teaching
CLT	Cognitive Load Theory
CTML	Cognitive Theory of Multimedia Learning
DCT	Dual Coding Theory
EMO	Educational Management Organization
ESP	Electronic Slideshow Presentation
GLT	Generative Learning Theory
HQT	Highly Qualified Teachers
iNACOL	International Association for K-12 Online Learning
MRI	Magnetic Resonance Imaging
PL	Phonological Loop
SOT	Synchronous Online Teaching
SPSS	Statistical Packages for Social Sciences
TD	Transactional Distance
TDT	Transactional Distance Theory
VSSP	Visuospatial Sketch Pad
WM	Working Memory
WMT	Working Memory Theory

Chapter I

Introduction

In the last 20 years, a proliferation of virtual K-12 schools has ushered public school education in the United States in a new direction (Barbour, 2015). Even before the COVID pandemic forced schools worldwide to transition to distance learning, it appeared the battle to persuade teachers to accept and use technology tools in the classroom was shifting toward a focus on helping educators integrate these tools into the classroom more effectively (Nguyen & Bower, 2018). Research into best practices in instructional slide design specifically for teachers has not kept pace with online learning environments or the use of technology in face-to-face classrooms (Leacock & Nesbit, 2007).

Electronic Slideshow Presentation (ESP) software such as PowerPoint is used extensively in both virtual and face-to-face instruction across all grade levels from K-12 through graduate school (Bolkan 2019; Kosslyn et al., 2012; Ferreira et al., 2018; Levasseur & Kanan Sawyer, 2006). Proficient use of PowerPoint or similar software is a basic competency for online instructors (Martin et al., 2019; Pantazes, 2021). Yet, research shows there is very little evidence that slide software tools contribute to student learning (Baker et al., 2018; Bolkan, 2019; Savoy et al., 2009). Nor is there evidence that instructors apply proven pedagogical practices when using ESP software (Baker et al., 2018; Beaulieu & Poyo, 2020).

Framing the Problem

In the United States, there were over 290,000 fully virtual K-12 students enrolled in 2019-2020 school year (U.S. Department of Education, 2020), with nearly 26,000 in the state of Ohio. Yet, several studies have shown that students enrolled in K-12 virtual schools achieve significantly lower academic growth and graduation rates than students in other schools (Ahn, 2016; Ahn & McEachin, 2017; Barbour, 2015; Fitzpatrick et al., 2020; Molnar et al., 2019; Yllmaz & Keser, 2017; Zimmer et al., 2009; Zimmer et al., 2014).

Research indicates there are unique challenges inherent to virtual instruction (Azevedo et al., 2004; Cavanagh et al., 2004). For instance, the psychological phenomenon known as Transactional Distance (TD), characterized by feelings of separation between and among members of a learning community, has proven to affect distance learners negatively (Bolliger & Halupa, 2018; Moore & Kearsley, 2011; Murphy & Rodriguez, 2008; Rabinovich et al., 2017; Shin, 2003). TD was found responsible for negative student perceptions of teacher effectiveness as well (Lemak et al., 2005).

To reduce TD and increase interactive communication between students and instructors, many virtual schools choose to conduct classes synchronously (in real time) (Huang et al., 2016; McBrien et al., 2009). Increased interactions between students and instructors can improve relationships; unfortunately, highly interactive online classroom environments can also cause cognitive overload for users, resulting in lack of comprehension and feelings of frustration (Çakiroğlu & Aksoy, 2017; McBrien et al., 2009).

The Problem of Practice

Given the steady increase of online K-12 virtual schools combined with their historically poor outcomes, it is crucial for hundreds of thousands of K-12 children that more effective teaching practices be investigated. There is a need to assess how well instructors in a synchronous online environment present new material to learners in a way that best aligns with how the brain manages and integrates new information into long-term memory. Is it possible to engage in a synchronous, interactive virtual learning environment without causing extraneous cognitive load for students?

Theoretical Framework

The Cognitive Theory of Multimedia Learning (CTML) offers evidence-based guidelines for effective multimedia design based on over 200 experimental studies (Beaulieu & Poyo, 2021: Mayer, 2014, 2021; Noyes et al., 2019). Many studies have shown improvement in student learning outcomes when CTML principles are applied to ESP design (Issa et al., 2011, 2013; Nagmoti, 2017; Noyes et al., 2019; Pate & Posey, 2016).

The CTML theory integrates findings from Dual Coding Theory (DCT), Working Memory Theory (WMT), and Cognitive Load Theory (CTL). Based on these theories, three assumptions are made: 1) we take in multimedia information through two channels, the ears (phonological) and the eyes (visuospatial); 2) we each have a unique limited capacity working memory; and 3) we must actively filter, select, organize, and integrate the new information with our prior knowledge to generate new understanding (Mayer, 2014). CTML design principles are organized into three instructional goals: 1) to minimize extraneous processing (eliminate anything not directly related to the instructional goal); 2) to manage essential processing (enable the learner to create their own mental representations); and 3) to maximize generative processing (help the learner make sense of the material). It is unknown if instructors work with these assumptions in mind when designing effective multimedia environments. These principles may take on even greater importance in a virtual school environment because unlike in blended or face-to-face environments, where only a portion of communication is presented digitally, virtual teachers may be exclusively limited to using ESP in their synchronous communication with their students.

Significance

This research is significant in two ways. First, this study contributes to the literature by focusing on the perceptions and practices of virtual K-12 teachers, a group that has received very little attention. Not much is known about virtual K-12 instructors other than they share similar demographics, education levels, and licensure as regular K-12 public school teachers. Yet their schools are failing. It is important to investigate whether their practices are similar to or different from their face-to-face counterparts.

Second, this study is a starting point on the way toward supporting virtual instructors. Research has shown that online teachers often create their own ESP slides without the knowledge of best practices in ESP design (Nguyen & Bower, 2018; McKenney et al., 2015). Instructor use of CTML principles to mitigate extraneous cognitive load in higher education courses has resulted in greater learning outcomes (Issa et al., 2011, 2013; Nagmoti, 2017; Noyes et al., 2019; Pate & Posey, 2016). If K-12 virtual instructors are already designing their ESP according to the CTML principles, then other reasons for the poor performance of K-12 virtual schools should be investigated. However, if virtual teachers are not implementing CTML design principles into their ESP designs, an effort can be made to improve their instructional practices.

Purpose

This study's purpose is to investigate to what extent virtual K-12 teachers design their lesson slides to reduce cognitive overload for their students. Responses to the following research questions will help determine whether there is a need for future research or professional development specific to improving synchronous K-12 virtual classroom learning outcomes in the context of ESP design.

Research Questions

The following four questions address the goals of this study:

RQ1: To what extent do ESP designed by virtual K-12 teachers adhere to four CTML principles that reduce extraneous cognitive processing?

RQ2: Is there an association between virtual K-12 teachers' perceptions of their ability to reduce extraneous cognitive load and their implementation of the design recommendations for these four principles?

RQ3: Are there group differences between virtual K-12 teachers' adherence to the four target principles according to gender, content area, teaching level, education level, number of years teaching, or number of years' experience teaching in an online synchronous environment?

RQ4: How much do gender, content area, teaching level, education level, number of years teaching, and number of years' experience teaching synchronous online classes explain the variation in virtual K-12 ESP design adherence to the Cognitive Theory of Multimedia Learning principles?

Definitions of Terms

- **Asynchronous Online Teaching (AOT):** "AOT involves students working with online curricular materials on their own time, under the guidance of a teacher (Friend & Johnston, 2005; Zucker & Kozma, 2003). The teacher and students are separated in time and space and are, therefore, geographically and temporally independent and diverse" (Murphy et al., 2011, p. 584).

- **Blended Online Teaching:** "The combination of online-based dissemination of content with face-to-face active learning experiences" (Killian et al., 2019, p. 111).
- **Cognitive load**: "The relative demand imposed by a particular task, in terms of mental resources required. Also called mental load; mental workload" (American Psychological Association [APA], 2022).
- **Cognitive Load Theory (CLT):** An instructional design theory based on human cognitive architecture which postulates that working memory capacity is limited, and that when cognitive load exceeds capacity, the learner will not be successful in the learning task (Sweller & Chandler, 1991).
- **Cognitive overload:** "The situation in which the demands placed on a person by mental work (the cognitive load) are greater than the person's mental abilities can cope with" (American Psychological Association [APA], 2022).
- **Cognitive Theory of Multimedia Learning (CTML):** "… a research-based theory of learning aimed specifically at explaining how people learn from words and pictures" (Mayer, 2020, p. 31).
- **Dual Coding Theory (DCT):** "The theory that linguistic input can be represented in memory in both verbal and visual formats" (American Psychological Association [APA], 2022).

- **Generative Learning Theory (GLT):** A teaching model where the instructor guides the learner to actively generate meaning from activities and experiences (Wittrock, 1992).
- **Phonological Loop (PL):** "… a component that holds and manipulates auditory information over short intervals of time" (American Psychological Association [APA], 2022).
- **Synchronous Online Teaching (SOT):** In SOT, students and teachers are separated in space, but not by time. They use web conferencing software to meet at certain times (Murphy et al., 2011).
- **Transactional Distance Theory (TDT):** A pedagogical challenge in online courses where "distance of understandings and perceptions, caused in part by the geographic distance that has to be overcome by teachers, learners and educational organizations if effective, deliberate, planned learning is to occur" (Moore, 1991, p. 4, as cited in Huang et al., 2016).
- **Working Memory:** "… the short-term maintenance and manipulation of information necessary for performing complex cognitive tasks such as learning, reasoning, and comprehension" (American Psychological Association [APA], 2022).
- **Virtual school:** "All instruction offered by the school is virtual. This does not exclude students and teachers meeting in person for field trips, school-sponsored social events, or assessment purposes. All students receive all instruction virtually" (U.S. Department of Education, 2021a).

- **Visuospatial sketch pad (VSSP):** "… a component that briefly holds and manipulates information about the appearance of objects and their location in space… divided into two parts: the visual cache, specializing in information about form, color, and other aspects of visual identity, and the inner scribe" (American Psychological Association [APA], 2022).

Assumptions

It was assumed that the sample would be representative of all the virtual K-12 teachers employed at this school district, that the teachers would answer the questionnaire honestly, and that those who chose to submit would present their own ESP sets rather than someone else's.

Delimitations

In this research, I limited the investigation to those principles that minimize extraneous processing specifically because I did not think I could get participants if the survey incorporated all the principles—it would be too long. As well, eliminating extra and unnecessary elements is a prerequisite for the next two groups of principles. A lesson is effectively ruined if this first step is not taken. My experience as a virtual teacher and observer at this school led me to hypothesize that most ESP decks would contain low adherence to the principles and be filled with many violations of the principles in this category. In addition, I eliminated the temporal contiguity principle because it was not practical to analyze video recordings and ESP decks because the video recording software the school uses does not include chat or external video, and it was cumbersome at the time of collection to share recordings.

Summary

The number of online K-12 for-profit EMO-managed schools in the United States has grown steadily over the last twenty years (Molnar et al., 2019; Sturtevant et al., 2021), yet the learning outcomes of the students in these schools continues to be significantly low in comparison to brick-and-mortar K-12 schools (Ahn, 2016; Ahn & McEachin, 2017; Barbour, 2015; Fitzpatrick et al., 2020; Molnar et al., 2019; Yllmaz & Keser, 2017; Zimmer et al., 2009; Zimmer et al., 2014). Research indicates that teacher competency is an unlikely factor for this failure; instead, there may be something inherent to teaching in the virtual environment that requires something other than what is currently taught in teacher-preparation programs (Barbour et al., 2009; Fitzpatrick et al., 2020; Pulham et al., 2018).

PowerPoint or similar ESP software is used extensively in classrooms across all grade levels (Martin et al., 2017), although research indicates presentation software itself does not contribute to learning (Baker et al., 2018). Many scholars have called for a more thorough investigation into pedagogical practices concerning the use of ESP (Bernard et al., 2004b; Clark, 1994; Jahng et al., 2007; Russell et al., 2003). It is possible that ESP design practices contribute to student learning outcomes. CTML provides a proven set of principles known to increase learning outcomes (Mayer, 2020), and scholars have found that application of these principles to the design of ESP results in positive benefits for learners (Issa et al., 2013; Nagmoti, 2017; Noyes et al., 2019; Pate & Posey, 2016).

However, little is known about online K-12 teachers' perceptions or practices (Black et al., 2009; DiPietro et al., 2008; Martin & Parker, 2014; Zweig & Stafford, 2016). For instance, it is not clear which software online K-12 teachers use, to what extent they interact with students, or how those synchronous virtual interactions are characterized. As well, it is unknown if K-12 online teachers know of or implement CTML principles into their ESP designs. It is possible that some groups of teachers are aware of and use the principles more than other groups. More experienced synchronous online teachers may have developed design practices that are more in tune with cognitive learning than those new to online teaching. On the other hand, it is possible that younger teachers are more technologically savvy or more recently attended teacher preparation programs that specifically addressed multimedia design and are therefore more aware of the principles and more adept at designing virtual materials. It is more likely that teachers who are familiar with the principles will implement them into their ESP practices at higher rates than teachers who are not familiar with them.

It is important to note that some principles are not intuitive and may run counter to typical practices. For example, many teachers are concerned with providing information to students in multiple modalities due to student learning preferences (Gardner, 1993), even though CTML has proven that redundant material inhibits learning (Mayer, 2020). In an effort to minimize TD and make a personal connection with students, some teachers might include text, images, or sounds in their ESP slides that are irrelevant to the content being learned, thereby violating the principle of coherence. It is important to ascertain how virtual teachers address seemingly incompatible practices in their ESP designs.

Studies concerning multimedia learning and preferences according to gender have been conducted (Castro-Alonso et al., 2019b; Passig & Levin, 1999), but none were found to explore gender differences among virtual K-12 instructors. It is reasonable to expect few differences in how teachers design their ESP according to gender. Most of the research on the CTML principles has concerned higher education STEM-based content (Mayer, 2020). More research needs to be conducted concerning non-STEM-based courses and classes of younger students. Therefore, it is important to tease apart teacher perceptions and practices to determine a baseline of CTML adherence before any recommendations for teacher preparation or professional development can be made. The hypotheses for this research are listed below.

Hypothesis 1. There will be small and minimal adherence between ESPs designed by online K-12 teachers and four CTML principles that reduce extraneous cognitive processing.

Hypothesis 2. There will be a moderate and statistically significant positive correlation between teachers' perceptions of their ability to reduce extraneous cognitive load and their implementation of the recommendations for each of the four design principles. As teachers' self-perceptions of their ability to implement principles increases, their rate of adherence to them will increase as well.

Hypothesis 3a. There will be no statistically significant group differences between genders regarding teachers' adherence to the four target principles.

Hypothesis 3b. There will be no statistically significant group differences between content area (STEM-based or humanities-based materials) regarding teachers' adherence to the four target principles.

Hypothesis 3c. There will be no statistically significant group differences between teaching level (elementary, middle school, and high school levels) regarding teachers' adherence to the four target principles.

Hypothesis 3d. There will be no statistically significant group differences between education level (bachelor's degree, master's degree, specialist license, or doctoral degree) regarding teachers' adherence to the four target principles.

Hypothesis 3e. There will be no statistically significant group differences between number of years teaching experience regarding teachers' adherence to the four target principles.

Hypothesis 3f. There will be no statistically significant group differences between number of years teaching in an online synchronous environment regarding teachers' adherence to the four target principles.

Hypothesis 4. The combination of gender, content area, teaching level, education level, and experience teaching synchronous online classes will be small and significantly non-significant predictors of adherence to the Cognitive Theory of Multimedia Learning principles.

Chapter II

Literature Review

Online Learning

As technology has become more sophisticated and access to the Internet has spread, higher education has embraced distance education (Deming et al., 2012; Xu & Jaggars, 2014). The benefits to higher education include convenience, flexibility, access equity, and low-cost production (Bacolod et al., 2018). In 2019, over 7.3 million postsecondary learners (37%) enrolled in online courses in the United States; yet in the fall semester of the 2020 pandemic year, that number increased to more than 14.1 million (73%) (National Center for Education Statistics [NCES], 2021a).

Similarly, American K-12 schools have followed the trend toward online learning. Some students engage in "blended" courses, which Killian et al. (2019) define as "the combination of online-based dissemination of content with face-to-face active learning experiences" (p. 111). In 2015-2016, about 600,000 students took distance credit recovery or advanced class coursework from home provided through their local school district (Gemin et al., 2017). Most online K-12 learners, however, enrolled in full-time virtual schools run by for-profit Education Management Organizations (EMOs) (Molnar et al., 2019).

Distance vs. Face-to-face

Different conclusions have been drawn about the efficacy of distance learning since Moore and Kearsley (1996) predicted that online teaching would become a normal practice. Several studies report that distance education students perform better than those in traditional face-to-face courses (Bernard et al., 2004a; Machtmes & Asher, 2000;

Shachar & Neumann, 2003). In contrast, other research has determined distance and classroom instruction are equally effective, with each having its own strengths and weaknesses (Cavanaugh et al., 2004; Means et al., 2009). Some studies assert that a blended or hybrid approach is superior (Xu & Jaggars, 2014; Zhao et al., 2005).

Transactional Distance

Transactional Distance Theory (TDT), first proposed by Moore (1973), suggests that the psychological perception of distance and communication gaps can affect learning (Moore & Kearsley, 2011; Rabinovich et al., 2017; Shin, 2003). While perceived transactional distance (TD) can be a detriment in a face-to-face setting, it is more common for distance learners. In online learning, TD is determined by the structure of the course and the nature of the discourse between the teacher and student, the student and peers, the student and the content, and the student and school (Rhim & Han, 2020; Shin, 2003). Moore's hypotheses related to TDT suggests that high interaction (dialog) combined with few impediments between the student and teacher (structure) will reduce feelings of distance and provide more student autonomy (Murphy & Rodriguez-Manzanares, 2008). Moore suggests that students who feel supported by and connected to the instructor have a richer learning experience than those who do not.

A robust body of evidence on TDT has emerged, and many empirical instruments have been developed to measure TD in different learning environments (Rabinovich et al., 2017). Student engagement, perceived learning outcomes, and TD are found to be correlated (Bolliger & Halupa, 2018; Force, 2004; Stein et al., 2005). Research has also confirmed that student engagement in a course can be predicted by TD (Bolliger & Halupa, 2018).

Who Succeeds in Online Learning?

As the number of online courses grows, more research is investigating who does well in the environment, who does not, and what additional supports students need. In higher education, several studies maintain that successful distance learners must have a highly developed sense of autonomy and self-regulation (Azevedo et al., 2004; Cavanagh et al., 2004; Keegan, 2013; Wedemeyer, 2010).

Xu and Jaggers (2014) examined the gap in success rates between community college students taking online and face-to-face courses. They found that fewer males, ethnic minorities, and younger pupils arrive in online courses with the self-directed learning skills needed to succeed than females, Whites, and students with higher educational experience. In one experiment where all factors were identical but the use of the Internet for live delivery, live instruction provided only modest positive results, but the negative effects were significant for males, Hispanics, and low-achieving students (Figlio et al., 2013). Xu and Jaggers (2014) point out “the continued expansion of online learning could strengthen, rather than ameliorate, educational inequity” (p. 651).

Bacolod et al. (2018), focusing on members of the Navy taking online distance courses, confirmed that students who usually excel in school are not affected by the format of delivery. However, those who usually perform in the bottom two-thirds of their classes experience a significantly harmful effect on both grades and completion rates in online courses. Similarly, Park et al. (2019) determined that undergraduates who did well in high school courses typically excel in hybrid courses. However, they found a second predictive factor was persistent participation. Even students who performed poorly in high school but persisted with online activities in a college hybrid environment completed courses.

But completing a course and thriving as a learner are markedly different things. College students who take courses online rather than in-person are not as successful during school (Alpert et al., 2016; Bettinger et al., 2017; Hart et al., 2018; Xu & Jaggers, 2014). Nor are they as successful after graduation (Deming et al., 2012). In fact, Deming et al. (2016) found that college students who attended for-profit online schools received fewer callbacks for job applications, earned less, and had higher loan default rates. As previously mentioned, a majority of full-time online K-12 students are enrolled in virtual schools run by similar for-profit Educational Management Organizations (EMOs) (Molnar et al., 2019).

K-12 Online Learning

Most research into online learning has been conducted at the postsecondary level. However, the number of studies concerning effects of distance learning on K-12 students is growing. Some suggest students under the age of eighteen have different needs than adults (Cavanaugh, 2001; Cavanaugh et al., 2004; Curtis & Werth, 2015). Yet children who take courses online do not always have the autonomy or sense of responsibility necessary for online learning success; children need more support than adult learners (Azevedo et al., 2004; Cavanagh et al., 2004; Keegan, 2013; Wedemeyer, 2010). Cavanaugh et al. (2004) warn against generalizing findings from higher education because "K-12 distance learning is fundamentally unique" (p. 6). They suggest online course instructors explicitly instruct and intentionally support younger students to develop self-regulation skills. It is clear from the literature that online K-12 teachers face a distinct set of challenges than online instructors face in higher education.

K-12 Virtual Schools

The term "virtual school" is often used as an umbrella expression to include K-12 learning environments which use blended or completely non-location-bound means to provide instruction (Molnar et al., 2019). The National Center for Education Statistics recently changed its definition of a virtual school to embrace more nuanced details. This research is concerned with what the U.S. Department of Education defines as "FULLVIRTUAL: Exclusively virtual. All instruction offered by the school is virtual. This does not exclude students and teachers meeting in person for field trips, school-sponsored social events, or assessment purposes. All students receive all instruction virtually" (National Center for Education Statistics [NCES], 2021b).

The first "virtual" K-12 school in the United States opened in 1991 (Archambault & Kennedy, 2012). Barbour reported in 2015 that because K-12 schooling had captured the attention of many Americans, several states expanded the number of virtual schools allowed to operate as well as the number of students each can enroll. In 2016, nearly 300,000 students attended publicly funded full-time elementary and secondary virtual schools across 34 states (Molnar et al., 2019). Before the COVID epidemic, enrollment in all K-12 digital learning schools was growing by about 6% per year ("Digital Learning Collaborative," 2019). During the COVID-19 pandemic, enrollment at one cyber school organization, K12 Inc., grew 39 percent from 2019 to 2020 (Stride Learning, 2021; Stride Newsroom, 2020).

According to the National Center for Education Statistics (2021b), in the school year 2019-2020, there were 691 fully virtual schools operating in the United States that enrolled 293,717 fully virtual students. Florida registered the highest number of fully virtual schools (222), but only enrolled 16,403 students, which was 0.6% of the total state enrollment. Ohio had only 14 fully virtual schools that enrolled 25,962 students, which was 1.5% of the total school enrollment. Only Pennsylvania (2.1%) and Idaho (2.3%) enrolled more fully virtual students as percentages of their entire state enrollment, and only Pennsylvania (35,808) and California (28,496) reported more virtual students than Ohio.

The perceived benefits of distance learning at the K-12 level include convenience, flexibility, credit recovery, accelerated or specialized learning, and the ability to study in an environment some families consider safer than a brick-and-mortar school (Rice, 2006). However, poor academic achievement in virtual schools compared to face-to-face and blended environments has been an ongoing concern. Molnar et al. (2019) reported graduation rates for virtual schools are approximately 44% compared to the national face-to-face school average of 82%. Among all virtual schools, 60% of district-operated schools were rated as “acceptable,” while only 25.7% of for-profit run schools received the same rating (Molnar et al., 2019).

K-12 virtual charter schools impose a significant negative impact on achievement (Ahn, 2016; Ahn & McEachin, 2017; Barbour, 2015; Fitzpatrick et al., 2020; Molnar et al., 2019; Yllmaz & Keser, 2017; Zimmer et al., 2009; Zimmer et al., 2014). For example, the Center for Research on Education Outcomes (CREDO, 2019), an outreach of Stanford University, reported weaker growth in math among Ohio charter school students “equivalent to 41 fewer days of learning” (p. 2) compared to traditional public-school students. Fitzpatrick et al. (2020) reported in a longitudinal study conducted in Indiana that students who left traditional public schools for virtual schools experienced large and negative effects in math and language arts that persisted over time. No clear explanation for the significant differences in achievement between face-to-face and online schools emerged in the review of the literature.

K-12 Virtual School Delivery Formats

Virtual schools and teachers concerned with increasing achievement or lowering the effects of TD must determine whether they should present lessons synchronously or asynchronously. Just as researchers come to contradictory conclusions about face-to-face compared to online instruction, they also come to different conclusions about the advantages and disadvantages of asynchronous and synchronous delivery. While some found no differences in outcomes between platforms (Chen & Shaw, 2006; Olson & McCracken, 2014; Roybler et al., 2007), others found differences (Duncan et al., 2012; Huang et al., 2016; McBrien et al., 2009; Murphy et al., 2011). From this review, it appears asynchronous environments result in higher achievement, while synchronous environments have a greater impact on lowering feelings of TD.

Asynchronous Delivery

Murphy et al. (2011) describe asynchronous learning as when teachers and students are permanently separated by space and time. Curricular materials created as text, audio, or video are provided by the instructor, and learners interact with those materials on their own. While the school under investigation provides asynchronous materials for students to use, this research does not focus on asynchronous instruction.

Synchronous Delivery

Synchronous distance learning is more similar to traditional face-to-face classroom instruction. Martin et al. (2017) define synchronous learning as when teachers and students are permanently separated geographically but not temporally. Curricular materials created as text, audio, or video are presented in real time, and students can communicate with the teacher and each other and give or receive immediate feedback. Collis (1996) suggested synchronous environments would increase motivation, build social presence, give quick feedback, and encourage students to stay on track. Duncan et al. (2012) investigated the relationship between the quality and quantity of interactions in online discussions, final exam scores, and overall course grades of participants. They found synchronous engagement has "twice the impact on final examination and overall course performance relative to asynchronous course enragement" (p. 432). Even though many studies confirm live communication in a synchronous virtual classroom enhances interaction, raises student satisfaction, and reduces feelings of TD, few significant differences have been found on academic achievement (Malinovski et al., 2014; Martin et al., 2017; Martin & Parker, 2014; Olsen & McCracken, 2014).

Blended Delivery

Abrami et al. (2011) distinguish between face-to-face teachers working with in-class students while "synchronous" students observe a live video of the class. Sometimes called "hybrid synchronous" or "blended synchronous," this type of environment offers a variety of benefits, but also many pedagogical challenges for the instructor (Huang et al., 2017; Raes et al., 2020).

Much of the research concerning both multimedia principles and online education has focused on the design of learning materials and delivery tools (de Freitas & Neumann, 2009). But many argue research should focus on improving pedagogical practice of instructors in online environments instead of concentrating on the delivery medium (Bernard et al., 2004b; Clark, 1994; Jahng et al., 2007; Zhao et al., 2005).

Pedagogical Challenges in Virtual K-12 Classrooms

There is no doubt both formats of instruction, synchronous and asynchronous, are each effective. In their follow-up assessment comparing asynchronous and synchronous environments, Bernard et al. (2004b) observed wide variability in effect sizes and concluded achievement, retention, and attitude in both types of classrooms are more dependent on pedagogical practices than the media employed. Roblyer et al. (2007) proposed that the decision about which environment to provide should consider variables, such as teacher quality, student achievement, and student skill level.

Several studies confirm Moore’s assertion that students perceive less TD when they are provided a rich environment, including live text and audio/visual components and interactive communication in a synchronous classroom (Huang et al., 2016; McBrien et al., 2009). Murphy et al. (2011) explain synchronous e-learning appears to increase motivation and understanding of complex information.

However, a rich environment can create another set of problems. Martin and Parker (2014), in a study to determine who uses synchronous classrooms and why, describe tools such as audio, video, text chat, polling, desktop sharing, and the use of breakout rooms and webcams as ways to promote interactivity and create communities of practice, which should reduce TD. Yet many high school students are reluctant to engage in synchronous learning (Duncan et al., 2012; Murphy et al., 2011). McBrien et al. (2009) emphasize students report feeling overwhelmed by the number of online tools during live synchronous sessions. This feeling of being overwhelmed may be a sign of cognitive overload. Çakiroğlu and Aksoy (2017) confirm that online synchronous software settings can also contribute to cognitive load. Of significant importance to this study is the fact there is as yet no easy, reliable way to measure online K-12 student cognitive overload quantitatively (Klepsch et al., 2017). Therefore, this research will concentrate on the practices of online teachers presenting synchronously, where teachers concentrate all their attention and effort on distance students.

Little is known about the effects of asynchronous compared to synchronous distance education on K-12 students. In their systematic review of synchronous research covering 1995-2014, Martin et al. (2017) found only twenty K-12 school studies compared with 108 studies from higher education. It is clear the growth of online schools is outpacing the amount of research that could guide these schools to provide effective delivery of online instruction (Barbour, 2017).

Gill et al. (2015) reported the majority (60%) of coursework in online charter high schools is asynchronous and teacher-guided synchronous discussion was only provided for 32% of student work. Yet Bernard et al. (2004b) suggested younger learners would benefit more from synchronous instruction because of their need for immediate feedback. Cavanaugh et al. (2004) confirm younger students have not yet developed the same level of autonomy as successful online adult learners have, and teachers take on an even more crucial role in the success of their online students as they scaffold specific learning skills and content.

Online Synchronous K-12 Teaching

Teaching effectively in a synchronous web-conferencing environment is not as simple as transferring face-to-face strategies, and therefore requires different pedagogical training (de Freitas & Neumann, 2009; DiPietro et al., 2008; Murphy et al., 2011; Smith et al., 2005). Although the skills needed to teach in this environment differ from those needed to teach face-to-face (Ferdig et al., 2009), only the District of Columbia and four states require teachers to complete training in online instruction before they teach a K-12 online course (Watson et al., 2014, as reported in Zweig & Stafford, 2016).

The International Association for Online Learning (iNACOL) recognized online virtual teaching differs from face-to-face teaching and published national standards for quality online teaching in 2011. In 2019, those standards were converted to competencies soon after iNACOL rebranded itself as the Aurora Institute (Quality Matters, 2022). According to these competencies, online instructors build online collaborative activities and support a range of technologies. Yet the only mention of "multimedia" in the document is at the end, under an optional standard. This standard contains a list of online teacher abilities that states, "The online teacher is able to incorporate multimedia and visual resources into an online module," and online teachers should also be able to "arrange media and content to help transfer knowledge most effectively in the online environment" (p. 17). There is no other mention of pedagogical use of design or incorporation of multimedia principles to accommodate the complex distance synchronous learning environment in the revised competencies.

It is possible the difference in achievement in online virtual schools is caused by variation among the teachers. However, teachers at the school in this investigation are considered Highly Qualified Teachers (HQT), according to the school handbook (Ohio Virtual Academy, 2021b), meaning they received the same undergraduate or licensure training as teachers working in brick-and-mortar schools. While 58% of all public school teachers in the United States have earned a postbaccalaureate degree (National Center for Education Statistics [NCES], 2021c), only 48% of the teachers at this school hold a master's degree (Ohio Virtual Academy, 2021a). However, Fitzpatrick et al. (2020) reported the negative achievement impact seen over time between traditional and virtual schools could not be explained by differences between teachers or classroom characteristics. Instead, they concluded the nature of "virtual teaching format allows for less variation in instruction quality" (p. 169).

Online Synchronous K-12 Teaching Practices

Few studies investigate the practices or perceptions of virtual school teachers (DiPietro et al., 2008; Martin & Parker, 2014). Only one study was found that links instructor perception of learning resources to learning outcomes, and it was concerned with higher-education settings (Noyes et al., 2020).

It may be some pedagogical practices regularly used in education simply do not work in synchronous online classrooms. For instance, having students work together to support each other and collaborate on problem solving is a typical constructivist practice, but Smith et al. (2005) reported students perceive online teachers who use this method as less supportive and helpful, and Smith et al. (2011) confirmed that fewer channels of communication and logistical difficulties make collaborative work more difficult for online students, even when they meet synchronously.

Moderating TD is specifically a function of teacher pedagogy, but virtual teachers might experience their own TD; some have expressed dissatisfaction because they cannot see their students' faces and miss many nonverbal cues from learners (Smith et al., 2005). Wengrowicz and Offir (2013) determined that teachers with more years' experience perceived less TD between students and themselves. They also found instructors with larger numbers of students experienced a significantly greater perception of distance than those with small classes and advocated for smaller class sizes even though large classes provide an economic advantage. It is unknown if teachers enter the online classroom with complete knowledge of effective pedagogies for managing online classrooms and reducing TD. Barbour et al. (2013) reported less than 40% of first-time virtual teachers receive specific training before they teach online.

Although much is known about the crucial role of teachers in face-to-face learning environments, little is clear about the perceptions or practices of online K-12 teachers (Borup et al., 2014; DiPietro et al., 2008; Murphy & Rodríguez-Manzanares, 2008; Smith et al., 2005).

PowerPoint in K-12 Virtual Classrooms

Although several alternative presentation software programs exist, instructors and teachers in both higher education and K-12 classrooms often create electronic slideshow presentation (ESP) decks with PowerPoint (Bolkan, 2019; Kosslyn et al., 2012; Martin & Carr, 2015; Martin et al., 2019; Pantazes, 2021). This is not surprising, considering that Microsoft has about ninety-five percent of the market for presentation software (Parker, 2001). PowerPoint is part of MS Office, a suite of software tools used by approximately 1.2 billion people around the world ("StackCommerce").

Much of the research on the efficacy of ESP software has showed little evidence it improves learning outcomes (Baker et al., 2018; Bolkan, 2019; Pate & Posey, 2016; Savoy et al., 2009; Zhang et al., 2022). Yet, the ability to use PowerPoint is considered a basic competency for researchers and online instructors (Grech, 2018; Martin et al., 2019). Scholars have emphasized that the exact software tool used to create ESP decks is less important than the pedagogy behind how teachers design learning sessions (Baker et al., 2018; Garner & Alley, 2013; Horvath; 2014). It may be that some instructors implement proven practices more than others; however, very little is known about the specific use of PowerPoint or similar ESP software programs in synchronous online K-12 classes.

Gender has an impact on learning from multimedia (Castro-Alonso et al., 2019b; Wong et al., 2015), and it may be an important variable in teacher/designer application of ESP design principles. A recent study regarding faculty perspectives of the quality of online vs. face-to-face instruction showed no differences between gender or age (Fish & Snodgrass, 2019). However, Honebein and Honebein (2014) found a statistically significant difference between what male and female instructional designers judged as more valuable instructional methods. They found that "Nearly all of the instructional methods judged more useful by females involve groups and/or some form of discussion, which is consistent with the feminine communion values" (p. 65). According to Guillén-Gámez et al. (2021), there are conflicting research results concerning pedagogical digital competence between males and females. Only one study was found that concerned K-12 teacher design of PowerPoint, and that was not focused on a virtual environment: Annetta et al. (2007) found that female preservice science teachers prefer to integrate graphics into their PowerPoint designs more than males. There is a need for research to clarify who virtual teachers are and how they use ESP.

The Cognitive Theory of Multimedia Learning

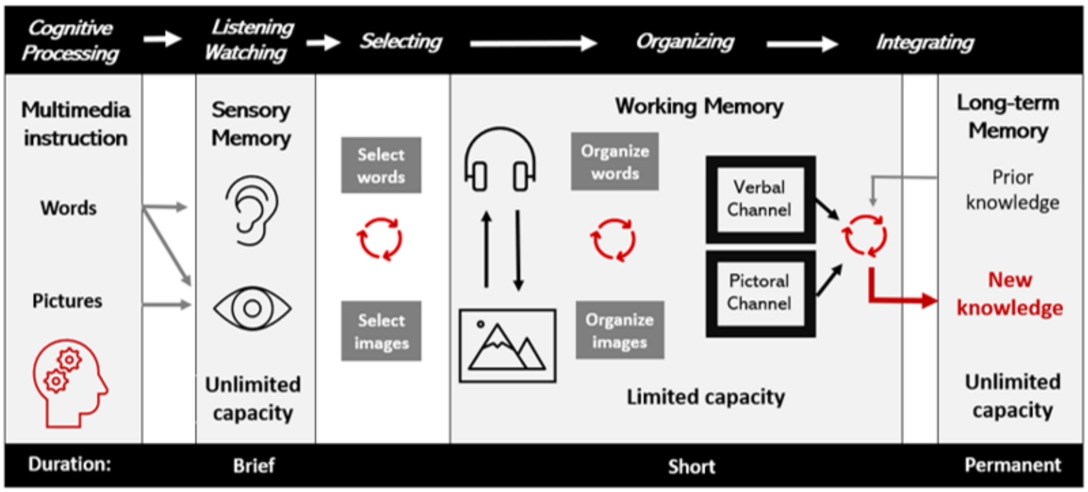
CTML blends findings from three theories with the working memory model and applies them to multimedia learning (Mayer, 2020). Baddeley's (1992) version of working memory provides a sensory framework to explain how learners process new information. Paivio's (1991) Dual Coding Theory (DCT) forms CTML's understanding of how learners select and organize words and images into mental verbal and pictorial channels. Finally, Wittrock's (1992) Generative Learning Theory (GLT) explains how learners integrate new knowledge into long-term memory.

Multimedia instructional messages, whether they are presented on paper, a projector, or a screen, comprise words and pictures. According to Mayer (2020), images are perceived through the eyes and narrated words are understood through the ears. However, written words are processed in both channels: they travel through the eyes but must be converted into internal sounds, meaning they take an extra step to be understood by the learner. Learners are limited in what they can process at one time through visual and auditory channels (Mayer & Moreno, 2003). If too much new information is presented at one time to learners, the result can be cognitive overload and reduced comprehension (Chandler & Sweller, 1991).

To make meaning from words and images, learners select and organize multimedia input. Mayer and Fiorella (2014) argue that making connections between word-based and picture-based representations is "the most crucial step in multimedia learning" (p. 57). Finally, relevant prior knowledge must be activated and retrieved from long-term memory into the working memory for integration of the new knowledge to be complete. Figure 1 displays the Cognitive Theory of Multimedia Learning.

Figure 1

Mayer's Cognitive Theory of Multimedia Learning



Note. Adapted from "Applying the science of learning to medical education" by Mayer, R. E. (2010). *Medical Education*, *44*(6), 543-549.

Foundations and Evolution of the Cognitive Theory of Multimedia Learning

CTML is concerned with testing conditions that reduce cognitive overload, facilitate comprehension, and activate deep, long-term retention (Mayer, 2020). The first edition of *Multimedia Learning* (Mayer, 2001) presented seven principles based on results from 45 experiments concerning CTML. The most recent edition (2020) expanded to fifteen principles developed from 200 experiments. While the original theory concentrated on reducing extraneous processing, its present incarnation broadens the theory's significance by exploring essential and generative processing. Recent research into emotional and motivational design principles shows the theory will continue to expand (Mayer, 2020).

However, the three underlying assumptions of the theory remain the same today as they did in 2001. Multimedia learning theory assumes learners have a dual coding process to take information into working memory (Baddeley, 1992; Clark & Paivio, 1991). It also assumes that each element of working memory is limited in capacity and ability (Baddeley, 1992; Clark & Paivio, 1991; Mayer, 2019; Sweller et al., 2019). The third assumption of CTML is that learners must take active steps to integrate and make sense of the new information (Sorden, 2013).

Assumption 1: Dual Channels

The first foundational assumption of CTML — Dual Channels — is grounded in both Dual Code Theory and Working Memory Theory.

Dual Code Theory. Dual Coding Theory (DCT) assumes there are two cognitive processing systems involved in learning — a verbal channel and a pictorial channel. Each has different capacities (Paivio et al., 1968; Paivio & Csapo, 1971). Paivio's separation of the two processing channels is a representational approach; it considers how learning material is represented — verbally or non-verbally — as most important. According to DCT, all words, spoken or written, are categorized as verbal input, whereas pictures, video, animation, and background sounds are categorized as non-verbal input (Mayer, 2020).

Paivio was the first to conduct an empirical, systematic study of performance related to memory (Paivio, 1991). By the 1990s, the idea of separate but interrelated pathways in the brain for visual and verbal processing had become widely accepted (Sadoski & Paivio, 1994). As of today (2022), the theory is foundational to cognitive psychology and is applied in several fields of study (D'Esposito & Postle, 2015;

Kanellopoulou et al., 2019; Liu et al., 2020; McClanahan & Nottingham, 2019; Scheiter & Eitel, 2017; Sorden, 2013). For an in-depth description of the technical cognitive elements involved, see "Intelligence, dual coding theory, and the brain" (Paivio, 2014).

Working Memory Theory (WMT). As Paivio was developing the DCT, other cognitive psychologists were also building on the work of previous research to develop a deeper understanding of the working memory (Baddeley, 1983). Baddeley (1992) defined working memory as a "system for the temporary maintenance and manipulation of information, necessary for the performance of… complex cognitive activities" (abstract). In 1968, Atkinson & Shiffrin posited a short-term memory model used as a temporary holding spot for information before it entered long-term memory (Sorden, 2013). Baddeley and Hitch (1974) proposed a different model of working memory, one with two limited-capacity subsystems to replace the then-current understanding of memory as a "single unitary short-term memory with an alliance of subsystems" (Baddeley, 1983, p. 84). This "modal model" contained two types of short-term, limited-capacity memory storage units. The first unit held sensory input. This sensory information was fed into the second unit: a short-term storage tank. Slowly, the storage tank would transfer the learning into long-term memory. However, no empirical research proved the modal model (Baddeley, 1983).

Baddeley and Hitch's model of working memory includes a phonological loop (PL) that processes new auditory and written material by storing and rehearsing verbal information (Sorden, 2013). The PL processes kinesthetic, visual, and spatial information (Gocognitive, 2010). A second subsystem is the visuo-spatial sketchpad (VSSP), which processes spatial and visual information, such as movement and images (Baddeley, 1983;

Sorden, 2013). Baddeley's separation of the two processing channels differs from Paivio's. Baddeley takes a sensory rather than a representational approach. According to Baddeley, spoken words and background sounds are categorized as PL input, whereas pictures, video, animation, and printed words are categorized as VSSP input (Mayer, 2020).

In 1986, Baddeley and Hitch added the idea of a central executive (CE) processor to their working memory model. The CE explained how the working memory controls attention and coordinates information from each subsystem, linking it into long-term memory. In 2000, the theory was updated again to include an episodic buffer (EB). The EB better explained how multimodal information is temporarily held in the working memory (Schüler et al., 2011), and "functions as a storage structure which acts as a limited capacity interface to integrate multiple sources of information from other systems" (Sorden, 2013, p.160). In a 2010 video interview, Baddeley clarified how the episodic buffer acts as a binder, connecting and filtering input. He stated,

We now have a new version that actually sees the episodic buffer as a passage/passive store that is fed by a stream of information from the visuo-spatial sketchpad, which in turn is fed by visual, spatial, kinesthetic, and the phonological loop, which in turn is fed through sound, through language, probably through sign language, and probably also through smell and taste. (Gocognitive, 2010).

Hitch et al. (2020) confirmed that the EB combines multiple features of an event (an episode) into integrated, coherent representations and ties together evidence on the effect focused attention has on memory.

Research into working memory continues to develop. Recent work suggests that instead of a CE moderating the working memory subprocesses, long-term memory schemas act as the executive moderator (Anmarkrud et al., 2019; Sorden, 2013). For an in-depth explanation of the research in neurological and biological sciences, see "The cognitive neuroscience of working memory" (D'Esposito & Postle, 2015).

Application of the Dual Channel Assumption in CTML. It is important to point out that Mayer's framework is specific to multimedia learning while Baddeley's and Paivio's work apply to all learning. In the CTML, Mayer's stated purpose is to construct practical design principles to answer the question, "How can we design multimedia instruction that improves learner understanding of the presented material?" (Mayer, 2020, p. 1). In order to develop these design guidelines, he frames CTML's dual channel assumption on both Baddeley's and Paivio's work. However, Baddeley and Paivio categorized types of input differently. Mayer created a "compromised" approach combining elements of both Paivio's DCT, which considers how the new material is represented as key with Baddeley's work, that considers which physical sense modality the material is initially received through as more accurate. Mayer's approach in CTML synthesizes the sensory and representational approaches into one auditory/verbal channel that processes narration and background sounds and one visual/spatial channel that processes pictures, video, animation, and on-screen printed words. Table 1, Different Approaches to Dual Channel Input by Paivio, Baddeley, and Mayer, charts the differences in each approach and the "compromised" version the CTML has adapted (Mayer, 2020).

Table 1

Different Approaches to Dual Channel Input by Paivio, Baddeley, and Mayer

	Representational Mode Approach Dual Code Theory (Paivio)		Sensory Mode Approach Working Memory (Baddeley)		Compromised Approach Cognitive Theory of Multimedia Learning (Mayer)	
	Verbal	Non-verbal	Phonological Loop	Visuo-spatial sketchpad	Auditory/ verbal	Visual/ spatial
Input	Spoken words (narration)	Images, video, narration	Spoken words (narration)	Pictures, video, animation	Spoken words (narration)	Pictures, video, animation
	Printed words (text)	Background sounds	Background sounds	Printed words (text)	Background sounds	On-screen printed words

Note. Adapted from *Multimedia Learning*, by R.E. Mayer, 2020, p. 199-200. Copyright 2021 by Cambridge University Press.

Schüler et al. (2011) criticized Mayer's version and claimed CTML is a faulty theory because it adapts neither working memory nor dual code theory exactly. Instead, CTML selects parts of each theory to fit its purpose. Criticism is not unwarranted. Yet, it may be premature to demand pure adherence to individual elements of the theory that are still in development themselves. In fact, several of the theories contributing to CTML are still developing. For example, Hitch et al. (2020) demonstrated that knowledge of working memory has changed when they recently distinguished between working memory's visual buffer storage and the focus of attention. Similarly, CLT has changed since its first inception and now includes a focus on evolutionary psychology (Sweller et al., 2019). As theories develop and grow, continual criticism and constant re-evaluation naturally result in change. It is reasonable to expect changes will be made to a theory as it develops.

Assumption 2: Limited Working Memory and Cognitive Load

The second foundational assumption of CTML draws from Cognitive Load Theory (CLT), which investigates the limitations of cognitive capacity and the duration of working memory as related to learning (Anmarkrud et al., 2019). The main assertion of CLT is that humans can only process a small amount of information at one time, so superfluous activities or information cause the cognitive load to increase and learning to decrease (Sweller et al., 2019).

Three Types of Working Memory. There are three kinds of memory. Sensory memory can be considered "raw data." It refers to fleeting moments (from milliseconds to five seconds) of visual (iconic), kinesthetic (haptic), or sound (echoic) imagery (Dharani, 2015). Light trails seen when cars are moving at night, the sensation of a hypodermic needle in the arm, and the sound of screeching tires followed by a crashing sound are examples of things perceived through sensory memory. While there is no limit to sensory memory capacity, working memory is limited, so not everything perceived is transferred to long-term memory (Cowan, 2008). Sensory memories quickly move to working memory.

Working memory is a temporary storage system where we consciously manipulate information by selecting, rearranging, and organizing (Mayer, 2020). Items usually stay in working memory about 30 seconds. Miller's Law suggests that most people can hold up to six bits of information in working memory before they forget (Miller, 1994).

Long-term memory refers to everything a person has experienced in their lifetime, and although memories must be brought into working memory for a person to be cognizant of them, the capacity of long-term memory is a lifetime (Cowan, 2008; Dharani, 2015; Mayer, 2010).

CTML incorporates into its design principles three basic concepts drawn from CLT: 1) working memory has a limited capacity to process information, 2) the limited capacity of working memory is moderated by the auditory and visual channels, and 3) the act of learning involves the brain's ability to filter, select, and organize new information into long-term memory (Mayer & Fiorella, 2014; Mayer, 2020). For a detailed explanation of the history of CLT, its development from 1998 through 2018, and newly discovered compound effects of the theory, see "Cognitive architecture and instructional design: 20 years later" (Sweller et al., 2019).

Three Kinds of Cognitive Load. CLT research shows that learners transfer information into long-term memory more easily when cognitive load is reduced (Anmarkrud et al., 2019; Paas et al., 2003; Sweller, 1988; Sweller & Chandler, 1991; Sweller et al., 2019). Paas et al. (2003) describe three types of cognitive load: intrinsic, extraneous, and germane. All three types of cognitive load are interconnected; each affects and is affected by the other types of cognitive load (Sweller, 2010a).

Intrinsic (or essential) cognitive load refers to the difficulty and complexity of the thing being learned. Element interactivity is considered the basis of intrinsic cognitive load (Kirschner et al., 2018; Sweller et al., 1998), and refers to how many chunks of information learners hold in their working memory simultaneously during a learning task (Ginns, 2005). A higher intrinsic value means the learner must engage with many interactive elements. For instance, comprehending the many contributors to and results of the complete water cycle is more difficult than understanding the concept of precipitation. While a learner's prior knowledge acts as a moderating influence of intrinsic cognitive load (Kirschner et al., 2018), the essential difficulty level of the material cannot be changed by the instructor (Sweller, 2010a). CLT advocates eliminating extraneous activities and teaching students how to manage distractions to reduce intrinsic cognitive overload.

Element interactivity is also a common contributor to the second kind of cognitive load, extraneous (or ineffective) load (Kirschner et al., 2018; Paas et al., 2003). Extraneous load refers to the part of the working memory that must process anything not specifically relevant to the lesson. Unlike intrinsic load, extraneous load is unrelated to the material and is determined by the instructional design, presentation, or the actions learners are required to perform during instruction (Sweller, 1994; Sweller et al., 2019). Instruction places heavy demands on working memory and interferes with the learner's construction of mental representations if it includes extraneous material (Kirschner et al., 2018; Klepsch et al., 2017; Sorden, 2013). Sweller, 1994) found that a reduction in element interactivity is associated with a decrease in extraneous cognitive load and argues that "extraneous cognitive load, by definition, is entirely under instructional control" (p. 303). Both CLT and CTML place heavy emphasis on investigating instructional techniques that result in reduced element interactivity and better availability of working memory resources (Kirschner et al., 2018; Mayer, 2020).

The third category of cognitive load is germane (or effective) load, and it refers to the resources in working memory that learners use to synthesize essential (intrinsic) elements with their prior knowledge and store the new learning in long-term memory (Kirschner et al., 2018; Paas et al., 2003). Studies have shown that extraneous elements “steal” limited cognitive resources needed to synthesize germane knowledge (Sweller et al., 2019). If learners use too much of their working memory trying to process extraneous material or multiple materials presented in the same modality, they may deplete their resources and have no capacity left to work on germane learning. Unlike intrinsic and extraneous loads, germane cognitive load does not impose a load of its own; instead, it redirects attention to the intrinsic elements of the learning task (Kirschner et al., 2018; Sweller et al., 2019). Germane load directly contributes to student comprehension and retention, but its effectiveness depends on how willing learners are to invest their cognitive resources to construct meaning and mental schemas (Costley & Lange, 2017; Sweller, 2010b).

Application of the Limited Capacity Assumption in CTML. Different learning situations can cause cognitive overload. For instance, either the visual or the auditory channel (or both) could be overloaded by the essential (intrinsic) nature of the material. One or both channels might be overloaded with extraneous items or by a confusing presentation. In addition, if learners are tasked with holding something in mind while simultaneously processing other information, they can feel overwhelmed (Mayer & Moreno, 2003). CTML principles have been developed and tested to reduce learners’ cognitive load during multimedia instruction; its three categories of design principles align with CTL’s three categories of cognitive load (Mayer, 2020). Table 2 shows the parallels between CTL and CTML.

Table 2

Three Types of Cognitive Load Parallel Three Sets of Design Principles

Theory Alignment	
Cognitive Load Theory	Cognitive Theory of Multimedia Learning
Germane Load	Principles to Foster Generative Processing
	Multimedia
	Personalization
	Voice
	Generative Activity
	Image
	Immersion
Intrinsic Load	Principles to Manage Essential Processing
	Pretraining
	Segmenting
	Modality
Extraneous Load	Principles to Minimize Extraneous Processing
	Coherence
	Signaling
	Spatial Contiguity
	Temporal contiguity
	Redundancy

Note. This table demonstrates the alignment of the CTML design principles with their counterparts in CLT. Adapted from *Multimedia Learning*, by R.E. Mayer, 2020, p. 199-200. Copyright 2021 by Cambridge University Press.

Assumption 3: Active Processing

The third assumption underlying the CTML is that learners must select, organize, and integrate information to learn meaningfully (Mayer & Moreno, 2003; Mayer, 2010). In 1974, Wittrock introduced the Generative Model of Learning and stated its premise: "People tend to generate perceptions and meanings that are consistent with their prior learning" (Wittrock & Farley, 2010, p. 41). He advocated for cognitive research that brought together two fields of psychological study: experiential and cognitive. Wittrock's goal was to find practical techniques that helped learners actively generate associations leading to meaningful understanding, long-term memory, and transfer. Learners actively process in multimedia environments when they select words, select images, organize words, organize images, and integrate the words and images in working memory into long-term memory (Mayer & Moreno, 2003).

Fiorella and Mayer (2016) stated that the purpose of a generative learning activity is to help learners better understand the material by requiring the learner to participate during the lesson. Typical activities include summarizing, rewriting, mapping, teaching, enacting, self-explanation, self-testing (Mayer, 2020). Generative activity results are powerful. Recently, Lawson and Mayer (2021) found that college students who were prompted to write explanations during pauses in multimedia learning performed significantly better on delayed posttests than student who were not prompted to action during the same lesson.

CTML has investigated methods of instruction using multimedia tools that improve learning outcomes for over twenty years. (Mayer, 2020). According to Mayer, the theory is still being developed and tested. However, CTML is a very well-known theory around the world (Mayer has been cited over 67,000 times since 2017, and more than 60 co-authors have contributed to its robust research foundation) (Google Scholar, 2022). CTML relies on dual coding, limited working memory, cognitive load, and active generative learning theories to explain how sub-optimal cognitive processing effects are created and can be improved (Mayer & Moreno, 2003; Mayer, 2001; Noyes, 2019).

Adherence to the CTML Principles

Mayer (2020) stated two overlapping goals of CTML are contributing to both learning theory and instructional practice. Hattie and Clarke (2018) pointed out that one appeal of the theory may be that it has practical applications. While many scholars exhort instructors to implement the CTML into their multimedia messages for best learning outcomes (Baker et al. 2018; Grech, 2018; Levinson, 2010; Mahajan et al., 2020), it is unclear if K-12 virtual instructors are aware of the importance of designing instructional materials according to the CTML or any design principle. Tang et al. (2018) reviewed 45 journal articles concerning the creation of flipped classes and found little mention of any multimedia design principles. Mahajan et al. (2020) called for clinical medical instructors to develop their instructional PowerPoint slides to adhere to the CTML principles, claiming that the theory, "primarily based upon four scientific criteria—theoretical plausibility, testability, empirical plausibility, and applicability" (p. 555), will make lectures more interesting and effective, thus increasing student retention rates.

One long-term goal of this research is to help virtual K-12 teachers improve their use of multimedia tools with proven design practices. It is important to know if teachers are already using any of the principles as a first step toward that goal. No studies on virtual K-12 educators' use of ESP or CTML principles were found to inform this research. However, a small group of researchers within the CTML community—mostly practitioners in the higher-education science community with the goal of improving instruction for their students—have tested the redesign of PowerPoint ESP decks to adhere to the CTML principles. In five studies, statistically significant differences were found. Table 3, *Electronic Slideshow Presentation (ESP) Redesign Studies*, highlights the results.

Table 3

Electronic Slideshow Presentation (ESP) Redesign Studies

Study	Course	Design	Outcome
Garner, J. K., & Alley, M. P. (2013).	Engineering	Experimental groups with traditional and redesigned ESP. Immediate and delayed essays.	Significant statistical differences found in favor of the CTML-aligned group for recall, misconceptions, delayed retention, and self-reported mental effort.
Issa, N., Schuller, M., Santacaterina, S., Shapiro, M., Wang, E., Mayer, R. E., & Darosa, D. A. (2011).	Medicine	Experimental groups with traditional and redesigned ESP. Immediate test.	Both groups showed significant improvements in retention ($p < 0.0001$), transfer ($p < 0.05$) and total scores ($p < 0.0001$) between pre- and posttests. Statistically significant greater improvements in retention ($F = 10.2$, $p = 0.0016$) and total scores ($F = 7.13$, $p = 0.0081$) for students in the modified design group.
Issa, N., Mayer, R. E., Schuller, M., Wang, E., Shapiro, M. B., & Darosa, D. A. (2013).	Medicine	Experimental groups with traditional and redesigned ESP. Immediate and delayed transfer tests.	The group with CTML-influenced ESP significantly outperformed the traditional condition group on immediate tests of retention ($d = 1.49$) and transfer ($d = 0.76$). The modified condition group significantly outscored the traditional condition group on delayed tests of transfer given 1 week ($d = 0.83$) and 4 weeks ($d = 1.17$) later, and on delayed tests of retention given 1 week ($d = 0.83$) and 4 weeks ($d = 0.79$) after instruction.
Nagmoti, J. M. (2017).	Microbiology	One group, five traditional lectures and five redesigned ESP. Immediate pre- and posttests each lecture and delayed test.	Significant differences in favor of PowerPoint slides designed to adhere to CTML for both short-term retention ($p = 0.019$) and long-term comprehension ($p < 0.001$).
Pate, A. & Posey, S. (2016).	Pharmacy	Student scores on identical exam items were compared and a voluntary student survey was used to evaluate the activity.	Students in the redesign groups performed statistically better on identical exam items, were satisfied with the redesigned PowerPoint format, felt confident in their potential exam performance, and wanted to see pictures and narration more often.

The five adherence studies presented in Table 3 *Electronic Slideshow Presentation (ESP) Redesign Studies* were chosen because they 1) examined ESP slides according to the CTML principles, 2) were conducted in authentic learning environments (rather than short lessons conducted in controlled laboratories), and 3) tested differences empirically.

Three studies used a pretest/posttest control group design (Issa et al., 2011, 2013; Nagmoti, 2017). Issa et al. (2011) tested two sets of medical students before and after a 50-minute lecture. All factors were the same other than the design of the ESP slides. One group received traditional PowerPoint design slides, and the other group viewed ESP slides redesigned to adhere to multiple CTML principles. Posttests were given an hour after the lecture, following a second, unrelated lesson. In a follow-up study also conducted with different medical students but the same content, Issa et al. (2013) added measurements for transfer and long-term retention. Their results were the first to provide evidence CTML principles applied to ESP in an authentic medical classroom result in significant learning outcome differences.

Nagmoti (2017) conducted a similar study with medical students as well. Participants attended 10 fifty-minute lectures concerning parasitology, each accompanied by a pretest and a posttest. The first five lectures presented traditional PowerPoint slides, and the last five presented ESP slides modified in accord with CTML principles. In addition, students were given a posttest essay test six months after the course ended. Student scores on the content presented with modified ESP were statistically significant for both short-term and long-term learning gains.

A 2013 study by Garner and Alley examined undergraduate engineering students learning about the complex Magnetic Resonance Imaging (MRI) process with ESP slides that either adhered to or violated CTML principles. Presentations were identical in narration. Following an eight-minute, recorded ESP-based video presentation, each group of participants took an immediate posttest. A second, unannounced posttest was given in class one week after the presentation consisting of fill-in-the-blank, multiple choice, and essay questions assessing both simple and complex concepts taught in the lesson. Findings show redesigned ESP decks have favorable immediate and long-term effects on learning outcomes.

Research conducted by Garner and Alley (2013) differed from the other studies in this group by testing a specific ESP template format useful for instructors: the "assertion-evidence approach." The slide design approach integrated relevant images according to the CTML rather than relying on PowerPoint default bullet point format. The authors explained their study rationale by stating:

> An abundance of experimental evidence suggests that learners benefit from presentations in which multimedia learning principles have been adhered to. However, this conclusion stands in stark contrast to the structure of the vast majority of instructional slides, the structures of which are deeply influenced by the default settings of one commonly used slide software program: Microsoft PowerPoint. (Garner & Alley, 2013, p. 1565)

The last adherence study in Table 3 spanned three years of a pharmacology course concerning osteomyelitis and septic arthritis (Pate & Posey, 2016). In the first year, a traditional PowerPoint ESP deck was used. In the subsequent two years, the same lecture was delivered, but the ESP decks were reformatted to adhere to the CTML. Again, significant differences were reported from posttest scores between participants in the traditional and modified conditions. Pate and Posey explained how they went about redesign of the slides, which took about 14 hours to choose material and quality images and minimize words. The traditional ESP deck contained 46 slides: nine slides with pictures and 37 slides with approximately seven bullet points each. The redesigned version totaled 88 slides, nearly twice the original version. However, text was reduced to an average of 0.3 bullet points on half of the slides, and the other 43 slides only contained pictures.

All five studies resulted in significantly better learning outcomes when CTML principles were applied to ESP decks. The level of detail describing the changes the researchers made when redesigning the ESP decks varied. In all cases, redesign according to CTML incorporated multiple principles per slide. Where appropriate, representative visual examples of changes made to traditional slides from these studies are included in the discussion of each principle in the section below.

Although only five ESP redesign studies were found, other researchers have highlighted the lack of quality studies and called for more thorough studies to report on the development and design of materials so they can be replicated and result in concrete guidelines and context (Sundararajan & Adesope, 2020). Much of the research reviewed for this study came from higher education STEM-based classrooms, but some scholars are applying the theory for younger students. Schrader and Rapp (2016), to determine if CTML data could be generalized to an authentic classroom of high school science students, conducted a study focusing on the modality and signaling principles and their application to static and dynamic media. While they found no significant difference between groups, their results directly apply to this research, which focuses on teachers' understanding and implementation of the CTML principles. All groups showed improvement from pretest to posttest, and the researchers attributed that growth in part to the fact that the teacher who created the study materials for both groups "implemented design that was directly informed by the CTML" (p. 40). Pate and Posey (2016) reported a similar effect that occurred for the instructor over the course of their three-year study. As the lecturer made the design changes and became more practiced at implementing the CTML principles, they "may have inadvertently emphasized information more in the redesigned lecture by adhering to the coherence principle and only focusing on the main learning goal for each slide and limiting extraneous detail” (p. 238). Teachers who implement the CTML principles over time may become more effective instructors.

An additional two studies examined how well publicly available instructional animations adhered to the CTML principles. Noyes et al. (2020) analyzed 30 veterinary science animations for adherence to the CTML principles and found that the majority were used in less than 40% of the animations. Yue et al. (2013) conducted a much larger but similar study, analyzing 430 medical science animations. They reported similar results, with few animations adhering to the CTML principles, particularly for essential processing. Both studies found that poor design resulted in missed learning opportunities and an excess of extraneous elements.

More recently, instructional designer Pantazes (2021) published a dissertation with a case study design exploring the practical implementation of CTML principles by instructors in an online classroom environment. His focus was on instructional video created by higher education instructors, and results cannot be generalized to the population under investigation here. However, parallels emerged. First, both studies set out to contribute to the literature by exploring practical application in authentic learning scenarios. Second, both use the CTML as a theoretical framework. And third, both investigate the difference between how instructors perceive the materials they design and what they actually design. Pantazes’ (2021) results showed that although instructors in general do not know the specifics of CTML design principles, a portion “are applying some of the principles robustly and the overall application of the design principles appears to be better than 50%” (p. 177).

The CTML Principles

The following section presents the foundational multimedia principle and then introduces the other principles into three groups, according to their purpose. In each group, the individual principles are defined according to the CTML, effects are discussed, boundary conditions are mentioned, and implications for multimedia instruction are presented. When applicable, visuals from adherence studies are also shown. The first subsection concentrates on the principles that foster generative processing: multimedia, personalization, voice, image, embodiment, immersion, and generative activity. The second subsection describes the three principles proven to help learners manage essential processing: pretraining, segmenting, and modality. The third subsection describes the five design principles known to reduce extraneous processing: coherence, signaling, redundancy, spatial contiguity, and temporal contiguity.

Principles to Foster Generative Processing

The first group of principles facilitates the last—perhaps most important—step in the learning process: learners' integration of new knowledge into long-term memory. Mayer (2020) refers to generative processing as the mental effort learners must make to organize and make sense of new information, integrating each element into prior knowledge. I address this group briefly because they are not the focus of this research; however, it is important to understand how these principles fit into the overall learning process as described by the CTML.

Compared to the second and third groups of principles, the generative process is the least researched and developed, and the principles will most likely continue to expand and be refined as research continues. Mayer presents the heart of his theory with the multimedia principle, followed by four principles shown to work as ways to foster generative processing. These four (personalization, voice, embodiment, and generative activity) are based on social cues with strong ties to motivation and relationship with the instructor (Mayer, 2005; Mayer, 2014), and they might reduce feelings of transactional distance. Two other principles are also included in this group (image and immersion), although they are worded negatively and have few positive effects reported in the scant research that exists so far.

The Multimedia Principle

A simplified version of the multimedia principle states, "People learn better from words and pictures than from words alone" (Mayer, 2020). In multimedia lessons, learners are presented with words and pictures. Complications can occur as different media (static images, dynamic images, diagrams, etc.) are processed differently, but Mayer (2020) claimed the premise for practitioners remains the same: "meaningful learning occurs when learners build systematic connections between word- and picture-based representations" (p. 134).

In 13 core studies Mayer (2020) examined, where text with a graphic or animation strictly aligned to the content and were presented concurrently, 100% of learners who received information in two representational forms as opposed to only one form (words or pictures) performed higher on transfer tests (effect size $d = 1.35$). Of the 13 studies, 12 were STEM lessons. The lone arts-based content area analyzed (history) had a large effect size of $d = 0.81$. A second set of 11 studies was also analyzed. The second set of studies featured nine STEM-based lessons, but the graphics, video, or narration were categorized as unrelated, redundant, excessive, decorative, unlabeled, or otherwise marred and therefore did not meet the standards to be included in the first set of studies. Still, modest effect sizes in favor of presenting lesson information in both words and pictures were found. However, effect sizes for retention in other studies have been found to be more modest (Butcher, 2014), and the multimedia effect was not found significant when applied to problem-solving skills (Hu et al., 2021).

Mayer (2020) concluded from the second set of studies mentioned above there are several boundary conditions for the multimedia principle. First, there is evidence that the multimedia principle applies more for low prior knowledge learners. Students with low prior knowledge performed better when the text or audio narration was accompanied by diagrams. This confirms a large body of research that has found significant implications for instructional design depending on the learners' previous experience (Kalyuga, 2005, 2007; Ollerenshaw et al., 1997; Stiller & Jedlicka, 2010). On the other hand, a high level of prior knowledge can lead to the expertise reversal effect, when "expert" or advanced students experience detrimental consequences because of the instructional design (Kalyuga, 2014; Kalyuga & Renkl, 2010).

Another boundary condition Mayer found for the multimedia principle is the quality of graphics. For instance, he cited several studies (again, most revolved around STEM-based lessons) that found poor learning results because of unlabeled, abstract, or irrelevant images or animations. Mayer also included a study on the negative consequences of the presence of too many graphics. Graphic quality and effect on learning have been areas of concern to researchers for many years (Brasell, 1987; Huang, 2005; Gligora Marković et al., 2014; Sung & Mayer, 2012).

A small but growing body of research is focusing on the analysis of visuals in K-12 classrooms (Coleman et al., 2018; Guo et al., 2018, 2019, 2020a, 2020b; Roberts et al., 2015; Roberts & Brugar, 2017; Schrader & Rapp, 2016). Recently, Guo et al. (2020b) conducted a meta-analysis of 39 experimental studies measuring the effects of graphics on readers' comprehension across all age levels. This study is significant to this research because it focuses specifically on art-based literacy content material, an area seldom researched in CTML studies. Guo et al. (2020b) argued that the field of literacy education overemphasizes verbal aspects of text and is biased against visual representations. As a result, readers' comprehension of modern texts may suffer.

The study found that compared to adults, students in elementary through secondary grade levels showed lower but insignificant differences in learning from graphics than adults. The authors postulated that younger students might require more intentional scaffolding to process semantics and integrate information from graphics than adults do. Texts with pictures were more effective than texts with mixed graphics, which may confirm Mayer's hypothesis that too many graphics impede learning. Inclusion of a graphic had a medium effect on reading comprehension, but "design quality may be more a feature of alignment between reader, text, and task" (Guo et al., 2020b, p. 14). The authors called for more empirical research into how, when, and for whom graphics increase reading comprehension.

Mayer (2020) stated that the multimedia principle applies to live, synchronous presentations as well as recorded, asynchronous instruction. To help students actively construct both pictorial and verbal mental models, instructors should present words and pictures, rather than just words alone. Redesign of ESP decks according to this principle shows the multimedia principle is effective in improving learning outcomes (Issa et al., 2011, 2013; Nagmoti, 2017; Pate & Posey, 2016).

The Personalization Principle

Mayer (2020) specified that learning is deeper when multimedia messages have a polite but conversational tone. Presenters create a more relaxed environment when they use pronouns more commonly associated with informal, friendly conversation, such as "I" and "you" and when they directly address the learner. Mayer's argument is that giving positive feedback, asking questions rather than giving directions, making comments that tell a story involving the learner, and relating the learning object to practical, everyday life can foster motivation (2020).

In a 2013 meta-analysis of the effects of designing instructional content in a conversational style, Ginns et al. found consistent effects on retention and transfer, as well as on perceived friendliness and effectiveness. Mayer (2020) confirmed support for the personalization principle in his analysis of 15 studies. In 13 of those studies, the median effect size for all learners presented "polite," personalized material was $d = 1.00$. None of these studies specifically analyzed synchronous distance learning environments. However, it would be worth exploring how instructors adhere to personalization strategies in synchronous distance environments, particularly as the research established an effect for low-achieving and low prior-knowledge students ($d = 0.58$), but not for high-achieving students ($d = -0.17$) (Mayer, 2020). Stiller and Jedlicka (2010) found similar results in a study of German grammar students: the benefit of personalization for low domain-specific prior knowledge students was higher than for others. They concluded that the personalization principle can create an expert reversal effect for high-knowledge students.

Boundary conditions for the personalization principle include novice learners with low prior knowledge, the level of student interest in the topic, and the duration length of the lesson (Ginns et al., 2013; Mayer, 2020; Schrader et al., 2018). Mayer (2020) pointed out an informal tone can be a source of distraction similar to a "seductive detail." Seductive details are usually highly interesting but irrelevant bits of material (Rey, 2012). While these details might cause an emotional response from the learner, they have been found to cause the learner to focus on irrelevant ideas rather than the material to be learned (Mayer et al., 2001; Rey, 2012).

Language proficiency may also be a confounding factor for the personalization principle: if a learner is not a native English speaker, but the lesson is presented in English, personalization seems to have no effect (Mayer, 2020). Other research confirmed the personalization principle applies to students learning in their native languages (Kartal, 2010; Stiller & Jedicka, 2010). In addition, personalized learning with content that could be considered emotionally unsettling might create an adverse effect, as Zander et al. (2017) found in an eye-tracking study concerning symptoms and causes of cerebral hemorrhages.

Mayer (2020) outlined six implications of the personalization principle for teachers using multimedia messages: 1) be aware of student experience level; 2) avoid straining student patience by adding personalized conversation to a long lesson; 3) maintain a polite, conversational style; 4) limit personal comments to relevance to the topic; 5) avoid personalizing emotionally upsetting content; and 6) refrain from exaggerated personalization. Both Issa et al. (2013) and Nagmoti (2017) found significant differences when they tested lessons using a conversational style of address.

The personalization principle will not be specifically analyzed in this research. However, when ESP decks are analyzed, attempts at personalization might be noted.

The Voice Principle

Mayer (2005) stated students learn more deeply when the instructor's voice is an appealing, friendly, standard-accented voice rather than an unappealing, a foreign-accented, or a computerized version of a human voice. In six out of seven tests, Mayer (2020) reported a median effect size of $d = 0.74$. This small base of studies showed results on the voice principle are only preliminary and more research is necessary. Recently, Davis et al. (2019) challenged assumptions that human voice is always preferable to computer-generated language when designing pedagogical agent instruction for second language learners. That study determined voice is more complicated than previously thought and argued that second language learners are significantly affected by the prosody of individual instructor voices. In a similar study, Craig and Schroeder (2017) found evidence that as voice engine software becomes more sophisticated, the difference in learning outcomes disappears.

While computerized voiceovers are not typically found in synchronous, online K-12 classrooms (and therefore will not be analyzed in this research), the voice principle has been found to apply most in studies where the tone of voice implies the instructor cares for the learner. Similar to the personalization principle, Mayer (2020) found learners may be more motivated to grasp a concept if they feel there is a relationship established with the instructor. As previously mentioned, perception of a relationship with the instructor is important in distance education because it is specifically tied to reducing feelings of TD. Another boundary issue applies to synchronous learning: When students cannot see socially accepted human gestures as the instructor is speaking, the voice principle becomes even more important (Mayer, 2020). An important implication of the voice principle for multimedia instruction is using a tone of voice that transmits a positive rapport between the instructor and the student.

The Embodiment Principle

Mayer (2020) explained, "People learn more deeply from multimedia presentations when an on-screen instructor displays high embodiment rather than low embodiment" (p. 341). Static images have low embodiment, as do virtual pedagogical agents with imprecise features, gestures, actions, or perspectives. High embodiment is measured by human-like eye contact, hand motions, explanatory drawings, and realistic body gestures. Mayer reported a medium median effect size of $d = 0.58$ across 16 of 17 empirical studies (all were STEM-related content). Studies researching embodied cognition that Mayer cites are relatively new; the oldest was published only 20 years ago. Therefore, boundary conditions and implications for multimedia instruction are still emerging. The embodiment principle will not be analyzed in this research because the K-12 school under investigation uses synchronous, live instruction with instructors' faces viewed on-screen during lessons.

The Generative Activity Principle

The generative learning activity principle is defined as "People learn more deeply when they are prompted to engage in generative activities during learning (e.g., summarizing, mapping, drawing, imagining, self-testing, self-explaining, teaching, or enacting)" (Mayer, 2020, pp. 387-388). The purpose of generative activity, as with the other principles in this group, is to help students integrate new material into long-term memory. It is reasonable to expect deep engagement with content through an activity will improve retention and transfer. A large body of research is the foundation for this principle, and Mayer reported an overall median effect size (across a range of content areas) for eight generative activities (in 37 studies) as $d = 0.71$. Three boundary conditions were found to affect generative activities negatively: when the activity is too complicated or demanding; when the activity is confusing; and when the learners are less-skilled or low-achieving.

An important implication for online instructors is to choose generative activities that are easy to understand and complete. Scaffolding or pretraining may be helpful. Combining generative activities may increase effectiveness. While this principle is not specifically investigated in this research, it is likely that ESP decks analyzed will contain graphics intended to be used for generative learning activity.

The Image Principle

Mayer (2020) claimed that "People do not learn better from multimedia presentations when a static image of the instructor is added to the screen" (p. 331). Static images are often found on instructive slideshows, in textbooks, or inside videos. Mayer argued that static images of humans are not lifelike and can be more of a distraction than a help to learners. As evidence, he presented a small median effect size ($d = 0.20$) from seven studies investigating STEM lessons. He also cited 10 other studies that found similar small or negative effects. However, Mayer also reported that if a static image is lifelike or explicitly draws attention to information crucial to understanding the material, then it might be helpful (p. 331).

A boundary condition for the image principle is closely tied to the previously mentioned embodiment principle. Mayer (2020) found that when the static image of an instructor contains high embodiment elements, such as lifelike gazes, gestures, or movement, then the embodiment principle applies, and when the static image points to pedagogically relevant information, then the signaling principle may apply (p. 336-337). Mayer recommends that more research needs to be done, but online instructors should consider social cues, such as images of participants, as they can distract learners and reduce learning outcomes.

The Immersion Principle

The immersion principle applies to learning environments where learners wear head-mounted displays and feel like they are moving through and interacting with an actual space (Pausch et al., 1997). Mayer (2020) gave this definition: "People do not necessarily learn better in 3D immersive virtual reality than with a corresponding 2D desktop presentation" (p. 357). The words "do not necessarily" imply that more research is needed. A recent meta-analysis conducted by Han et al. (2021) confirms this need. Their study concerning cognitive load and immersive virtual reality environments reported conflicting results with large research gaps. The literature reviewed showed certain factors appear to complicate learning results: individual differences (including attitude, gender, physical ability, age, and working memory); prior experience (including pretraining); task design and complexity; and the design of the immersive reality experience (instructional, environment, learning strategy, etc.).

Mayer (2020) reported a median negative effect size (*d* = -0.10) in six of nine studies using STEM content for the immersion principle and strongly cautioned against embracing virtual reality as a teaching strategy until more extensive empirical research is conducted. Mayer acknowledged other researchers find value in arousing learners' attention (priming behavioral activity) and have found that there are motivational features of immersive virtual reality, such as increased feelings of presence—feelings which may positively affect learner's motivation (p. 360). Yet, he argued it is more important to determine the efficacy of an instructional technique based on meaningful learning outcomes (priming cognitive activity) instead of motivation (p. 20). Mayer stated on page 361 that "it is possible that both hypotheses have merit such that the challenge of instructional design is to mitigate the distracting potential of high-immersion environments while maximizing their motivating potential" (p. 361). Others have also confirmed the inconclusive nature of current findings regarding immersive virtual reality and call for deeper investigation (Baceviciute et al., 2021).

Mayer (2020) pointed out that one boundary condition for the immersion principle is the lack of transfer between experimental groups when two instructional methods with different materials are compared. For example, 3D VR (three-dimensional Virtual Reality) instruction is active and 2D (two dimensional) static laptop instruction is passive (p. 365-366). A second boundary condition is the learner's individual experience with VR technology since those with experience may have results different from those who do not have experience (p. 366). According to Mayer (2020), current test evidence does not provide a "strong rationale to call for a large-scale conversion of multimedia lessons… to delivery in 3D immersive virtual reality" (p. 366-367). 3D VR learning is not the subject of this investigation.

Principles to Manage Essential Processing

A second type of mental processing during learning is called "essential," and it occurs in the working memory when new information is first perceived. It is during this essential stage learners select and organize images and sounds so they make sense (Çakiroğlu & Aksoy, 2017; Mayer, 2020). It is impossible to eliminate the cognitive load required to select and organize new material, but it is possible to manage the load during this working memory stage, thereby increasing the possibility of generative processing in the next stage. Three closely connected and effective ways to facilitate essential learning are to ensure learners are familiar with terms and definitions before the application of skills is modeled (the pretraining principle); to present the material in small, manageable chunks (the segmenting principle); and to use verbal narration rather than printed words when presenting images (the modality principle) (Mayer, 2020).

The Pretraining Principle

Mayer (2020) found that people learn more deeply from a multimedia message when they understand key terms and characteristics of the individual parts before a complex lesson (pretraining). Mayer reported a median effect size of $d = 0.78$ in 10 of 10 studies for the pretraining principle (2021). In addition, a large body of research conducted by scholars investigating CLT shows consistent and similar support for what Mayer calls the pretraining principle (Kester et al., 2004; van Merriënboer et al., 2006; van Merriënboer & Kirschner, 2018). Pretraining is most effective in managing essential processing when the learners are unfamiliar with the material, when the material is complex, and when the lesson is fast paced (Mayer, 2020; Pollock et al., 2002). Obvious implications for teachers would be to ensure they know their students' experience levels and domain knowledge and to determine which individual students need pretraining.

Yue et al. (2013) found that only 7.7% of 430 instructional medical animations included a glossary of key terms used. Similarly, Noyes et al. (2020) determined only 13% of 30 veterinary medical education animations included any pretraining elements. Pantazes (2021) concluded from triangulating data from surveys, interviews, and observed videos of instructors in online higher education that none of those interviewed had explicit knowledge of the pretraining principle, and "one out of every four instructors reports that they are not instructing students on key vocabulary or concepts prior to watching their instructional video" (p. 113). It is unknown how many online K-12 teachers pretrain important terms or ideas when teaching a complex idea, and considering adherence reports from the literature, it is reasonable to assume some teachers will include slides with definitions as part of their ESP submissions while others will not.

The Segmenting Principle

Research on CLT and CTML shows that when instructors present material in a series of smaller segments that build sequentially instead of presenting a linear lesson with several interacting parts (i.e., highly complex material), cognitive load is reduced, and learners are better able to construct new mental models (Mayer, 2020; Pollock et al., 2002; Yue et al., 2013). A median effect size of $d = .67$ across seven of seven STEM-related tests revealed that instructional multimedia lessons broken into user-controlled segments are more easily understandable than one long, continuous presentation (Mayer, 2020). Rey et al. (2019) reported a median effect size of $d = 0.36$ when 56 segmented experiments were tested for transfer, but that effect size increased to a significant number, $d = 0.45$, when only the 16 segmented tests that also allowed users to control the pacing were analyzed. An expertise reversal effect might apply to students with more domain knowledge (Khacharem et al., 2020). More research is needed.

Yue et al. (2013) analyzed publicly available medical animations and found that 61.2% allowed user pacing, permitting students to control navigation through segments and to manipulate various elements. A 2020 study conducted by Noyes et al., however, only found 30% of veterinary science animations had similar features. Pantazes (2021) clarified that all the instructors he interviewed said they used the segmenting principle by intentionally dividing content into manageable chunks and limiting their video length, but none explicitly defined their actions in terms of the segmenting principle.

Students using the ESP materials to learn in this synchronous study will not control the pace of the material presentation unless they are asynchronously watching a recording rather than participating in a live session. No analysis of the segmenting principle will be included. However, it will be possible to tell from the ESP decks whether some teachers break complex material into smaller chunks by creating separate ESP slides for each part.

The Modality Principle

Mayer (2020) defined the modality principle simply: "People learn more deeply from pictures and spoken words than from pictures and printed words" (p. 281). This principle is based on DCT. If learners attend to visual processing of an image or animation, then cognitive energy is saved when concurrent verbal information is presented aurally. But if learners are forced to split their visual attention to process multiple images simultaneously, learning may be reduced. Mayer (2020) reported a median effect size of $d = 1.00$ in 18 out of 19 experimental tests using STEM-based lesson content. He also cautioned that printed text should not be avoided altogether, but instructors should consider the specific learning conditions.

Mayer (2020) stated that the modality principle is stronger when these conditions are present: 1) the lesson pace is fast, with no learner control; 2) the lesson contains vocabulary the learner is unfamiliar with (such as second-language learners); 3) the lesson material is complex; or 4) the skill tested is transfer (rather than simply retention). Castro-Alonso et al. (2019a) added that the modality principle (referred to as the modality effect in CLT literature) can also be influenced by individual learner's visuo-spatial processing ability.

Yue et al. (2013) found that very few (17.4%) medical animations incorporated the modality principle, but Noyes et al. (2020) stated the veterinary science animations they examined adhered to the modality principle approximately 75% of the time. This large discrepancy is not explained in the literature. More adherence studies are needed, and succinct descriptions should be normalized for those studies. Pantazes (2021) reported that in his small case study, videos created by online instructors contained written text in addition to audio narration of the text; he concluded that even though those instructors stated in a survey they adhered to the modality principle, in fact, they did not.

Researchers undertaking redesign of ESP decks saw significant improvement in learning when their new slide designs adhered to the modality principle (Issa et al., 2011, 2013; Nagmoti, 2017; Pate & Posey, 2016).

Principles to Reduce Extraneous Processing

The human information processing system, according to CTML, has been presented in reverse order in this literature review. The first step covered, generative learning, is the ideal culmination of well-taught lessons: when learners actively connect and integrate new material into long-term memory. It is not a given that learners will master new material if someone simply feeds them information; the students must allocate time and apply mental effort. Rather, it is less likely students will understand at a deep level unless they have correctly selected and organized the essential material (the second step in the process). Therefore, the first step in the process—the initial presentation of new material—takes on crucial importance. As explained previously, CTML assumes each learner has a limited cognitive capacity. When an instructor presents lessons that are confusing or filled with irrelevant materials, the learner must spend limited cognitive resources weeding out unessential details (Mayer, 2014, 2020; Mayer & Moreno, 2003; Noyes, 2019; Sweller et al., 1998, 2019). In this situation, some students suffer from extraneous overload (Mayer, 2014). The five principles in this group (coherence, signaling, spatial contiguity, temporal contiguity, and redundancy) are used to minimize cognitive overload by reducing extraneous processing.

The Coherence Principle

The coherence principle states that people learn better when extraneous material does not compete for mental processing resources (Mayer, 2020). Any unrelated information can hinder the learner's ability to process new information and build new schema (Mayer et al., 2008; Mayer & Fiorella, 2014; Moreno & Mayer, 2000; Sweller, 2010a). Çakiroğlu and Aksoy (2017) cautioned that browser-based problems, audio issues, and reduced visibility during screen sharing violate the coherence principle and negatively interrupt learning. However, incoherent materials are most often caused by poor instructional design (Shamim, 2018; Sweller et al., 1998; Sweller & Chandler, 1991). Garner and Alley (2013) found that PowerPoint-based instruction that violated the coherence principle caused cognitive overload and negatively affected learning outcomes.

Seductive Details. The coherence principle is violated when learning materials cause confusion. Instructors or designers may inadvertently create confusion by attempting to "arouse" learners' attention by adding interesting items, inserting extra words or symbols (unnecessary details), or including unessential background music or sounds (Lehmann & Seufert, 2017; Mayer, 2020; Mayer & Moreno, 2003; Moreno & Mayer, 2000). Design that relies on stimulating student interest by introducing off-topic ideas creates the "seductive details" effect (Garner et al., 1989, as cited in Sundararajan & Adesope, 2020). Seductive details interfere with selecting, organizing, and integrating new information (Mayer, 2020; Mayer et al., 2008; Rey, 2012).

Three meta-analyses confirmed learning with seductive details results in lower outcomes (Rey, 2012; Sundararajan & Adesope, 2020; Thalheimer, 2004). Different conditions moderate the effect, such as the nature of the seductive detail, the timing, the format (static or dynamic images or text), the placement on the page or slide or at different times during the lesson, the subject content, and student characteristics such as language, spatial ability, or prior knowledge (Harp & Mayer, 1998; Harp & Maslich, 2005; Park et al., 2015; Sundararajan & Adesope, 2020; Wang et al., 2021). Rey (2012) reported in their meta-analysis that in some studies, participants who received material with seductive details spent more time on the lesson, but not necessarily on the main content to be learned. Perhaps seductive details cause confusion for leaners, and instructors must then spend valuable instructional time clarifying. It is unknown whether K-12 virtual teachers who have set time periods for their classes inadvertently lose instruction time due to seductive details in their ESP decks.

Coherence and Background Music. Moreno and Mayer (2000) found evidence that adding extraneous auditory information to multimedia instructional messages interfered with learners' comprehension and transfer. The experiment investigated two-to-three-minute lessons that included visual elements and both narration and background music. Brunken et al. (2004) confirmed across several experiments that the presentation of audiovisual materials creates a higher cognitive load compared to visual-only presentations. Those results were primarily concerned with the modality principle. However, the study also explored whether background music would interfere with learning outcomes when it was present without narration. This difference in conditions led the authors to conclude: "Only in a situation where the auditory channel is already used for information processing–as in the audiovisual presentation condition–does background music have a load effect and, as a result, a negative impact on learning" (p. 130). In addition, they suggested that differences in other conditions between the two studies, including lesson duration (2-3 minutes compared to 15 minutes), might have contributed to the contrasting results. More recently, Lehmann and Seufert (2017) investigated the influence of background music through multiple theoretical lenses, with working memory as a factor. Their results align with the seductive details assumption that learners with higher working memory capacity are less influenced by background music than students with low working memory capacity.

Coherence Effects. In his review of studies measuring performance by learners who received concise, coherent multimedia presentations rather than lessons with extraneous material, Mayer (2020) found a median effect size of $d = 0.86$ in 18 out of 19 studies. When broken down further, these studies showed a median effect size of $d = 1.27$ when seductive details were removed, $d = .70$ when additional details were removed, and $d = 0.95$ when background music was removed. In the meta-analysis of 58 studies conducted by Sundararajan and Adesope (2020), the authors found no significant effects were found for dynamic seductive details, but a moderate effect of g = -0.43 resulted from static seductive details. Individual attention and spatial ability, as well as prior knowledge levels, have been found to moderate the effects of seductive details (Park et al., 2015; Rey, 2012).

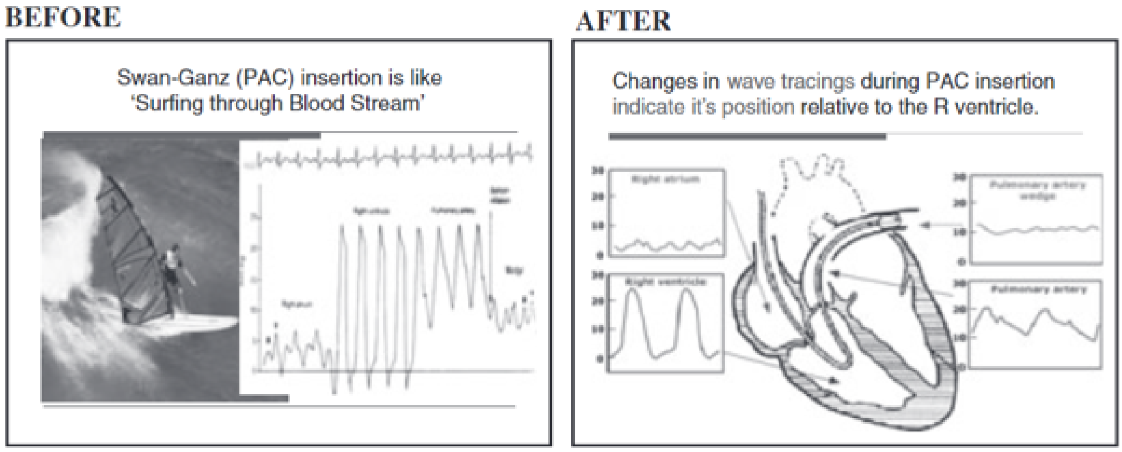
Recommended Design Practices: The Coherence Principle. A multimedia message can be evaluated for adherence to the coherence principle by examining it for seductive or unnecessary details and background music that is not relevant to the subject content. To reduce extraneous cognitive processing, instructors and designers should delete seductive details, remove additional text and images, and eliminate unnecessary sounds, including background music (Mayer, 2020). Known boundary conditions associated with the coherence principle include the interestingness level of the seductive detail and the students' working memory capacities (Castro-Alonso et al., 2019a; Mayer, 2020).

Adherence to the Coherence Principle. Yue et al. (2013) examined 430 publicly available medical animations and found that 67% adhered to the coherence principle. However, they also stated that over two-thirds contained at least one design element that could lead to extraneous processing (e.g., background music, distracting or irrelevant images). Noyes et al. (2020) investigated adherence to the coherence principle in a much smaller study. They examined 30 veterinary education animations and found 87% coherence "by presenting essential information without adding text, graphics, or narration that was unrelated to the learning material" (p. 73). Pantazes (2021) found that 90% of online college instructors surveyed said they avoided including unnecessary music in their class videos, but 73.5% said their videos contained "decorative visuals or video that are not essential for learning" (p. 83). On a secondary question, only 54% said they never used extra visual or auditory elements in their videos. Those results may show instructors are not consistent in their implementation of the coherence principle. A different element in Pantazes' study was a set of interviews with five instructors who had the highest CTML implementation scores from the survey. Interview results suggested that most participants believed adding background music is inappropriate to learning situations, although none of the interviewees demonstrated explicit knowledge of the CTML principles.

ESP Redesign: Coherence Principle. Issa et al. (2011, 2013) found that when instructional PowerPoint slides were modified from a traditional design to a style that implemented CTML principles, there was a significant difference in test scores and retention (although not for transfer) between groups. Figure 2 *Coherence ESP Redesign* displays before and after slides from Issa et al. (2011). The "seductive" detail, a pun-based image of a surfer, was removed, and a more relevant image of a heart was substituted. In similar PowerPoint redesign studies, researchers reported eliminating images or text not directly related to the content being taught (Garner & Alley, 2013; Nagmoti, 2017; Pate & Posey, 2016).

Figure 2

Coherence ESP Redesign



Note: PowerPoint slides were redesigned to adhere to the coherence principle according to CTML. Reprinted from "Applying multimedia design principles enhances learning in medical education" by Issa, N., Schuller, M., Santacaterina, S., Shapiro, M., Wang, E., Mayer, R. E., & DaRosa, D. A. (2011). *Medical Education, 45*(8), 818-826. Copyright 2011 by Blackwell Publishing Ltd. Reprinted with permission.

The Signaling Principle

The signaling principle, sometimes called the "cueing" principle, is defined by Mayer (2020) as: "People learn better when cues are added that highlight the organization of the essential material" (p. 166). When signals direct learner attention to essential elements of the material, learning outcomes improve (Mautone & Mayer, 2001; Mayer, 2014; van Gog, 2014). Mayer (2020) delineated two types of signaling (visual and verbal) and found that each has a different set of boundary conditions. Visual signals are processed through the eyes and accompany narration. Examples of visual signals include the use of bold, highlighting, arrows, zooming, transparency effects, different colors and physical gestures. Verbal signals are processed through the ears; the label refers to the use of words, whether delivered out loud or in print. Verbal signals include titles, headers, labels, and graphic organizers (Castro-Alonso et al., 2019a; Liu et al., 2020; Mautone & Mayer, 2001; Mayer, 2020; Noyes et al. 2020; Richter & Scheiter, 2019; Schneider et al., 2018; Xie et al., 2019).

Bolkan (2017) suggested that signaling not only works to prevent extraneous load but also functions to help students integrate essential information (germane processing). In a meta-analysis of the signaling principle covering 1995-2016, Xie et al. (2017) confirmed previous studies showing that cueing "reduces learners' perceived cognitive load" (mental difficulty) and positively affects retention and transfer (p. 11). Signaling can lead to increased learning in both static and animated multimedia presentations (Alpizar et al., 2020; De Koning et al., 2007; Richter & Scheiter, 2019; Tabbers et al., 2004). However, others suggested the benefit of cueing is not statistically tied to a reduction in perceived cognitive load, and therefore the beneficial consequence of signaling needs further exploration (Schneider et al., 2018; Schroeder & Cenkci, 2019). Schneider et al. (2018) also determined "signaling was most effective in geology/geography/ecology and psychology/education. Biology and physics/mechanics had smaller effect sizes. Math/statistics was the only category in which the effect was non-significant" (p. 17), and may, therefore, be an area of interest to virtual K-12 instructors.

The Expertise Reversal Effect. Kalyuga (2007) explained, "Studies of expert–novice differences in recent decades have clearly demonstrated that learner knowledge base is a single most important cognitive characteristic that influences learning and performance" (p. 510). Several studies and meta-analyses have confirmed that, while the signaling effect is moderated by pacing, format, complexity, and type of signals, it is most significantly influenced by prior knowledge (Alpizar et al., 2020; Arslan-Ari, 2018; Johnson et al., 2015; Mautone & Mayer, 2001). While it would be easy to assume that if a multimedia principle applied effectively to one student, it would apply to all students. The opposite is true. Expert learners with high prior knowledge of content can be affected by the expertise reversal effect (Kalyuga et al., 2007). This effect was found as a result of an investigation into the interaction between the effectiveness of an instructional technique and students with varying levels of prior knowledge (Kalyuga, 2007; Kalyuga & Renkl, 2010). For example, in one eye-tracking study with secondary students, Richter and Scheiter (2019) confirmed novice, or low prior knowledge, learners were aided by multimedia signals, but high prior knowledge students were not affected because of a partial expertise reversal, which induced higher cognitive load.

Signaling Effects. Mayer (2020) reported that in 15 of 16 tests covering verbal signals, the signaling principle showed an average median effect size of $d = 0.69$. Likewise, a similar average effect size of $d = 0.71$ was found across 11 of 12 tests concerning visual signaling. When data was limited to only the studies on multimedia lessons, the effect was not as high, but was still powerful: in 7 of 8 tests, the median effect size was $d = 0.51$.

Recommended Design Practices: The Signaling Principle. In chapter seven of *Multimedia Learning*, Mayer (2020) encourages teacher designers to add verbal, visual, and physical signals. When considering whether a multimedia message adheres to the principle, evaluators should consider the following questions: Are verbal signals in the form of outlines, headings, pointer words, or graphic organizers included? Are visual signals in the form of color coding, spotlights, or arrows included? Are gestures included to focus attention? Are vocally stressed key words coordinated with visual movement or size/color changes in real time? To counter known boundary conditions associated with the signaling principle, it is recommended to avoid extraneous material, organize material logically, and use signals (sparingly) when learners have low working memory capacity or low prior knowledge.

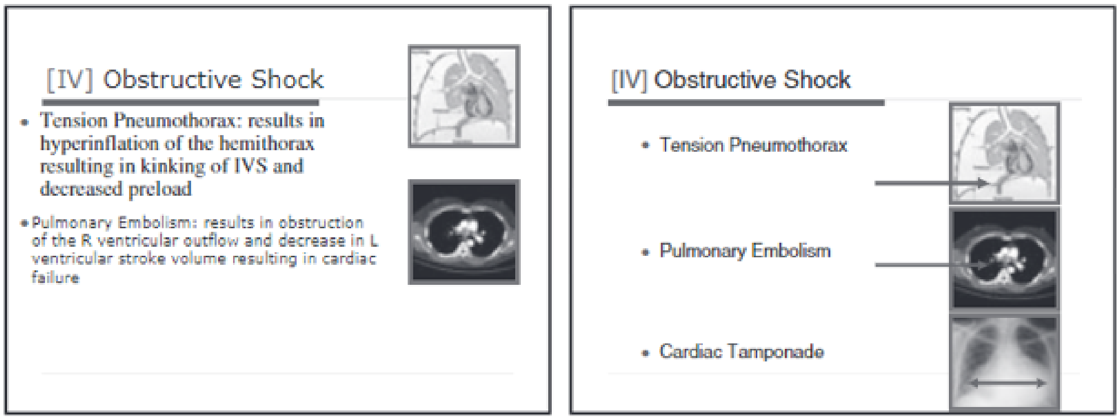
Adherence to the Signaling Principle. In a 2020 study examining adherence of instructional animations to the signaling principle, Noyes et al. reported that approximately one third of animations showed the principle by including verbal headings and outlines or visual signals such as arrows or highlighting. Yue et al. (2013) found similar statistics. In that study, less than 20% of instructional animations demonstrated the signaling principle. Although 73.0% of the animations examined provided a verbal header signal, less than 20% provided an outline and less than 10% included labels. Pantazes (2021) found 76% of online instructors who created a video for their students said they included signals such as vocal cues, and visual shapes and colors. However, discrepancies were found when the videos were analyzed for adherence. Although these results cannot be generalized, it is a possibility that K-12 virtual teachers will implement the signaling principle at various levels.

ESP Redesign: The Signaling Principle. Five studies testing the difference in learning outcomes when PowerPoint ESP decks were redesigned to adhere to the CTML were previously identified in this literature review. Each study reported beneficial effects, but none separated those results by principle. Each study made several changes to the ESP slides, often addressing multiple principles per slide. Therefore, it is impossible to draw any conclusions or generalizations. However, it may be helpful to see the images provided by Issa et al. (2011) demonstrating their ESP deck before and after they applied the signaling principle (Figure 3 *Signaling ESP Redesign*). Issa et al. (2013) stated: "We highlighted important teaching points by using a larger font and a different colour" (p. 390), and Nagmoti (2017) explained about their redesign study: "Important and essential key points were highlighted and were reinforced during presentation" (p. 200). Pate and Posey (2016) reported they placed arrows and words next to important concepts in their redesign study. Garner and Alley (2013) transformed slides in their

ESP deck to include one short textual assertion as a headline and supported that assertion with visual evidence on the main part of the slide. They suggested this format reduces the number of mental steps a learner must do to understand the material.

Figure 3

Signaling ESP Redesign



Note: PowerPoint slides were redesigned to adhere to the signaling principle according to CTML. Reprinted from "Applying multimedia design principles enhances learning in medical education" by Issa, N., Schuller, M., Santacaterina, S., Shapiro, M., Wang, E., Mayer, R. E., & DaRosa, D. A. (2011). *Medical Education, 45*(8), 818-826. Copyright 2011 by Blackwell Publishing Ltd. Reprinted with permission.

The Contiguity Principle: Spatial and Temporal

Split Attention. Cognitive load is increased and learning outcomes are reduced when multiple pieces of content required to understand a lesson are separated from each other (Chandler & Sweller, 1991; Sweller & Chandler, 1994; Tarmizi & Sweller, 1988). According to CLT, learners' attention can suffer from a split attention effect whenever learning materials required for comprehension are disconnected from each other. Instructional materials might be separated by space (physical proximity) or by time (successive presentation rather than concurrent). Disparate materials can cause overload in any learning environment: multimedia only, paper-based only, or a combination (Mayer, 2020). This split attention can occur with various materials: multimedia, paper, or a combination (Mayer, 2020).

CTML, in contrast, parsed the split attention effect into three different principles: spatial contiguity, temporal contiguity, and modality, "because they translate more directly into clear design principles" (Mayer, 2020, p. 233). If learners attempt to examine a diagram and read explanatory text placed on the other side of the page or slide simultaneously, they experience a split attention effect. By offloading the second form of visual information (the text), and replacing it with narration, the teacher designer would reduce competition for cognitive resources. If live narration is impossible, a second alternative, adding a simple label near the image, was also reported as effective. However, material complexity and learner prior knowledge have found to moderate the spatial contiguity principle (Mayer, 2020**).**

Mayer explained that "People learn better when corresponding words and pictures are presented simultaneously rather than successively" (p. 227) and labeled this the temporal contiguity principle. When learners examine a graphic presentation of the material and experience a time delay between reading or listening to an explanation of the content, they can experience split attention. According to CTML, it would be better for learners to receive graphic content and auditory explanation simultaneously. Ginns' (2006) meta-analysis confirmed learning outcomes improve by increasing temporal contiguity, particularly when novice learners with low prior knowledge study complex material. However, Khacharem et al. (2020) found that while novice learners with low prior knowledge saw greater learning outcomes when materials were presented simultaneously in time, those with high prior knowledge experienced an expertise reversal effect.

The temporal contiguity principle will not be analyzed in this study, so the following sections are limited to the spatial contiguity principle.

Spatial Contiguity Effects. Mayer (2020) reported that in nine of nine tests, an effect size of $d = 0.82$ was found for transfer when words and pictures were placed near each other. Ginns (2006) analyzed 50 studies, 20 from primary through secondary school and 30 from adult learning environments in STEM-based courses. The studies were reported between 1983 and 2004. The meta-analysis confirmed earlier findings that when multimedia materials are presented in proximity, learning is enhanced. An overall effect size for spatial contiguity was $d = 0.72$, and the impact was strongest when the materials were complex. Schroeder and Cenkci (2018) arrived at comparable effect size results in a more recent study covering studies reported with similar STEM content (they reported effects at the K-12 level as $g = 0.99$ compared to $g = 0.72$ at the postsecondary level). While effect sizes were large for both groups, these results show future studies should focus more on the differences between K-12 and higher education students.

Florax and Ploetzner (2010) replicated the split attention effect when they tested text segmentation. They saw effects on retention, but only a partial effect due to picture labeling, and they found no enhancement of learning with spatial integration. They suggested working memory capacity does not affect performance as much as spatial ability.

In 2019, Schroeder and Cenkci analyzed 12 studies concerning the effects of integrated visual images with spatially contiguous images and words that assessed perceived and objectively measured cognitive load. The purpose of the study was to find empirical evidence the positive effect of the spatial contiguity principle is due to a reduction of extraneous cognitive load. Instead, the authors determined most of the studies did not find statistically significant differences in measured cognitive load between integrated graphic designs and spatially distant designs. They pointed out there is “no generally agreed upon best practice for measuring cognitive load” (p. 3) and suggested looking to other theories to explain the spatial contiguity effect until a robust way to measure cognitive load is determined.

Recommended Design Practices: The Spatial Contiguity Principle. CTML-recommended design practices published in *Multimedia Learning* (Mayer, 2020) include removing seductive details, deleting additional images or text, eliminating unessential sounds, and coordinating color-coded text to auditory cues when possible. Ginns (2006) confirmed teacher designers should be diligent about reducing split attention with spatially distant words and images, especially when learning materials have high interactivity.

Adherence to the Contiguity Principles. The contiguity principle appears to be one of the most frequently implemented of all CTML principles in animated multimedia messages. Yue et al. (2013) reported 92% of animations that used labels presented them close to their corresponding, and Noyes et al. (2020) found a similar rate of 70% in their study.

ESP Redesign: Contiguity Principle. The only description of the contiguity principle mentioned in the ESP redesign study by Issa et al. (2013) stated the instructors placed graphics near related words. It is unknown if the traditional ESP slides were significantly out of line with the contiguity principles or not. Nagmoti (2017) specified that the traditional slide group in their redesign study received slides with text and pictures placed away from each other and presented in succession, therefore violating both the spatial and the temporal contiguity principles. The redesign group received ESP where text and pictures were presented close to each other and simultaneously. Figure 4 *Spatial Contiguity ESP Redesign* from Pate and Posey (2016) shows spatial contiguity was achieved by the addition of short labels next to corresponding images.

Figure 4

Spatial Contiguity ESP Redesign

Before After

Note: PowerPoint slides were redesigned to adhere to the signaling principle according to CTML. Reprinted from "Effects of applying multimedia design principles in PowerPoint lecture redesign" by Pate, A. and Posey, S. (2016). *Currents in Pharmacy Teaching and Learning, 8*(2), 235-239. Copyright 2015 by Elsevier Inc. Reprinted with permission.

Leslie et al. (2012) compared elementary school low prior knowledge and high prior knowledge learners in two conditions: either auditory alone or auditory plus visual presentations. The knowledge levels were determined by grade levels (the groups had a one-year difference between them), and by each grade level's experience of the concept from the previous year. Knowledge level was not determined by individual student ability. The high prior knowledge students (second-year learners) who received auditory-only instruction of the essential information had the highest outcomes, but for the younger, low prior knowledge students, "audio presentation might be facilitated by the inclusion of additional, visual information" (p. 11). Kalyuga et al. (2000) found learners with low prior knowledge were more affected by redundant elements, and high prior knowledge learners performed best when presented with a visual diagram with no text.

The Redundancy Principle

According to the CTML, "People do not learn better when printed text is added to graphics and narration" (Mayer, 2020, p. 186). Rather, if a learner is simultaneously using their eyes to process graphic information and their ears to process verbal information, then they will learn better when a human narrates an explanation instead of adding printed text. Experimental evidence showing that including redundant information reduces learning outcomes is referred to as the redundancy effect (Kalyuga & Sweller, 2014). Many people find the principle to be counterintuitive, as it appears logical to assume repetition will deepen student understanding of an idea (Chandler & Sweller, 1991; Kalyuga & Sweller, 2014; Sweller et al., 2019). However, in an extensive review of the literature, Kalyuga & Sweller (2014) documented a long history of experimental results in support of eliminating redundant information across all grade levels and subject areas (see also Dousay, 2016 and Leslie et al., 2012). Any information can be redundant, including diagrams, materials, pictures, animations, and text, depending on what is being taught (Kalyuga & Sweller, 2014).

Some researchers adhere to a broad definition of the redundancy effect in multimedia. That is, when any form of redundant information is eliminated, learning should increase. This meaning includes two scenarios: when identical information is presented in more than format (audio and visual) and when repetitive elaboration is added (Castro-Alonso et al., 2019a; Kalyuga & Sweller, 2014). Mayer (2020) provides a slightly different definition and refers to redundancy as when identical material is presented in different modalities. Mayer differentiates between a scenario in which learners perceive graphics and narration as good for learning (modality effect), but as soon as identical text is added to the online screen, a negative competition for visual cognitive resources impairs learning.

Both groups of researchers agree that, to improve learning outcomes, instructors should avoid overloading cognitive processing capacity. Kalyuga and Sweller (2014) explicitly connected instructional design to the redundancy principle and insisted, "Multiple versions of the same information or unnecessary additional information do not compensate for an inadequate instructional design. Rather, they compound design problems" (p. 260). They also pointed out that instructors often use simultaneously spoken and written text during PowerPointpresentations, which could impede learning by introducing redundant conditions.

Most of the common learning problems mentioned in this review so far converge on the redundancy principle. For example, the redundancy principle is compounded when divided materials are presented in split-attention conditions (Kalyuga et al., 1999; Kalyuga & Sweller, 2014). As well, seductive details presented as interesting but redundant information can interfere with mental processing (Yue & Bjork, 2017). Kalyuga and Renkle (2010) posited that student prior knowledge is the single-most important predictor of outcome and is a significant factor in the expertise reversal effect, which moderates the redundancy principle (see also Rey & Buchwald, 2011). Care must be taken by instructors and designers because of the complexity of factors.

Redundancy Effects. Mixed results have been found concerning redundancy effects. Mayer (2020) documented a low median effect size of d = 0.10 in eight of 12 tests where participants were in a condition that received information in graphics and narration instead of graphics, narration, and print. However, in five of five tests, a high median effect size of d = 0.72 was found in the same group conditions but with the addition of a fast pace. In contrast, Adesope and Nesbit (2012) found no significant differences between groups of participants who received material with and without redundant elements. These mixed results can probably be explained by the boundary conditions mentioned previously (Pantazes, 2021).

Recommended Design Practices: The Redundancy Principle. CTML (Mayer, 2020) suggested helping learners organize material by using cues to point out essential information. CTML suggests teachers avoid reading long segments of text aloud or adding text that duplicates narration. While specific boundary conditions need more investigation to inform ESP design practices, Mayer stated there is enough evidence to encourage instructors and designers to avoid presenting mixed text (spoken and written) when visual images are present, the lesson is fast-paced, or the pace cannot be controlled by the learner. Mayer provided evidence that, in some situations, violating the redundancy principle might not have adverse consequences. For example, adding short text labels when there is also narration can be helpful if the vocabulary is new to the learner.

Other studies confirmed the redundancy principle and suggested specific design recommendations for controlling the redundancy effect. For instance, Castro-Alonso et al. (2019a) found redundancy is relevant for students with low visuospatial processing skill. As a result, they state instructors and designers should not require students to coordinate multiple forms of the same information, nor should they add unnecessary details or elaboration.

While a majority of Mayer's studies focus on short segments of instruction, Kalyuga (2004) addressed longer segments of text. To reduce both the split attention and redundancy effects, they suggest teachers break text passages into small, logical sections with time to process the content after each. Kalyuga and Sweller (2014) pointed out that in studies that failed to find a redundancy effect, the length of the text passage, whether narrated or written, appeared to influence results. They found longer passages of around 350-word segments may exceed learners' working memory. Online virtual teachers in content areas with heavy text may be affected.

Adherence to the Redundancy Principle. Yue et al. (2013) analyzed animations of basic science, pathophysiology of diseases, or surgical procedures and found only 45.6% of the 430 samples relied on verbal narration rather than adding printed text to a visual, and 54.4% used verbatim text with narration. In addition, they found that in most (about two-thirds) of the animations, learners had no control over any interactive parts.

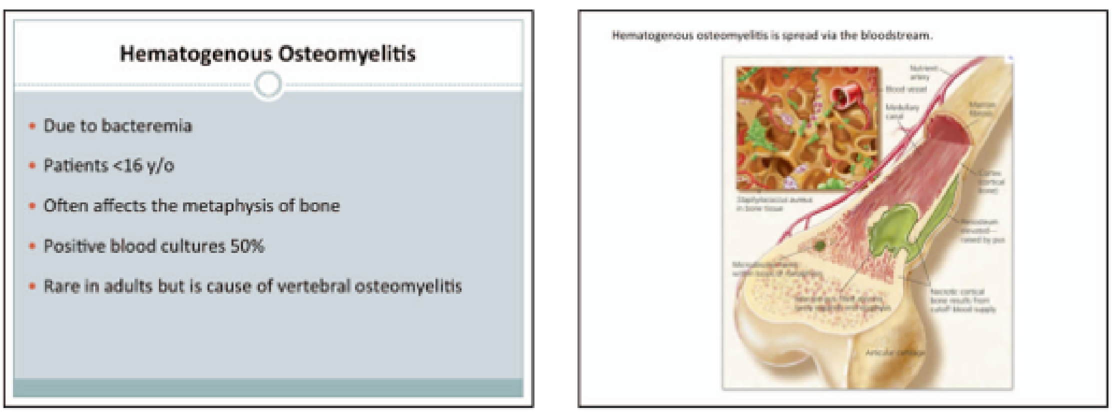
In a second study, Noyes (2020) analyzed 30 veterinary science animations and determined a significantly higher percentage, 90%, of those animations adhered to the redundancy principle because the speakers did not narrate the on-screen text verbatim. However, they did not report how many samples refrained from adding redundant text that simply presented the same content in a different modality.

When Pantazes (2021) analyzed video artifacts created by five university professors for their students, he found less than 40% applied the redundancy principle. Pantazes stated that "instructors may find it necessary to occasionally violate the principle in order to meet the signaling principle" (p. 105). This study also described how the instructors planned for their videos, and four of the five created PowerPoint presentations in advance. Interestingly, only the professor who did not preplan or use PowerPoint adhered completely to the redundancy principle. The other four indicated their slides were text heavy because they were either using the slides as the textbook for the students or they were relying on the slides to act as an outline for what they needed to explain.

ESP Redesign: Redundancy Principle. Figure 5, *Redundancy ESP Redesign*, includes before and after ESP images from Pate and Posey (2016), demonstrating how the authors eliminated redundant text when redesigning a traditional bullet-point ESP to adhere to CTML principles. As with the other redesign examples provided in this review, more than one principle was applied in the redesign, so the before and after images look significantly different. The authors stated they presented narration to eliminate on-screen text. In addition, they applied the spatial contiguity principle by adding text labels to the image they added to the slide.

Figure 5

Redundancy ESP Redesign



Note: PowerPoint slides were redesigned to adhere to the redundancy principle according to CTML. Reprinted from "Effects of applying multimedia design principles in PowerPoint lecture redesign" by Pate, A. and Posey, S. (2016). *Currents in Pharmacy Teaching and Learning, 8*(2), 235-239. Copyright 2015 by Elsevier Inc. Reprinted with permission.

Conclusion

K-12 students who attend for-profit virtual schools managed by EMOs are more likely to see significant negative impact on achievement scores persist over time. The CTML principles have been proven to improve learning outcomes for students in multimedia learning environments when implemented correctly. Based on the currently available literature, it is reasonable to assume that K-12 virtual school students may see improvement in learning when CTML principles are applied to the ESP their instructors use to conduct classes. It is unknown whether online virtual K-12 teachers and ESP designers are aware of the principles or implement them.

Chapter III

Method

The focus of this study is to analyze the perceptions of virtual K-12 teachers and their practice in creating electronic slideshow presentations (ESP) that minimize extraneous cognitive processing. Teachers will complete a questionnaire and submit an ESP which will be examined. Both tasks are based on Mayer's *Multimedia Learning* (2021) and developed by the researcher to answer the following questions specific to this study:

1. To what extent do ESP designed by online K-12 teachers adhere to the four CTML principles that reduce extraneous cognitive processing?
2. Is there an association between teachers' perceptions of their ability to reduce extraneous cognitive load and their implementation of the design recommendations for these four principles?
3. Are there group differences between teachers' adherence to the four target principles according to gender, content area, teaching level, education level, or number of years' experience teaching in an online synchronous environment?
4. How much do gender, content area, teaching level, education level, and experience teaching synchronous online classes explain the variation in adherence to the Cognitive Theory of Multimedia Learning principles?

Setting and Participants

The setting for this study was an online, public, chartered community school district located in Ohio. Established in 2002, the academy currently serves over 20,000 full-time K-12 students living across the state of Ohio (Ohio Virtual Academy, 2021a). The district is organized as an academy with one elementary school (grades K-5), one middle school (grades 6-8), and one high school (grades 9-12) (Ohio Virtual Academy, 2021a). The district has an administrative office but no physical classrooms. In the fall of 2021, 9,089 students were enrolled in the elementary school; 6,596 students were enrolled in the middle school; and 6,678 students were enrolled in the high school (Ohio Department of Education, 2021).

Participants for the study were drawn from the 299 licensed teachers at the school who live within the state of Ohio and work remotely from home. Teachers at this school are licensed by the state and meet requirements to be considered highly qualified according to Common Core State Standards. In accord with Ohio law, teachers are assigned placements based on their areas of expertise and licensure (Ohio Virtual Academy, 2021b). In the state of Ohio, there is no requirement for a special, separate license to teach online.

Within the academy, there are two elementary school principals, one middle school principal, and five high school principals, all supervised by the Head of School. Stride Inc., formerly known as K12 Inc. (Bradley, 2020), is contracted to provide curriculum, administration, and technology services to the academy (United States Securities and Exchange Commission, 2017). Stride K12 provides services for 170,000 students in over 70 schools across the world (Stride Newsroom, 2020).

Instrument

The instrument was an online questionnaire that uses question stems such as “I do” and “It is important” statements with five-point Likert scale responses. The instrument consisted of 23 questions organized in four groups. Part one (six questions) gathered demographic information, including grade level, content area, total years teaching in a virtual school, highest level of education, and gender. The second part (five questions) concerned general slide use. One question confirmed that the participant creates their own ESP. The other four asked which software is most often used, the number of virtual classes the teacher presents each week, how many students attend a typical lesson, and the estimated duration of each class period. The third part of the questionnaire (four questions) concerned boundary issues known to affect the principles under investigation (students' prior knowledge, working memory capacity, and second language learner status) and asked teachers to determine the nature of their course content (STEM-based or humanities-based content). The fourth part of the questionnaire comprised eight questions intended to measure teachers' perceptions of their slide design practices in relation to the reduction of extraneous cognitive load.

At the end of the questionnaire, teachers were asked to complete a second task: submit an ESP deck. The text inside the questionnaire read:

> Thank you for submitting a slide deck from a virtual lesson you created and taught in a live classroom this school year. To ensure anonymity, please be sure to remove any personal identification before you submit. As a precaution, a third-party colleague will review the slide set to make sure you do not inadvertently leave any personal information in the slide set. For your convenience, there are two ways to submit. Here, you can upload a document. Or, you can paste a link to your slide set below if you prefer.

Raffle Entry Form

Thank you for your time!

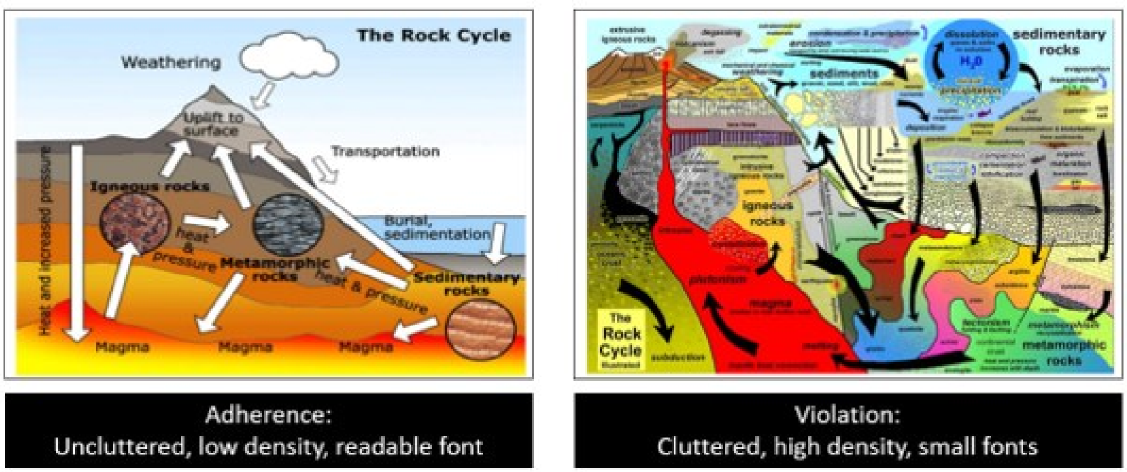
The Adherence Rubric

Frequency of adherence to the principles data was calculated by scoring the submitted ESP sets with an evaluation rubric. The adherence rubric contained 16 items. The rubric included graphic examples for each of the four principles. The statement, "By 'graphic,' we mean a visual photo, image, diagram, or symbol, etc." is included for clarification. The first two items direct the evaluator to mark the content area and the grade level band for the lesson. The rest of the rubric was separated into four sections: one for each of the principles under investigation.

The Adherence Rubric: Coherence Principle. The coherence principle was examined by establishing how often slides contain graphics, symbols, or words that are unrelated or unnecessary to the lesson content. Raters were prompted to determine the purpose of any extraneous information included in the ESP: to communicate reminders about the course; to add visual interest; to personalize the slide for students; to provoke an emotional response; or for some other reason. This item addressed the nature of any extraneous information. Evaluators were asked to rate how often the slides in the ESP deck adhered to the principle of redundancy. Figure 6 *Coherency Adherence Rubric* illustrates coherent and incoherent slides that provided the evaluators guidance as they evaluated ESP submissions.

Figure 6

Coherency Adherence Rubric

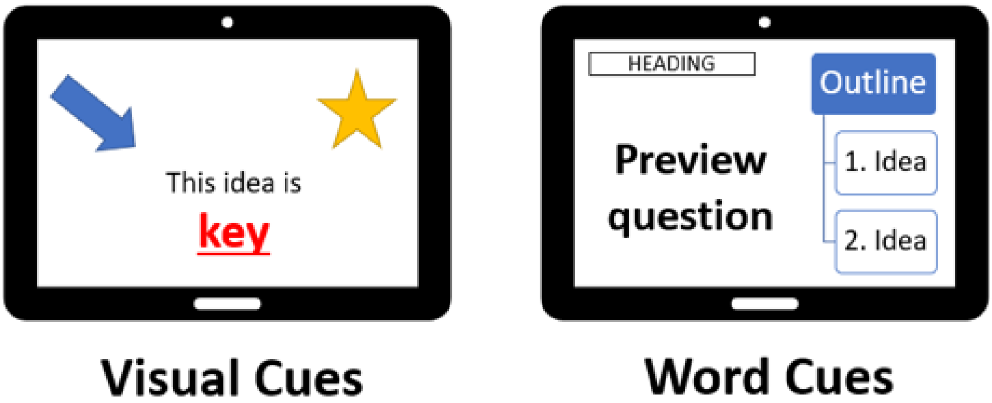


Note: Images provided to the rubric evaluators.

The Adherence Rubric: Signaling Principle. A score for implementation of the signaling principle was calculated by examining the slides for verbal and visual signals. Figure 7 shows examples of different types of signals. First, raters were asked to document the frequency of visual cues (color coding, spotlights, arrows, etc.) and the frequency of word signals (outlines, preview questions, headings, etc.). They calculated the estimated number of word signals that are typically found on a single slide in the ESP deck. The last item asked evaluators to rate how often the slides in the ESP adhered to the signaling principle.

Figure 7

Signaling Adherence Rubric



Note: Images provided to the rubric evaluators.

The Adherence Rubric: Spatial Contiguity Principle. The next principle under investigation, spatial contiguity, was examined by determining the frequency of text labels placed very close to corresponding components. Figure 8 shows examples of corresponding text labels while Figure 9 demonstrates corresponding explanations. The final section asked evaluators how often the slides in the ESP deck adhered to the spatial contiguity principle.

Figure 8

Spatial Contiguity Adherence Rubric: Labels

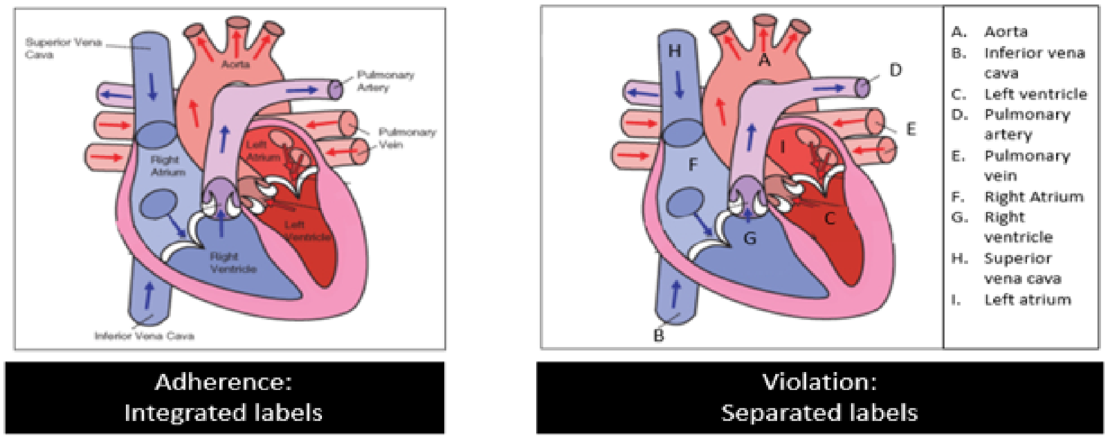
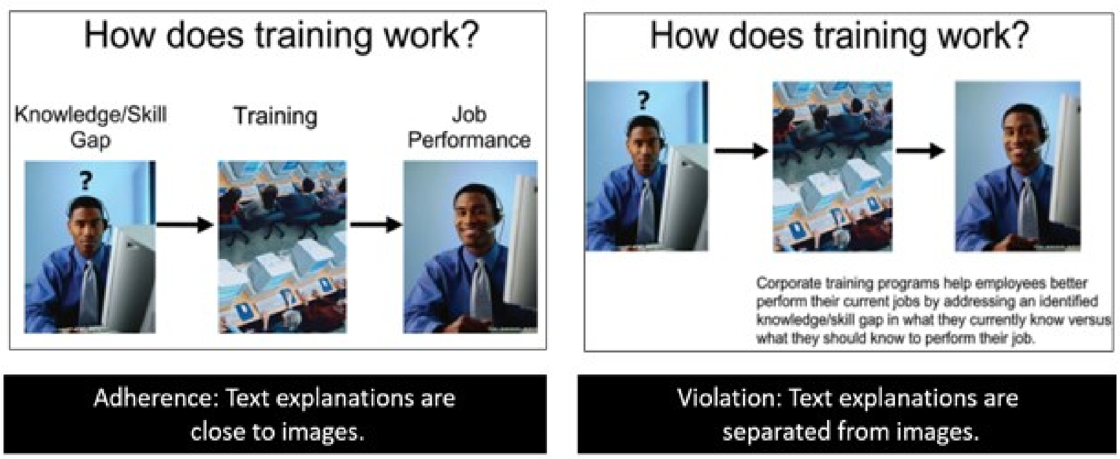


Figure 9

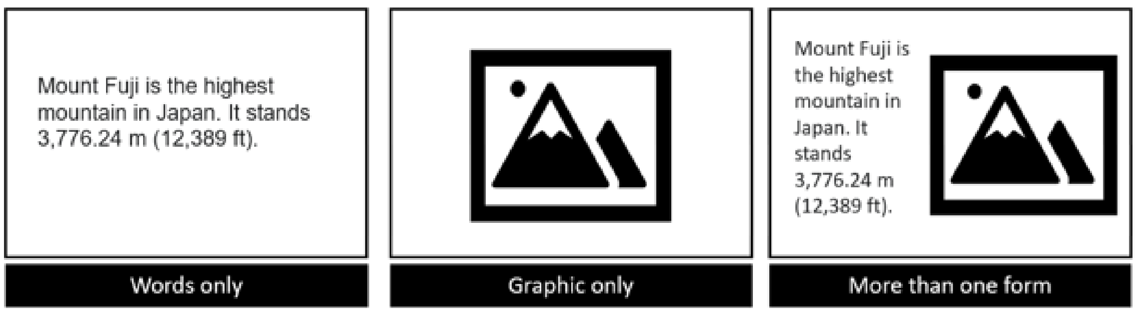
Spatial Contiguity Adherence Rubric: Text Explanations



The Adherence Rubric: Redundancy Principle. Using a Likert scale where 1 means "Never," and 5 means "Always," evaluators rated how often a slide contained both a graphic and a full paragraph of text. The second redundancy item indicated how often content on a slide was presented in only one form (only graphics or only text, but not both). The last element in the section asked evaluators to indicate how often the slides in the ESP deck generally adhered to the principle of redundancy. Figure 10 illustrates an example provided for the evaluators to use an example when marking ESPs. One example is labeled "Words only;" another is labeled "Graphic only," and the last is labeled "More than one form," and contains both an image and a short textual description.

Figure 10

Redundancy Adherence Rubric



Procedure

Once IRB approval was obtained from Duquesne University, a formal request (Appendix A: Formal Request of School District) was submitted to the Head of School for the K-12 academy. The request included the study's purpose, a description of the questionnaire instrument and procedure, an explanation of the adherence rubric and the procedure for collecting sample ESP sets, and a clear explanation of the incentives offered. Dates for data collection, the letter of consent to participate, and assurance of confidentiality were included.

After approval from the Head of School was obtained, an email was sent to the principals for each of the school levels (elementary, middle school, high school) (see Appendix B: Request for School Principals to Distribute Email to Teachers) by the investigator's team principal. The email briefly explained the parameters of the study, showed that approval from the Head of School had been granted, and requested that on Monday, April 25, 2022, the principals distribute an email to all teachers in their school with the link to the questionnaire (see Appendix C: Email

Request to Teachers to Participate). A request to include a reminder in the May 2, 2022 weekly update was included.

The email to teachers told the purpose of the study and made a request for their participation. The importance of obtaining informed consent and protecting participants' personal information was emphasized. A clear description of the questionnaire and the process to submit an ESP set and register for the raffle was included. Finally, participants were presented the link to access the on-line questionnaire (see Appendix D: Teacher Questionnaire).

Participants who opened the link completed an informed consent section giving their permission to proceed to the first question (Appendix E: Informed Consent). If a participant decided to quit the questionnaire at any time, the incomplete data was deleted and unavailable to the researcher.

The teacher questionnaire was open for two weeks, and a reminder to complete it before it closed was posted in the weekly school newsletter on the Monday of the last week. After the two-week collection period passed, a third-party colleague collected and reviewed the ESP decks from Qualtrics to ensure there was no personal, identifiable information about the teacher who submitted them. She forwarded the cleaned slide decks to the investigator for evaluation. These ESP links were kept on the researcher's password protected computer.

In accord with routine practice at this academy, incentives were offered to all participants. A second third-party colleague agreed to conduct three raffles for participants who submit an ESP deck. She created and owned the Google Form that collected names for the raffles. The form asked for the work email of the participant and asked which grade band they belonged to: K-5 elementary, 6-8 middle school, or 9-12 high school. She separated participants into the three schools and assigned numbers to each respondent. For each school, the colleague conducting the raffle used a random number generator to identify four winners. She contacted the winners by email and asked them for their mailing address. She then sent each winner a $25 Amazon gift card, provided to her by the researcher. The 12 gift cards totaled $300.

Rubric Scoring

Three raters used the evaluation rubric to measure adherence to the principles. They met virtually to learn more about each principle under investigation. In the first meeting, they read through definitions and examples from Mayer's *Multimedia Learning* (2021). Together, the raters rated two sample ESP lessons. Each rater left that initial meeting with a third sample ESP to rate. They met a second time to share their ratings and worked through problems they encountered while working on their own. The evaluators determined in the second meeting that a third was necessary; therefore, they again independently scored a sample ESP on their own and come back together to compare and discuss. Raters used definitions, examples, and non-examples to refer to as they worked.

Each ESP from participants was scored by the researcher and by one of the other two raters. The two scores were averaged for adherence to each of the four principles.

Data Collection

This study collected data through a researcher-designed survey instrument deployed through Qualtrics software. Qualtrics software employs Transport Layer Security encryption (TLS), also known as HTTPS, to protect data. IP addresses are masked to ensure anonymity. Data was stored on the researcher's password protected Qualtrics account provided by Duquesne University. It was analyzed using IBM Statistical Packages for Social Sciences (SPSS) 28 (IBM Corp., 2020).

In a second task, ESP decks created by virtual, synchronous K-12 teachers during the 2021-2022 school year were collected for analysis. Participants were asked to remove personal information from their slide sets before they submitted. Anonymity was ensured by having a third-party colleague review the submitted ESP sets and remove any personal information that could lead to the researcher seeing identifiable information. The collected ESP sets were saved digitally in one Microsoft Word document owned by the colleague and privately shared with the researcher. This document was saved to the researcher's password-protected computer.

Analysis

SPSS 28 (IBM Corp., 2020) was used to analyze the data. Demographic information was analyzed using descriptive statistics including frequencies, means, and standard deviations. Group differences were examined using *t*-tests (2 groups) and Analyses of Variance (ANOVA) tests. Finally, the association among variables were examined with simple correlation and multiple linear regression tests.

Research question one asked, "To what extent do ESP designed by online K-12 teachers adhere to four CTML principles that reduce extraneous cognitive processing?" Hypothesis one stated there would be small and minimal adherence between ESPs designed by online K-12 teachers and the four CTML principles that reduce extraneous cognitive processing. Statistical analysis consisted of visual examination of means, ranges, and standard deviations. The six independent variables were gender, content area taught, school level taught, highest education level, experience teaching, and experience teaching virtual synchronous K-12 courses. Because an extremely large number of statistical tests were performed, a conservative statistical significance level of .001 was selected, using the Bonferroni correction procedure. The final section examines the associations among variables.

Research question two asked, “Is there an association between teachers’ perceptions of their ability to reduce extraneous cognitive load and their implementation of the design recommendations for these four principles?” Hypothesis two stated there would be a moderate and statistically significant positive correlation between teachers’ perceptions of their ability to reduce extraneous cognitive load and their implementation of the recommendations for each of the four design principles. As teachers’ self-perceptions of their ability to implement principles increases, their rate of adherence to them will increase as well. Statistical analysis consisted of a Pearson correlation test, and statistical significance was set at $p <.001$. The independent variable, teachers’ perceptions of their ability to design slides that mitigate extraneous load, and the dependent variable, teachers’ rate of adherence to the principles, were measured through the teacher survey and the adherence rubric.

Research question three asked, “Are there group differences between teachers’ adherence to the four target principles according to gender, content area, teaching level, education level, number of years’ teaching experience, or number of years’ experience teaching in an online synchronous K-12 environment?” Hypothesis 3a stated there would be no statistically significant group differences between genders regarding teachers’ adherence to the four target principles. The hypotheses was tested with a *t*-test, and statistical significance was set at $p <.001$.

Hypothesis 3b stated there would be no statistically significant group differences between content area (STEM-based or humanities-based materials) regarding teachers’ adherence to the four target principles. The hypotheses was tested with a *t*-test, and statistical significance was set at $p <.001$.

Hypothesis 3c stated there would be no statistically significant group differences between teaching level (elementary, middle school, and high school levels) regarding teachers’ adherence to the four target principles. The hypotheses was tested with ANOVA, and statistical significance will be set at p <.001.

Hypothesis 3d stated there would be no statistically significant group differences between education level (bachelor's degree, master's degree, specialist license, or doctoral degree) regarding teachers' adherence to the four target principles. The hypotheses was tested with a *t*-test, and statistical significance was set at p <.001.

Hypothesis 3e stated there would be no statistically significant group differences between number of years teaching experience regarding teachers' adherence to the four target principles. The hypotheses was tested with ANOVA, and statistical significance was set at p <.001.

Hypothesis 3f. stated there will be no statistically significant group differences between number of years teaching in an online synchronous environment regarding teachers' adherence to the four target principles. The hypotheses was tested with ANOVA, and statistical significance was set at p <.001.

Research question four asked, "How much do gender, content area, teaching level, education level, and number of years' experience teaching synchronous online classes explain the variation in adherence to the Cognitive Theory of Multimedia Learning principles?" Hypothesis four predicted the combination of gender, content area, teaching level, education level, and experience teaching synchronous online classes would be small and significantly non-significant predictors of adherence to the Cognitive Theory of Multimedia Learning principles. The hypotheses was tested with multiple linear regression, and statistical significance was set at p <.001.

Chapter IV

Results

The first part of this chapter presents descriptive statistics of the participants, class ESP slides and sessions, results for questions pertaining to the boundary issues students might encounter in those sessions, and reported perception scores for participants as collected through the questionnaire. The second part of the chapter presents results of the adherence rubric used to observe practices implemented by teachers that might mitigate extraneous load in ESP slide design. Due to the large number of statistical calculations computed, the Bonferroni correction procedure was used, setting the family-wise error rate of .05, resulting in per case values of $p <$ .001. The final section examines the associations among variables.

Participants

Overall percentages for participants' gender are reported in Table 4; Table 5 presents characteristics of participants by content area; Table 6 displays characteristics of participants by school level taught; Table 7 shows characteristics of participants by teacher education level; and Table 8 show characteristics of participants by number of years' experience and by experience in a K-12 virtual environment.

Table 4

Demographic Characteristics of Participants' Gender

Characteristic	*n*	%
Gender		
Male	14	6.9
Female	187	92.6
Other	1	0.5
Total	202	100

Table 5

Demographic Characteristics of Participants' Content Area

Characteristic	*n*	%
Content area		
Process-based (STEM)	108	53.5
Non-STEM	87	43.1
No Response	7	3.5
Total	202	100

Table 6

Demographic Characteristics of Participants' School Level Taught

Characteristic	*n*	%
School level taught		
K-5 elementary	49	24.3
6-8 middle school	77	38.1
9-12 high school	76	37.6
Total	202	100

Table 7

Demographic Characteristics of Participants' Highest Education Level

Characteristic	*n*	%
Education level		
Bachelor degree	89	44.1
Master degree	107	53.0
Specialist degree	1	0.5
Doctoral degree	3	1.5
No Response	2	1.0
Total	202	100

Table 8

Demographic Characteristics of Participants by Experience Level

Characteristic	*n*	%
Number years teaching [a]		
1-5	34	16.8
6-10	33	16.3
11-15	54	26.7
16-20	49	24.3
21 or more years	31	15.8
Total	202	100
Number years synchronous virtual K-12 [b]		
1-5	85	42.1
6-10	66	32.7
11-15	39	19.3
16-20	12	5.9
Total	202	100

Notes. [a] One teacher reported 38 years of experience teaching. As this length of teaching career is not unheard of, the participant's response was kept. [b] One respondent indicated 33 years of experience teaching in an online virtual environment, which is highly unlikely because the virtual school, one of the oldest in the country, is only twenty years old. This respondent also left several questions blank and did not submit a sample ESP deck. Because of these reasons, the participant was removed from the data.

Electronic Slide Presentation Creation

Questionnaire responses show that most participants designed their own ESP slide sets while the rest used slides prepared by someone else (Table 9).

Table 9

Demographic Characteristics of Electronic Slide Presentation Creation

Teacher Created Slides	*n*	%
I design my own ESP slides	149	73.8
I use ESP slides prepared by someone else	50	24.8
No Response	3	1.5
Total	202	100

Among teachers who designed their own slides, most reported using PowerPoint software. Fifty-four participants did not specify which software they use. Responses are displayed in Table 10.

Table 10

Demographic Characteristics of Presentation Software

Software Used	*n*	%
PowerPoint	142	70.3
Google Slides	6	3.0
Canva	1	0.5
No Response	53	26.2
Total	202	100

ESP Creation and Gender. Table 11 presents means and standard deviations of those who design their own slides according to gender. Because only one participant chose to identify as a gender other than male or female, that respondent was omitted from this t-test, which was conducted to determine if either gender was more likely to create their own ESP slides or use slides designed by someone else. No significant difference was found between groups ($t13.73 = -.185$, $p = .428$).

Table 11

Electronic Slide Presentation Creation by Gender

Gender	*n*	*M*	*SD*
Male	10	1.0	0.4
Female	137	1.0	0.4
Other	1		
No Response	1		
Total	149		

ESP Creation and Content Area. Most participants categorized their subject content matter as process-based (STEM) rather than arts-based (humanities) (see Table 12). An independent-samples *t*-test was conducted to discover differences between arts-based and STEM-based teachers. No significant differences were found ($t_{169.77} = 1.42$, $p = .079$), but teachers who consider their content arts-based create their own slides slightly more often than STEM-based teachers.

Table 12

Demographic Characteristics of Electronic Slide Presentation Creation by Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	58	1.3	0.5
Process-based (STEM)	84	1.2	0.4
No response	7		
Total	149		

ESP Creation and School Level Taught. Table 13 shows that the average number of teachers who created their own slide designs increased from elementary to middle school to high school, in that order. A one-way ANOVA was performed to compare the effect of school level on ESP creation, and a significant difference between groups was indicated (Table 14).

Table 13

Demographic Characteristics of Electronic Slide Presentation Creation and School Level Taught

School Level Taught	*n*	*M*	*SD*
Elementary K-5	47	1.5	0.5
Middle school (6-8)	77	1.3	0.4
High school (9-12)	75	1.1	0.3
No response	3		
Total	202		

Table 14

Analysis of Variance: Electronic Slide Presentation Creation by School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	5.0	2	2.5	15.23	**<.001**
Within Groups	32.4	196	0.2		
Total	37.4	198			

Note. Bolded values are statistically significant at p <.001 level.

Tukey's HSD Test for multiple comparisons (see Table 15) showed elementary school teachers are more likely to use ESP slides created by someone else than are high school teachers.

Table 15

Analysis of Variance Multiple Comparisons: Electronic Slide Presentation Creation by School Level Taught

Grade Level 1	Grade Level 2	Mean difference	Standard Error	Sig.
Elementary K-5	Middle school 6-8	.26	.08	.002
Middle school 6-8	High school 9-12	.15	.07	.06
High school 9-12	Elementary K-5	-.42	.08	**<.001**

Note. Bolded values are statistically significant at p <.001 level.

ESP Creation and Highest Education Level. Means and standard deviations of those who design their own slides according to the highest education level achieved are shown in Table 16. A one-way ANOVA test was carried out, but no significant differences were noted (see Table 17).

Table 16

Electronic Slide Presentation Creation by Highest Education Level

Education Level	*n*	*M*	*SD*
Bachelor degree	88	1.3	.5
Master or Specialist degree	106	1.2	.4
Doctoral degree	3	1.0	.0
No response	5		
Total	202	1.3	.4

Table 17

Analysis of Variance: Electronic Slide Presentation Creation by Highest Education Level

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	0.3	2	.1	.67	.5
Within Groups	36.6	194	.2		
Total	36.9	196			

ESP Creation and Number of Years' Experience Teaching. Most participants had between 11- and 20-years' experience as teachers, as seen in Table 18.

Table 18

Electronic Slide Presentation Creation by Number of Years' Experience Teaching

Years' Experience Teaching	*n*	*M*	*SD*
1-5 years teaching	33	1.4	0.5
6-10 years teaching	33	1.4	0.5
11-15 years teaching	53	1.2	0.4
16-20 years teaching	48	1.1	0.3
21 or more years teaching	32	1.2	0.4
No response	3		
Total	202		

A one-way ANOVA test did not indicate a statistically significant difference existed among groups according to their total years' experience teaching (Table 19).

Table 19

Analysis of Variance: Electronic Slide Presentation Creation by Number of Years' Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	2.5	4	.6	3.48	.01
Within Groups	34.9	194	.2		
Total	37.4	198			

ESP Creation and Synchronous K-12 Virtual Experience. Table 20 shows the last demographic category analyzed to determine which groups create their own ESP slides: the number of years of synchronous K-12 virtual teaching.

Table 20

Electronic Slide Presentation Creation by Number of Years' Synchronous K-12 Virtual Experience Teaching

Years' Synchronous K-12 Virtual Experience	*n*	*M*	*SD*
1-5 years	83	1.4	.5
6-10 years	66	1.1	.3
11-15 years	38	1.1	.3
16-20 years	12	1.3	.5
No response	3		
Total	202	1.3	.4

An analysis of variance test showed a significant difference between groups (Table 21), so a Tukey post hoc test was conducted to determine where the interaction occurred. Table 22 shows that the teachers with the least experience (one to five years) teaching virtual K-12 classes created their own ESP slide decks statistically significantly less often than teachers with between six- and fifteen-years' experience.

Table 21

Analysis of Variance: Electronic Slide Presentation Creation by Number of Years' Synchronous K-12 Virtual Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	5.4	3	1.8	10.84	**<.001**
Within Groups	32.1	195	0.2		
Total	37.4	198			

Note. Bolded values are statistically significant at p <.001 level.

Table 22

Analysis of Variance Multiple Comparisons: Electronic Slide Presentation Creation and Years' Synchronous Virtual K-12 Teaching

Experience 1	Experience 2	Mean difference	Standard Error	Sig.
1-5 years	6-10 years	.34	.07	**<.001**
	11-15 years	.33	.08	**<.001**
	16-20 years	.10	.13	.9
6-10 years	11-15 years	-.01	.08	.1
	16-20 years	-.24	.13	.2
11-15 years	16-20 years	-.23	.13	.3

Note. Bolded values are statistically significant at p <.001 level.

Class Sessions

To establish a basic understanding of teacher practices, the questionnaire asked participants to indicate how many live, synchronous virtual sessions they taught each week (n = 199, M = 10, SD = 10). Across all three schools, class lengths reported in minutes were similar (n= 199, M = 45, SD = 8). The tables below compare frequency of class sessions according to each of the six independent variables.

Frequency of Class Sessions and Gender. Table 23 shows the means and standard deviations for males and females according to how often per week they teach live, synchronous class sessions. A t-test was conducted and found that females offered nearly twice as many sessions per week as male teachers ($t_{24.9}$ = -3.57, p = .001).

Table 23

Frequency of Class Sessions by Gender

Gender	*n*	*M*	*SD*
Male	14	5.1	4.5
Female	188	10.3	10.4
Other [a]			
Total	202		

Note . [a] The single submission by a participant who identified as another gender was not used in this test.

Frequency of Class Sessions and Content Area. Table 24 shows means and standard deviations for teachers by content area and how often per week they teach live, synchronous class sessions. No significant differences between content area groups were found for the number of class sessions taught per week when an independent samples *t*-test was conducted ($t_{165.78}$ = .96, p = .170).

Table 24

Frequency of Class Sessions and Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	87	10.6	11.2
Process-based (STEM)	108	9.1	9.2
No response	7		
Total	202		

Frequency of Class Sessions and School Level Taught. Table 25 presents means and standard deviations for teachers by content area and how often per week they teach live, synchronous class sessions. A one-way ANOVA test (Table 26) did not detect any differences between groups.

Table 25

Frequency of Class Sessions and School Level Taught

School Level Taught	*n*	*M*	*SD*
Elementary K-5	49	11.8	9.1
Middle school (6-8)	77	10.1	10.4
High school (9-12)	76	8.2	10.5
Total	202	9.8	10.2

Table 26

Analysis of Variance: Frequency of Class Sessions and School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	390.3	2	195.2	1.91	.2
Within Groups	20313.8	199	102.1		
Total	20704.1	201			

Frequency of Class Sessions and Highest Education Level. Table 27 displays means and standard deviations for teachers by their highest level of education and how often per week they teach live, synchronous class sessions. A one-way ANOVA test (Table 28) found no differences in the number of class sessions taught weekly for groups of teachers by highest education level.

Table 27

Frequency of Class Sessions and Highest Education Level

Education Level	*n*	*M*	*SD*
Bachelor degree	89	9.9	10.6
Master or Specialist degree	108	9.6	9.7
Doctoral degree	3	7.3	7.6
No response	2		
Total	202	9.7	10

Table 28

Analysis of Variance: Frequency of Class Sessions and Highest Education Level

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	22.2	2	11.0	.11	.9
Within Groups	19998.9	197	101.5		
Total	20021.2	199			

Frequency of Class Sessions and Number of Years' Teaching Experience. Table 29 presents means and standard deviations for teachers by the number of years they have been a teacher and how often per week they teach live, synchronous class sessions. No significant differences were discovered in a one-way ANOVA test (Table 30).

Table 29

Frequency of Class Sessions by Number of Years' Teaching Experience

Years' Teaching Experience	*n*	*M*	*SD*
1-5 years	34	8.5	7.2
6-10 years	33	7.9	9.3
11-15 years	54	12.8	14.1
16-20 years	49	10.4	8.9
21 or more years	32	7.2	5.9
Total	202	9.8	10.2

Table 30

Analysis of Variance: Frequency of Class Sessions by Number of Years' Teaching Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	899.3	4	224.8	2.24	.07
Within Groups	19804.8	197	100.5		
Total	20704.1	201			

Frequency of Class Sessions and Number of Years' Synchronous Virtual K-12 Teaching Experience. Table 31 displays means and standard deviations for teachers by the number of years they have taught in a virtual, synchronous, K-12 environment and how often per week they teach live, synchronous class sessions. A one-way ANOVA test (Table 32) did not detect any differences between groups.

Table 31

Frequency of Class Sessions by Number of Years' Synchronous K-12 Virtual Experience Teaching

Years' Synchronous K-12 Virtual Experience	*n*	*M*	*SD*
1-5 years	85	9.5	10.1
6-10 years	66	9.6	9.2
11-15 years	39	10.9	12.6
16-20 years	12	9.6	7.7
Total	202	9.8	10.2

Table 32

Analysis of Variance: Frequency of Class Sessions by Number of Years' Synchronous K-12 Virtual Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	58.1	3	19.4	.19	.9
Within Groups	20645.9	198	104.3		
Total	20704.1	201			

Number of Students per Session

One question asked participants to estimate about how many students attend each live, synchronous virtual session (n = 199, M = 40, SD = 36). The tables below reflect participant responses according to each of the six independent variables.

Number of Students per Session and Gender. Because only one participant chose to identify as a gender other than male or female, that respondent was omitted from this t-test, which was conducted to determine if one or another gender was more likely to have a significantly different number of attendees. No significant difference was found between groups

($t_{14.51}$ = .48, p = .319). Table 33 presents means and standard deviations for the number of students who attended each session by gender of teacher.

A one-way ANOVA (Table 34) was used to determine differences in the frequency of class sessions taught per week by teacher gender, but no statistical differences were found.

Table 34

Analysis of Variance: Number of Students per Session and Gender

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	1841.3	2	920.7	.70	.5
Within Groups	262848.7	199	1320.9		
Total	264689.9	201			

Number of Students per Session and Content Area. Table 35 shows means and standard deviations for the number of students who attended each session by content area of the course. A *t*-test comparison between the two independent groups showed no significant differences between content area teachers and the number of students who attended sessions (t_{160} = 1.07, p = .144).

Table 35

Number of Students per Session by Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	87	43.0	40.5
Process-based (STEM)	108	37.4	31.6
No response	7		
Total	202		

Number of Students per Session and School Level Taught. Participants reported the typical number of students who attend live synchronous sessions (see Table 36). Attendance increased from elementary to the middle and high schools. A one-way ANOVA examined group differences (Table 37). Close examination revealed high school teachers had significantly higher numbers of students attend class than middle and elementary level teachers (Table 38).

Table 36

Number of Students per Session by School Level Taught

School Level	*n*	*M*	*SD*
Elementary K-5	49	17.0	9.4
Middle school (6-8)	77	35.8	36.4
High school (9-12)	76	59.1	37.4
Total	202	40.0	36.3

Table 37

Analysis of Variance: Number of Students per Session and School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	54755.5	2	27377.7	25.95	**<.001**
Within Groups	209934.5	199	1054.9		
Total	264689.9	201			

Note. Bolded values are statistically significant at p <.001 level.

Table 38

Analysis of Variance Multiple Comparisons: Number of Students per Session and School Level Taught

Teaching Level 1	Teaching Level 2	Mean difference	Standard Error	Sig.
Elementary K-5	Middle school 6-8	-18.79	5.94	.005
Middle school 6-8	High school 9-12	-23.22	5.25	**<.001**
High school 9-12	Elementary K-5	42.01	5.95	**<.001**

Note. Bolded values are statistically significant at p <.001 level.

Number of Students per Session and Highest Education Level. Table 39 displays means and standard deviations for the number of students who attended each session by teachers' education level.

Table 39

Number of Students per Session by Highest Education Level

Educational Level	*n*	*M*	*SD*
Bachelor Degree	89	41.8	38.0
Master or Specialist Degree	108	38.2	35.6
Doctoral Degree	3	46.7	27.5
No response	2		
Total	202	40	36.5

The subsequent one-way ANOVA test (Table 40) did not indicate a difference between groups.

Table 40

Analysis of Variance: Number of Students per Session by Highest Education Level

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	743.7	2	371.9	.28	.8
Within Groups	263820.5	197	1339.2		
Total	264564.2	199			

Number of Students per Session and Number of Years' Teaching Experience. Table 41 shows means and standard deviations for the number of students who attended each session by the number of years' experience teaching each participant had.

Table 41

Number of Students per Session by Number of Years' Teaching Experience

Years' Teaching Experience	*n*	*M*	*SD*
1-5 years teaching	34	38.8	38.8
6-10 years teaching	33	37.2	39.9
11-15 years teaching	54	39.7	29.4
16-20 years teaching	49	32.2	33.1
21 or more years teaching	32	56.6	41.6
Total	202	40.0	36.3

A one-way ANOVA test (Table 42) indicated a slight but insignificant difference between groups.

Table 42

Analysis of Variance: Number of Students per Session by Number of Years' Teaching Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	12107.1	4	3026.8	2.36	.06
Within Groups	252582.9	197	1282.2		
Total	264689.9	201			

Number of Students per Session and Number of Years' Synchronous Virtual K-12 Teaching Experience. Table 43 presents means and standard deviations for the number of students who attended each session by the number of years groups of teachers have taught in a virtual, synchronous, K-12 environment. An inverse pattern appeared: the more years of virtual synchronous teaching experience teachers had, the fewer students attended their live, synchronous sessions.

Table 43

Number of Students per Session by Number of Years' Synchronous K-12 Virtual Experience Teaching

Years' Synchronous K-12 Virtual Experience	*n*	*M*	*SD*
1-5 years synchronous K-12 virtual teaching	85	33.6	35.6
6-10 years synchronous K-12 virtual teaching	66	40.0	32.2
11-15 years synchronous K-12 virtual teaching	39	41.0	29.4
16-20 years synchronous K-12 virtual teaching	12	82.5	54.6
Total	202	40.0	36.3

A one-way ANOVA test (Table 44) indicated a difference between groups.

Table 44

Analysis of Variance: Number of Students per Session by Number of Years' Synchronous K-12 Virtual Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	25248.9	3	8416.3	6.96	**<.001**
Within Groups	239440.9	198	1209.3		
Total	264689.9	201			

Note. Bolded values are statistically significant at p <.001 level.

Tukey's post-hoc test (see Table 45) showed a significant statistical difference in attendance rates between teachers. Teachers with the most experience teaching virtual synchronous K-12 classes (16-20 years) had much higher rates of attendance than the teachers in the two groups with the lowest number of years' experience: 1-5 years and 6-10 years.

Table 45

Analysis of Variance Multiple Comparisons: Number of Students per Session by Number of Years' Synchronous K-12 Virtual Experience Teaching

SVK12 Teaching 1	SVK12 Teaching 2	Mean difference	Standard Error	Sig.
1-5 years	6-10 years	-6.45	5.71	.7
	11-15 years	-7.47	6.73	.7
	16-20 years	-48.95	10.72	**<.001**
6-10 years	11-15 years	-1.03	7.02	1.0
	16-20 years	-42.50	10.91	**<.001**
11-15 years	16-20 years	-41.47	11.48	.002

Note. Bolded values are statistically significant at p <.001 level.

Boundary Issues Impacting CTML Principles

Table 46 presents results of three questions concerning boundary issues affecting the CTML principles under investigation. According to the literature, students whose first language is not English, those with low prior knowledge, and those with low working memory capacity are more at risk of cognitive overload than their peers. Therefore, participant teachers were asked to characterize the students who attended the class when the teacher presented the submitted ESP slide deck. Approximately twenty percent of teachers indicated their slide presentations were used to instruct learners whose first language was not English. Nearly one third of the classrooms reported most of the students attending had low working memory capacity and entered the classroom with low prior knowledge of the content being taught.

Table 46

Boundary Issues Impacting CTML Principles

Boundary Issue	*n*	%	*M*	*SD*
Language			1.8	.4
English first language	159	79		
English not first language	40	20		
No response	3	2		
Working memory of most students attending			2.7	1.3
Low working memory capacity	55	27		
Average working memory capacity	46	23		
High working memory capacity	6	3		
Mix of working memory capacities	91	45		
No response	4	2		
Prior knowledge of most students attending			1.2	.4
Low prior knowledge of content	169	84		
High prior knowledge of content	29	14		
No response	4	2		

Reported Adherence to the Principles

The first research question (To what extent do ESP designed by online K-12 teachers adhere to four CTML principles that reduce extraneous cognitive processing?) was addressed in two different ways. First, a Reported Principles in Practice Perception Score (RPPPS) was calculated for participants who completed the questionnaire to determine how they perceived their own implementation of the principles. Second, an Observed Adherence to the Principles Score (OAPS) was calculated from submitted ESP decks.

Reported Principles in Practice Perception Scores

A Reported Principles in Practice Perception Score (RPPPS) was calculated for each participant by averaging the values for eight questions on the questionnaire. This score reflects participant knowledge of and stated adherence to the four CTML principles that mitigate extraneous cognitive load during multimedia presentations. The seven questions, assessed with a 5-point Likert score, are listed below. Responses can be seen in Table 47.

1. I create elaborate and detailed slides.
2. Including background music enhances multimedia lesson learning.
3. I only include background music if it is directly related to the content.
4. How often do you add text or images that are unrelated to the content being presented?
5. How often do you show both an image and a paragraph or more of text on one slide?
6. It is important to present a concept in more than one way on a slide.
7. When showing a slide with text, how often do you or someone else read the material aloud word-for-word?

Table 47

Reported Principles in Practice Perception Responses

Characteristic	*n*	%
I create elaborate and detailed slides		
Somewhat or strongly agree	69	35
Neither agree nor disagree	40	20
Somewhat or strongly disagree	87	44
Including background music enhances multimedia lesson learning.		
Somewhat or strongly agree	45	23
Neither agree nor disagree	85	43
Somewhat or strongly disagree	66	34
I only include background music if it directly relates to the content.		
Somewhat or strongly agree	114	58
Neither agree nor disagree	53	27
Somewhat or strongly disagree	29	15
How often do you add text or images that are unrelated to the content being presented?		
Always or often	31	16
Sometimes	41	21
Rarely or never	124	63
How often do you show both an image and a paragraph or more of text on a slide?		
Always or often	76	39
Sometimes	55	28
Rarely or never	65	33

RPPPS by Gender. Means by gender were similar between groups; there were no differences between gender regarding principles in practice perception scores, as shown in Table

48. An independent samples t-test confirmed no statistically significant differences, ($t_{14.10}$ = -.06, p = .956).

Table 48

Reported Principles in Practice Perception Score by Gender

Gender	*n*	*M*	*SD*
Male	14	3.1	.6
Female	187	3.0	.5
Other [a]	1	2.4	
Total	202	3	.5

Note. [a] The single submission by a participant who identified as another gender was not used in this test.

RPPPS by Content Area. Table 49 shows few differences between arts-based and STEM-based courses and perception scores. An independent samples t-test confirmed there were no statistically significant differences, ($t_{191.67}$ = -1.07, p = .143).

Table 49

Reported Principles in Practice Perception Score by Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	87	3.0	.5
Process-based (STEM)	108	3.0	.5
No response	7		
Total	202		

RPPPS by School Level Taught. Table 50 shows means and standard deviations for the reported principles in action perception scores for teachers teaching at different school levels earned similar scores. A follow-up one-way ANOVA test found no statistically significant difference between groups (Table 51).

Table 50

Reported Principles in Practice Perception Score by School Level Taught

School Level Taught	*n*	*M*	*SD*
Elementary K-5	49	3.1	.4
Middle school 6-8	77	3.0	.5
High school 9-12	76	3.1	.5
Total	202	3.1	.5

Table 51

Analysis of Variance: Reported Principles in Practice Perception Score and School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	1.6	2	.8	3.57	.03
Within Groups	43.8	199	.2		
Total	45.5	201			

RPPPS by Highest Education Level. Means and standard deviations for teacher education level and RPPPS were similar (Table 52). No differences were found according to the teachers' highest education level, as shown in Table 53.

Table 52

Reported Principles in Practice Perception Score by Highest Education Level

Education Level	*n*	*M*	*SD*
Bachelor degree	89	3.0	.5
Master degree or Specialist license	108	3.1	.5
Doctorate Degree	3	3.1	.2
No response	2		
Total	202	3.1	.5

Table 53

Analysis of Variance: Reported Principles in Practice Perception Score and Highest Education Level

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.33	2	.2	.74	.5
Within Groups	44.4	197	.2		
Total	44.7	199			

RPPPS by Number of Years' Teaching Experience. Table 54 shows no differences in scores between groups according to overall number of years teaching experience. A one-way ANOVA comparison confirmed no differences between groups (Table 55).

Table 54

Reported Principles in Practice Perception Score by Teaching Experience

Years' Teaching	*n*	*M*	*SD*
1-5 years	34	2.9	.5
6-10 years	33	3.1	.5
11-15 years	54	3.1	.5
16-20 years	49	3.1	.4
21 or more years	32	3.1	.4
Total	202	3.1	.5

Table 55

Analysis of Variance: Reported Principles in Practice Perception Score and Years' Teaching Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	1.1	4	.3	1.17	.3
Within Groups	44.4	197	.2		
Total	45.5	201			

RPPPS by Virtual Synchronous Experience. Table 56 shows means and standard deviations for groups according to number of years teaching in a synchronous, virtual environment. No differences between groups were found when a one-way ANOVA comparison was computed (Table 57).

Table 56

Reported Principles in Practice Perception Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Years' Synchronous K-12 Virtual	*n*	*M*	*SD*
1-5 years	85	3.1	.5
6-10 years	66	3.1	.5
11-15 years	39	3.2	.6
16-20 years	12	3.0	.3
Total	202	3.0	.5

Table 57

Analysis of Variance: Reported Principles in Practice Perception Score Analysis of Variance: Number of Students per Session by Number of Years' Synchronous K-12 Virtual Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.48	3	.2	.703	.6
Within Groups	44.9	198	.2		
Total	45.5	201			

Observed Adherence to the Principles

A majority of participants who answered the questionnaire also submitted ESP slide sets (n = 139, 69%). Of those, eight were eliminated: one contained corrupt data and could not be read; two were created with a software application which required a paid account to view; one contained only one slide; and four were identical copies of submissions by other participants. A total of 131 ESP sets remained for analysis. These slide decks were scored as a second way to address the first research question, "To what extent do ESP designed by online K-12 teachers adhere to four CTML principles that reduce extraneous cognitive processing?"

The principal investigator evaluated the submitted slide decks using a rubric and assigned a score for each of the four principles under investigation. Each slide deck was also evaluated by a second rater. The following tables present the descriptive statistics for the participants who submitted slide decks, followed by analysis of observed adherence to each of the four principles. The number of submitted ESP slide decks were split nearly evenly between arts- and STEM-based courses (Table 58). Table 59 shows the number of ESP slide decks according to teacher education level were similarly divided into majority bachelor and master degree level.

Table 58

Submitted Slide Decks by Content Area

Content Area	*n*	%
Arts-based (humanities)	62	47
Process-based (STEM)	69	53
No response	1	
Total	131	100

Table 59

Submitted Slide Decks by Highest Education Level

Education Level	*n*	%
Bachelor degree	63	48.1
Master or specialist degree	65	49.6
Doctoral degree	2	1.5
No response	1	
Total	131	100

While slide deck submissions came from a natural distribution with most participants falling in the middle range of 11-15 years' experience (Table 60), a majority of submissions came from teachers with fewer years' experience in a virtual, synchronous K-12 environment (Table 61).

Table 60

Submitted Slide Decks by Number of Years' Experience Teaching

Years' Experience Teaching	*n*	%
1-5 years teaching	26	19.8
6-10 years teaching	22	16.8
11-15 years teaching	38	29.0
16-20 years teaching	27	20.6
21 years or more	18	13.7
Total	131	100

Table 61

Submitted Slide Decks by Number of Years' Synchronous K-12 Virtual Teaching

Years' Synchronous K-12 Virtual	*n*	%
1-5 years	56	42.7
6-10 years	45	34.4
11-15 years	23	17.6
16-20 years	6	4.6
No response	1	
Total	131	100

Most ESP slide decks submitted came from ELA teachers, followed closely by math teachers. Science and history made up most of the other submissions, although teachers from other departments also contributed (Table 62). Participants were asked to self-identify their classroom as either more arts-based or more processed-based (also identified in Table 62).

Table 62

Submitted Slide Decks by Class Subject

Class Subject	n	%	How teachers identified the subject
Career Tech/Business	2	1.5	Arts-based Humanities
Counselor	3	2.3	Arts-based Humanities
Digital Photography	1	0.8	Process-based STEM
Economics	3	2.3	Process-based STEM
English Language Arts	43	32.8	Arts-based Humanities
History	12	9.2	Arts-based Humanities
Intervention Specialist [a]	6	13.7	Process-based STEM
Math	39	29.8	Process-based STEM
Music	1	0.8	Arts-based Humanities
Psychology	1	0.8	Arts-based Humanities
Science	19	14.5	Process-based STEM
World Languages	1	0.8	Process-based STEM
Total	131	100	

Note.[a] Twelve of the 18 intervention specialists were included separately to reflect the content area of the area they taught in the lesson presented.

Observed Presence of Extraneous Material

Raters evaluated slide sets according to this question: "How often do the slides in the ESP deck include extraneous material that causes competition for mental processing resources?" Table 63 presents how often each slide deck was rated as including extraneous material.

Table 63

Observed Presence of Extraneous Material

Frequency	*n*	%
Always or most of the time	98	37
About half the time	65	25
Never or seldom	99	38
Total [a]	262	100

Note. [a] Each submitted slide deck was evaluated twice, by different raters, so the total *n* is 262 rather than 131.

Raters characterized the apparent intention of the extraneous material (Table 64).

Table 64

Observed Reasons for Extraneous Material

Characteristic	*n*	%
To communicate reminders about the course	75	29
To add visual interest	212	81
To personalize slides for students	105	40
To add a social-emotional support message	53	20

Note. Raters were asked to choose all that apply.

Observed Extraneous Material by Gender. To determine if any one group was more likely to prepare ESP decks with extraneous material, a series of comparisons was conducted. Table 65 presents the means and standard deviations for extraneous material according to gender. An independent-samples *t*-test was conducted to discover differences between male and female teachers. No significant differences were found ($t_{5.5} = .32$, $p = .76$).

Table 65

Observed Presence of Extraneous Material by Gender

Content Area	*n*	*M*	*SD*
Male	6	1.3	.5
Female	124	1.4	.5
Other [a]	1	1.3	
Total	131	1.3	.5

Note. [a] The single submission by a participant who identified as another gender was not used in this test.

Observed Extraneous Material by Content Area. Table 66 presents the means and standard deviations for extraneous material according to content area. ESP decks were rated lower if they contained extraneous material. An independent-samples t-test was conducted to discover differences between arts-based and STEM-based teachers. No statistically significant difference was found ($t_{126} = -.28$, $p = .8$).

Table 66

Observed Presence of Extraneous by Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	61	1.4	.5
Process-based (STEM)	70	1.4	.5
Total	131	1.4	.5

Observed Extraneous Material by School Level Taught. Means and standard deviations for inclusion of extraneous material by school level are shown in Table 67. Scores were similar for elementary and middle school teachers, but slightly higher for high school teachers.

Table 67

Observed Coherence: Presence of Extraneous Material by School Level Taught

School Level	*n*	*M*	*SD*
Elementary K-5	37	1.5	.5
Middle School 6-8	36	1.4	.5
High School	58	1.3	.5
Total	131	1.4	.5

Results of a one-way ANOVA test showed no statistically significant difference between the groups (Table 68).

Table 68

Analysis of Variance: Presence of Extraneous Material by School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.5	2	.25	1.05	.4
Within Groups	30.8	128	.24		
Total	31.4	130			

Observed Extraneous Material by Number of Years' Experience Teaching. Table 69 presents the means and standard deviations for extraneous material according to teachers' experience level teaching classroom. No differences between teaching level groups were found when a one-way ANOVA comparison was completed (Table 70).

Table 69

Observed Coherence: Presence of Extraneous Material by Number of Years' Teaching Experience

Years' Teaching Experience	*n*	*M*	*SD*
1-5 years teaching	26	1.4	.5
6-10 years teaching	22	1.4	.5
11-15 years teaching	38	1.3	.5
16-20 years teaching	27	1.6	.5
21 or more years teaching	18	1.4	.5
Total	131	1.4	.5

Table 70

Analysis of Variance: Observed Coherence: Presence of Extraneous Material by Number of Years' Teaching Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	1.2	4	.3	1.24	.3
Within Groups	30.2	126	.2		
Total	31.4	130			

Observed Extraneous Material by Number of Years' Synchronous Virtual K-12 Experience. Table 71 presents the means and standard deviations for extraneous material according to teachers' experience level teaching in a synchronous K-12 virtual classroom. A one-way ANOVA comparison did not find significant differences between groups (Table 72).

Table 71

Observed Coherence: Presence of Extraneous Material by Synchronous Virtual K-12 Experience

Years' Synchronous K-12 Virtual	*n*	*M*	*SD*
1-5 years	56	1.4	.5
6-10 years	45	1.4	.5
11-15 years	23	1.4	.5
16-20 years	6	1.3	.5
Total	130	1.4	.5

Table 72

Analysis of Variance: Observed Coherence: Presence of Extraneous Material by Synchronous Virtual K-12 Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.16	3	.05	.212	.9
Within Groups	31	126	.3		
Total	31	129			

Observed Adherence to the Coherence Principle

Rater evaluation responses to the following five questions were used to calculate an observed average score for each slide set. Raters chose between options (Most of the time = 0, About half the time = 1, or Never = 2). Results are presented in Table 73.

1. How often do slides contain images or graphics that are unrelated to the lesson content?
2. How often do slides contain relevant images or graphics that are unnecessary (there is another image/graphic that clarifies the content to be learned)?
3. How often do slides contain items that take extra mental effort to read because of the size, color, font, or spacing?

4. How often do slides contain words/numbers/text that are unrelated to the lesson content?
5. How often do slides contain words/numbers/text that are unnecessary (relevant but extraneous because there is already a clear explanation of the content to be learned or it is much more than necessary to understand the content)?

Table 73

Observed Coherence Adherence

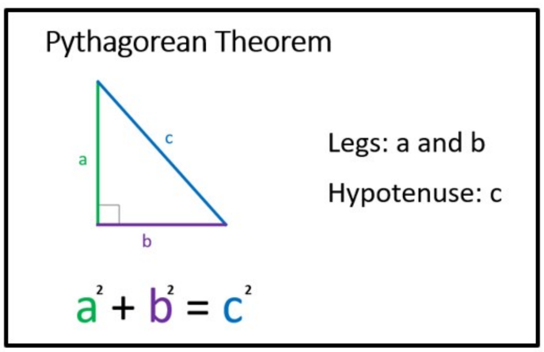
Characteristic	*n*	%
How often do slides contain images or graphics that are unrelated to the lesson content?		
Most of the time	27	21
About half the time	25	19
Seldom or never	79	60
How often do slides contain relevant images or graphics that are unnecessary (because there is another image/graphic that clarifies the content to be learned?)		
Most of the time	32	24.4
About half the time	33	25
Seldom or never	66	50.4
How often do slides contain words, numbers, or text that is unrelated to the lesson content?		
Most of the time	7	5
About half the time	12	9
Seldom or never	112	86
How often do the slides contain items that take extra mental effort to read because of the size, color, font, or spacing?		
Most of the time	31	24
About half the time	37	28
Seldom or never	63	48
How often do slides contain unnecessary words, numbers, or text (relevant but extraneous because there is already a clear explanation of the content to be learned or is much more in-depth than necessary to understand the content)?		
Most of the time	94	72
About half the time	36	28
Seldom or never	0	0
The slides in the ESP deck include extraneous material that causes competition for mental processing resources		
Most of the time	0	0
About half the time	79	61
Seldom or never	52	39

Figure 11 presents screenshots of slides illustrating high and low adherence to the coherence principle. The image on the left is based on a slide submitted by a middle school teacher and is representative of ESP decks rated as high coherence. No unrelated or unnecessary graphics or text are included. The image on the right is based on a slide submitted by an elementary school teacher and demonstrates a typical slide rated as violating the principle. The slide includes Bitmoji images unrelated to the reading task introduces seductive details.

Figure 11

Coherence ESP Submission Examples

Adherence



Violation

Observed Coherence Average by Gender. Observed scores take into account that each submitted slide deck was evaluated by two different raters, therefore, the following tables have a total sample size of 262 rather than 131. Means and standard deviations for coherence averages by gender are shown in Table 74. ESP sets created by male teachers were rated insignificantly higher on coherence (M = 1.4, SD = .1) than those created by female teachers (M = 1.2, SD = .3). The one submission by a participant who identified as another gender was not used in this test. An independent samples t-test found no statistically significant difference in coherence scores between males and females, t_{13} = 2.74, p = .017.

Table 74

Observed Average Coherence Score by Gender

Gender	*n*	*M*	*SD*
Male	12	1.4	.2
Female	248	1.2	.3
Other [a]	2		
Total	262	1.3	.3

Note. [a] The single submission by a participant who identified as another gender was not used in this test.

Observed Coherence Average by Content Area. An independent-samples *t*-test was conducted to discover observed coherence differences between arts-based humanities and processed-based STEM teachers (see Table 75). No significant difference was found, $t_{247} = 2.64$, $p = .009$.

Table 75

Observed Average Coherence Average by Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	124	1.2	.3
Process-based (STEM)	138	1.3	.3
Total	262		

Observed Coherence Average by School Level Taught. Means and standard deviations for coherence score averages by school level are shown in Table 76. Scores were similar for elementary and middle school teachers, but slightly higher for high school teachers.

Table 76

Observed Average Coherence Score by School Level Taught

School Level Taught	*n*	*M*	*SD*
Elementary K-5	74	1.2	.3
Middle School 6-8	72	1.2	.3
High School	116	1.3	.3
Total	262	1.2	.3

Results of a one-way ANOVA test indicated no statistically significant difference between groups the groups (Table 77).

Table 77

Analysis of Variance: Observed Average Coherence Score and School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.6	2	.3	2.67	.07
Within Groups	27.4	259	.1		
Total	28	261			

Observed Coherence Score by Highest Education Level. Means and standard deviations for observed coherence scores were then analyzed according to the teachers' highest education level (see Table 78). A one-way ANOVA exposed no statistically significant difference in coherence between any two groups (Table 79).

Table 78

Observed Average Coherence Score by Highest Education Level

Education Level	*n*	*M*	*SD*
Bachelor degree	126	1.2	.4
Master or Specialist degree	130	1.2	.3
Doctoral degree	4	1.5	.1
Total	260	1.2	.3

Table 79

Analysis of Variance: Observed Average Coherence Score by Highest Education Level

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.5	2	.2	2.27	.1
Within Groups	27.3	257	.1		
Total	27.8	259			

Observed Coherence Score by Number of Years' Experience Teaching. Means and standard deviations for coherence average scores according to teachers' number of years' teaching are presented in Table 80. A one-way ANOVA determined no statistically significant difference in coherence between groups (Table 81).

Table 80

Observed Average Coherence Score by Number of Years' Experience

Education Level	*n*	*M*	*SD*
1-5	52	1.2	.3
6-10	44	1.1	.4
11-15	76	1.3	.3
16-20	52	1.2	.3
21 or more	38	1.2	.3
Total	131	1.2	.3

Table 81

Analysis of Variance: Observed Average Coherence Score by Number of Years' Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.3	4	.09	.8	.5
Within Groups	28	257	.1		
Total	27.9	261			

Observed Coherence Score by Number of Years' Experience Virtual Synchronous Teaching. Finally, coherence scores were analyzed according to the number of years' experience teachers had in a virtual synchronous K-12 environment (see Table 82 for means and standard deviations). A one-way ANOVA test found no significant differences between groups (Table 83).

Table 82

Observed Average Coherence Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Years Virtual Synchronous Experience	*n*	*M*	*SD*
1-5	112	1.2	.4
6-10	90	1.3	.3
11-15	46	1.2	.3
16-20	12	1.3	.3
Total	260	1.2	.3

Table 83

Analysis of Variance: Observed Average Coherence Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.6	3	.2	1.9	.1
Within Groups	27.3	256	.1		
Total	28	259			

Observed Adherence to the Signaling Principle

Raters evaluated slide decks with the following five questions to establish an observed signaling score for each slide set. Ratings are presented in Table 84.

1. How often do slides contain visual cues (bold, color coding, spotlights, arrows, underlining, italics, etc.)? (Never or seldom= 1; 1 = About half the time; 2 = Most of the time).
2. Visual cues in this slide deck (bold, color coding, spotlights, arrows, underlining, italics, etc.) effectively highlight the essential elements of the lesson. (Disagree = 0; Some are effective, and some are not = 1; Agree = 2).

3. How often do slides contain verbal word cues (outlines, preview questions, HEADINGS, etc.)? (Never or seldom = 0, About half the time = 1; Most of the time = 2).
4. Verbal word cues in this slide deck (outlines, preview questions, headings, etc.) effectively highlight the essential elements of the lesson. (Disagree = 0; Some are effective, and some are not = 1; Agree = 2)
5. There are so many items on a slide it is difficult to tell what is important. (Never or seldom = 2; About half the time = 1; Most of the time = 0)

Table 84

Observed Signaling Adherence

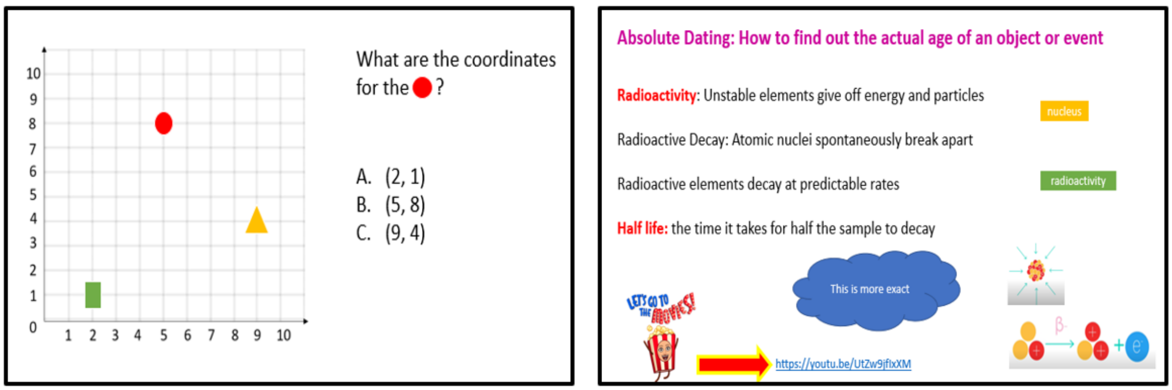
Characteristic	*n*	%
How often to slides contain visual cues (bold, color coding, spotlights, arrows, underlining, italics, etc.)?		
Never or seldom	97	74
About half the time	0	0
Most or all the time	34	26
Visual cues in this deck (bold, color coding, spotlights, arrows, underlining, italics, etc.) effectively highlight the essential elements of the lesson.		
Agree	0	0
Some are effective, and some are not	37	28
Disagree	52	40
No response	42	32
How often to slides contain verbal cues (outlines, preview questions, headings, etc.)?		
Never or seldom	64	49
About half the time	0	0
Most or all the time	66	50
No response	1	1
Verbal cues in this deck (outlines, preview questions, headings, etc.) effectively highlight the essential elements of the lesson.		
Agree	0	0
Some are effective, and some are not	53	41
Disagree	49	37
No response	29	22
There are so many items on a slide it is difficult to tell what is important.		
Never or seldom	47	36
About half the time	27	21
Most or all the time	54	41
No response	3	2

Figure 12 presents replicas of submitted slides illustrating high and low adherence to the signaling principle. The image on the left was rated as having high adherence. The image on the right was rated as violating the principle.

Figure 12

Signaling ESP Submission Examples

Adherence **Violation**



Observed Signaling Score by Gender. Each slide deck submission was observed for signaling by two raters. Table 85 presents the means and standard deviations for the use of verbal and visual signals according to gender. An independent-samples *t*-test found no differences among groups for the signaling principle, $t_{13.2} = 2.8$, $p = .01$.

Table 85

Observed Signaling Average Score by Gender

Gender	*n*	*M*	*SD*
Male	12	1.2	.4
Female	248	.9	.5
Total	260		

Note. [a] One participant who identified as "other gender" was not included in the *t*-test.

Observed Signaling Score by Content Area. Means and standard deviations for use of verbal and visual signals according to content area are displayed in Table 86. An independent-samples t-test was conducted to discover differences between arts-based and STEM-based teachers. No statistically significant difference was found ($t_{260} = 1.5$, $p = .2$).

Table 86

Observed Coherence: Presence of Extraneous by Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	124	.8	.5
Process-based (STEM)	138	.9	.6
Total	262	.9	.6

Observed Signaling Average Score by School Level Taught. Means and standard deviations for signaling showed that high school teachers adhered to the principle more often than teachers in the other groups (Table 87), but the difference was not significant (Table 88).

Table 87

Observed Average Signaling Score by School Level Taught

School Level Taught	*n*	*M*	*SD*
Elementary K-5	74	.9	.6
Middle School 6-8	72	.8	.6
High School	116	.9	.5
Total	262	.9	.5

Table 88

Analysis of Variance: Observed Average Signaling Score by School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.53	2	.3	.89	.4
Within Groups	75.8	259	.3		
Total	76.3	261			

Observed Signaling Score by Highest Education Level. Table 89 presents the means and standard deviations for signaling according to teacher education level, and Table 90 shows the results of ANOVA, which did not find a statistically significant difference.

Table 89

Observed Average Signaling Score by Highest Education Level

Education Level	*n*	*M*	*SD*
Bachelor degree	126	.8	.5
Master or Specialist degree	130	.9	.6
Doctoral degree	4	1.0	.3
Total	260	.9	.5

Table 90

Analysis of Variance: Observed Average Signaling Score by Highest Education Level

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	1.2	2	.2	2.05	.1
Within Groups	74.7	257	.2		
Total	76	259			

Observed Signaling Score by Number of Years' Teaching Experience. Means and standard deviations for observed adherence to the signaling principle are presented in Table 91.

A one-way ANOVA test indicated a statistically significant differences between groups (Table 92).

Table 91

Observed Average Signaling Score by Number of Years' Experience

Education Level	*n*	*M*	*SD*
1-5	52	.8	.4
6-10	44	.8	.3
11-15	76	1.1	.5
16-20	52	.9	.5
21 or more	38	.7	.4
Total	262	.9	.5

Table 92

Analysis of Variance: Observed Average Signaling Score by Number of Years' Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	6.2	4	1.6	8.72	**<.001**
Within Groups	45.9	257	.2		
Total	52.2	261			

Note. Bolded values are statistically significant at p <.001 level.

Tukey's HSD multiple comparisons test show an interaction between the groups. Teachers with between eleven and fifteen years of teaching experience more often adhere to the principle of signaling than those with 21 or more years' experience (Table 93).

Table 93

Analysis of Variance Multiple Comparisons: Observed Signaling Score by Number of Years' Teaching

Experience Teaching 1	Experience Teaching 2	Mean difference	Standard Error	Sig.
1-5 years	6-10	.02	.09	.99
	11-15	-.29	.08	.003
	16-20	-.028	.08	.99
	21 or more	.17	.09	.31
6-10 years	11-15	-.30	.08	.002
	16-20	-.05	.09	.98
	21 or more	.15	.09	.50
11-15 years	16-20	.25	.08	.01
	21 or more	.45	.08	**<.001**
16-20 years	21 or more	.20	.09	.17

Note. Bolded values are statistically significant at p <.001 level.

Observed Average Signaling Score by Number of Years' Virtual Synchronous Teaching Experience. Means and standard deviations for the signaling principle according to level of experience teaching in a synchronous virtual K-12 classroom are displayed in Table 94. A one-way ANOVA test did not indicate a statistically significant difference between groups (Table 95).

Table 94

Observed Average Signaling Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Years Virtual Synchronous Experience	*n*	*M*	*SD*
1-5	112	.8	.6
6-10	90	1.0	.6
11-15	46	.8	.5
16-20	12	.9	.5
Total	260	.9	.5

Table 95

Analysis of Variance: Observed Average Signaling Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	1.0	3	.4	1.18	.3
Within Groups	74.9	256	.3		
Total	75.9	259			

Observed Adherence to the Spatial Contiguity Principle

To calculate an observed spatial contiguity score, raters were asked to first answer this question: "There are slides in the deck that have diagrams or images with text or label explanations to teach the learning concept. (For example, a diagram of how something works or an image of something where the student needs to identify different parts.)" After filtering out ESP slide decks that did not have diagrams or images along with text labels or text explanations, only 44 ESP slide decks were evaluated by raters for the spatial contiguity principle.

Data from the ESP decks where the rater indicated the presence of labeled images were assigned an observed spatial contiguity score by averaging the raters' responses to these two questions below. Results are reported in Table 96.

1. This applies only to slides with a diagram or image to teach a concept along with text explanation. Do the slides show adherence to or violation of the spatial contiguity principle?
2. This applies only to slides with a diagram or image to teach a concept along with labels. Do the slides show adherence to or violation of the spatial contiguity principle?

Table 96

Observed Spatial Contiguity Adherence

Characteristic	*n*	%
Do the slides show adherence to or violation of the spatial contiguity principle? [a]		
Adherence: Text explanations are always/often placed in close proximity to the corresponding image. The learner does not need to look far from the image to understand.	13	29.5
Mix: Text explanations are placed in close proximity to the corresponding image about half the time.	15	34.1
Violation: Text explanations are never/seldom placed in close proximity to the corresponding image. Instead, they are placed separately, requiring the learner to look somewhere else.	10	22.7
Not applicable: There are no diagrams or images of things students are learning along with a text explanation.	6	13.6
Total	44	100
Do the slides show adherence to or violation of the spatial contiguity principle? [b]		
Adherence: Labels are always/often placed in close proximity to the corresponding image. The learner does not need to look far from the image to understand.	22	50
Mix: Labels are placed in close proximity to the corresponding image about half the time.	13	29.5
Violation: Labels are never/seldom placed in close proximity to the corresponding image. Instead, they are placed separately, requiring the learner to look somewhere else.	6	13.6
Not applicable: There are no diagrams or images of things students are learning along with labels.	3	6.8
Total	44	100

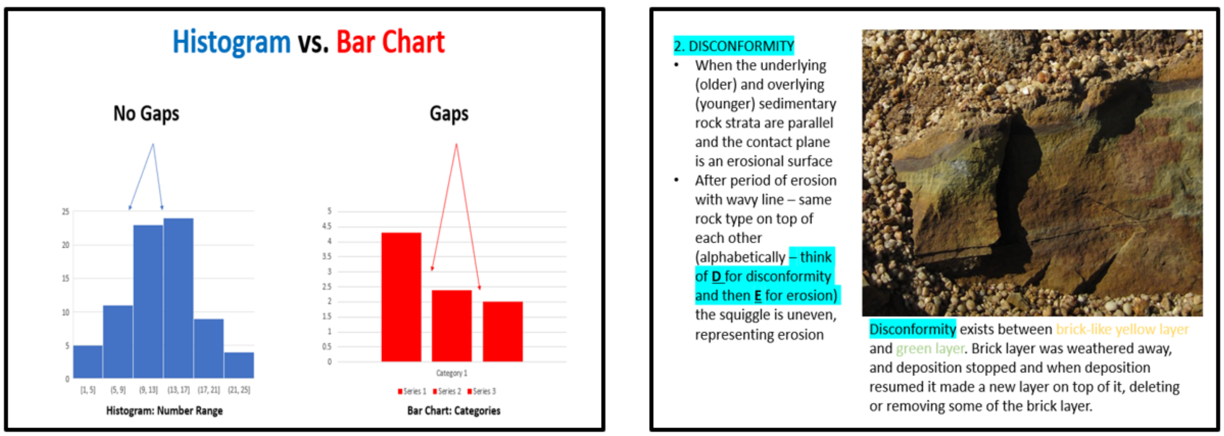
Note. [a] Applies only to slides with a diagram or image combined with explanatory text. [b] Applies only to slides with a diagram or image combined with short labels.

Figure 13 presents replicas of slides illustrating high and low adherence to the spatial contiguity principle. The image on the left was rated as having high coherence. The image on the right demonstrates a slide rated as violating the principle.

Figure 13

Spatial Contiguity ESP Submission Examples

Adherence **Violation**



Observed Spatial Contiguity Score by Gender. Table 97 displays the observed spatial contiguity score means and standard deviations for males and females. A *t*-test did not indicate a statistically significant difference between groups ($t_{10.6} = 1.6$, $p = .1$).

Table 97

Observed Spatial Contiguity Score by Gender

Gender	*n*	*M*	*SD*
Male	6	1.6	.4
Female	37	1.3	.7
Total	43	1.3	.6

Note. [a] The single submission by a participant who identified as another gender was not used in this test.

Observed Spatial Contiguity Score by Content Area. Means and standard deviations are shown in Table 98 for the observed spatial contiguity score for STEM and humanities teachers. No statistically significant differences were found between the groups, $t_{20.6} = -.46$, $p = .65$.

Table 98

Observed Spatial Contiguity: Presence of Extraneous by Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	12	1.4	.6
Process-based (STEM)	31	1.3	.6
Total	43	1.3	.6

Observed Spatial Contiguity Score by School Level Taught. Means and standard deviations for spatial contiguity adherence according to grade level taught are presented in Table 99. A one-way ANOVA test (Table 100) did not indicate any differences between or among the three groups.

Table 99

Observed Average Spatial Contiguity Score by School Level Taught

School Level Taught	*n*	*M*	*SD*
Elementary K-5	9	1.7	.4
Middle School 6-8	15	1.1	.8
High School	19	1.3	.6
Total	43	1.3	.6

Table 100

Analysis of Variance: Observed Average Contiguity Score by School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	1.9	2	.9	2.61	.1
Within Groups	14.4	40	.4		
Total	16.3	42			

Observed Spatial Contiguity Score by Highest Education Level. Means and standard deviations for adherence to the spatial contiguity score according to education level are reported in Table 101.

Table 101

Observed Average Spatial Contiguity Score by Highest Education Level

Education Level	*n*	*M*	*SD*
Bachelor degree	22	1.3	.7
Master or Specialist degree	21	1.4	.6
Total	43	1.3	.6

A one-way ANOVA could not be run because no participants with a doctoral degree included diagram or images along with text or label explanations, so a *t*-test was undertaken instead. No statistically significant differences were found between those with a bachelor degree and those with a master or specialist degree, $t_{38.75} = -.69$, $p = .5$.

Observed Spatial Contiguity Score by Number of Years' Teaching Experience. Means and standard deviations are presented in Table 102 for spatial contiguity scores according to the number of years the teacher has teaching. However, a one-way ANOVA test (see Table 103) did not show any adherence differences between the groups of teachers.

Table 102

Observed Average Spatial Contiguity Score by Number of Years' Experience

Education Level	*n*	*M*	*SD*
1-5	5	1.5	.5
6-10	8	1.3	.7
11-15	17	1.4	.6
16-20	10	1.2	.8
21-38	3	1.3	.3
Total	43	1.3	.6

Table 103

Analysis of Variance: Observed Average Spatial Contiguity Score by Number of Years' Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.7	4	.2	.42	.8
Within Groups	15.6	38	.4		
Total	16.3	42			

Observed Spatial Contiguity Score by Number of Years' Virtual Synchronous Teaching Experience. Means and standard deviations for teacher implementation of the spatial contiguity principle as observed by raters are displayed in Table 104. A one-way ANOVA test detected no differences between groups of teachers (Table 105).

Table 104

Observed Average Spatial Contiguity Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Years Virtual Synchronous Experience	*n*	*M*	*SD*
1-5	15	1.3	.7
6-10	20	1.4	.6
11-15	7	1.2	.5
16-20	1		
Total	43	1.3	.6

Table 105

Analysis of Variance: Observed Average Spatial Contiguity Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	2.2	3	.7	1.98	.1
Within Groups	14.2	39	.4		
Total	16.3	42			

Observed Adherence to the Redundancy Principle

Raters evaluated slide decks with three questions to establish an observed redundancy score for each slide set. Results are presented in Table 106.

1. How often does a slide contain both a graphic and a lot of text (enough text that requires time and mental energy to read and understand)?
2. How often does a slide contain more than one graphic demonstrating the same concept?
3. How often is content on a slide presented in only one form?

Table 106

Observed Redundancy Adherence

Characteristic	*n*	%
How often does a slide contain both a graphic and a large amount of text? [a]		
Never or seldom	43	33
About half the time	59	45
Most or all the time	29	22
How often does a slide contain more than one graphic demonstrating the same concept?		
Never or seldom	83	63
About half the time	38	29
Most or all the time	10	7
How often is content on a slide presented in only one form? [b]		
Never or seldom	30	23
About half the time	33	25
Most or all the time	68	52

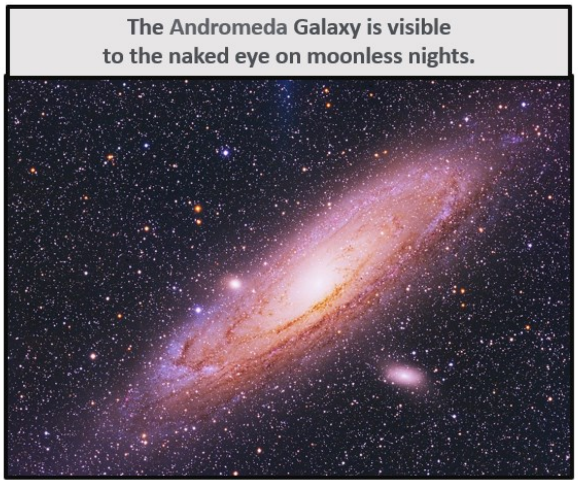
Note. [a] Text that requires time and mental energy to read and understand. [b] One form is an image or graphic; a second form is text.

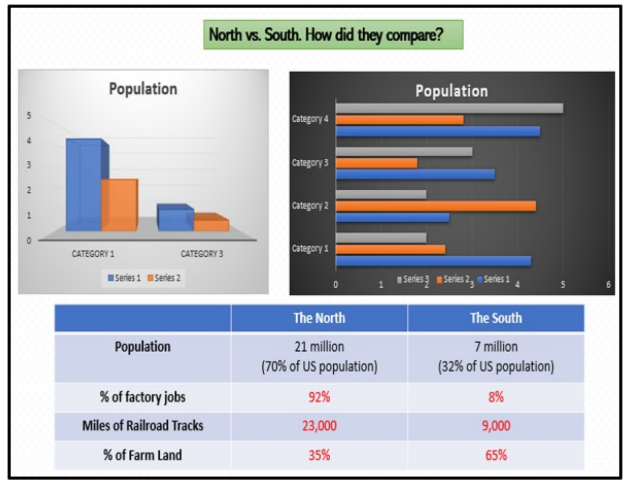
Figure 14 presents screenshots of slides illustrating high and low adherence to the redundancy principle. The image on the left was rated as having high coherence. The image on the right demonstrates a slide rated as violating the principle.

Figure 14

Redundancy ESP Submission Examples

Adherence | **Violation**





Observed Redundancy Score by Gender. Table 107 displays the observed redundancy means and standard deviations for teachers according to gender. The single participant who identified as a different gender was not included. No statistically significant difference for redundancy was found between groups ($t_{11.7}$ = -.34, p = .74).

Table 107

Observed Redundancy Score by Gender

Gender	*n*	*M*	*SD*
Male	12	1.0	.7
Female	248	1.1	.6
Total	260	1.1	.6

Note. [a] The single submission by a participant who identified as another gender was not used in this test.

Observed Redundancy Score by Content Area. Means and standard deviations for teachers' observed redundancy means and standard deviations according to content are shown in

Table 108. No statistically significant difference for redundancy was found between groups ($t_{257.5}$ = -.06, p = .95).

Table 108

Observed Redundancy Score by Content Area

Content Area	*n*	*M*	*SD*
Arts-based (humanities)	124	1.1	.6
Process-based (STEM)	138	1.1	.6
Total	262	1.1	.6

Observed Redundancy Score by School Taught. Means and standard deviations for observed redundancy according to school level taught can be seen in Table 109. A one-way ANOVA test did not show any differences for redundancy among groups (Table 110).

Table 109

Observed Average Redundancy Score by School Level Taught

School Level Taught	*n*	*M*	*SD*
Elementary K-5	74	1.1	.5
Middle School 6-8	72	1.2	.6
High School	116	1.1	.6
Total	262	1.1	.6

Table 110

Analysis of Variance: Observed Average Redundancy Score and School Level Taught

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.8	2	.4	1.25	.3
Within Groups	83.8	259	.3		
Total	84.6	261			

Observed Redundancy Score by Highest Education Level. Means and standard deviations for observed redundancy according to school level taught can be found in Table 111. A one-way ANOVA comparison test did not disclose any differences for redundancy among groups (Table 112).

Table 111

Observed Average Redundancy Score by Highest Education Level

Education Level	*n*	*M*	*SD*
Bachelor degree	126	1.1	.6
Master or Specialist degree	130	1.1	.6
Doctoral degree	4	1.2	.6
Total	260	1.1	.6

Table 112

Analysis of Variance: Observed Average Redundancy Score by Highest Education Level

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.08	2	.04	.122	.9
Within Groups	83.6	257	.3		
Total	83.7	259			

Observed Redundancy Score by Number of Years' Teaching Experience. Means and standard deviations for observed redundancy according to total years of teaching experience are displayed in Table 113. A one-way ANOVA test did not indicate any differences for redundancy among groups (Table 114).

Table 113

Observed Average Redundancy Score by Number of Years' Experience

Education Level	*n*	*M*	*SD*
1-5	52	1.2	.5
6-10	44	1.2	.6
11-15	76	1.1	.6
16-20	52	1.1	.6
21 or more	38	1.1	.6
Total	262	1.1	.6

Table 114

Analysis of Variance: Observed Average Redundancy Score by Number of Years' Experience

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	1.5	4	.4	1.15	.3
Within Groups	83	257	.3		
Total	84.6	261			

Observed Redundancy Score by Number of Years' Virtual Synchronous Teaching Experience. Means and standard deviations for observed redundancy according to total years of teaching experience in a virtual synchronous K-12 environment are displayed in Table 115. One-way ANOVA test did not indicate any differences for redundancy among groups (Table 116).

Table 115

Observed Average Redundancy Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Years Virtual Synchronous Experience	*n*	*M*	*SD*
1-5	112	1.1	.6
6-10	90	1.1	.6
11-15	46	1.0	.6
16-20	12	1.0	.6
Total	260	1.1	.6

Table 116

Analysis of Variance: Observed Average Redundancy Score by Number of Years' Synchronous K-12 Virtual Experience Teaching

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	.6	3	.2	.62	.6
Within Groups	83.6	256	.3		
Total	84.2	259			

An overall Observed Adherence Score was calculated for each participant who submitted an ESP slide deck for evaluation by averaging the observed scores for all four principles. Overall $M = 1.1$, $SD = .3$.

Associations Among Variables

One purpose of the study was to determine if there is a difference between teachers' stated perceptions of their attempts to design ESP slides to reduce extraneous cognitive load and their reported use of the four multimedia principles. Therefore, participants were asked to what extent did they agree with the statement, "I develop presentation slides that minimize extraneous cognitive load for my learners." A majority ($n = 152$, 75%) agreed or strongly agreed with the statement. Twenty-nine participants (14%) neither agreed nor disagreed, and only 21 (11%) disagreed or strongly disagreed (see Table 117).

Table 117

Reported Perception: "I develop presentation slides that minimize extraneous cognitive load for my learners"

Perception	*n*	%
Strongly disagree	7	4
Somewhat disagree	14	7
Neither agree nor disagree	29	14
Somewhat agree	97	48
Strongly agree	55	27
Total	202	100

Statistical analysis consisted of two Pearson correlation tests with a statistical significance of $p < .001$. To assess the relationship between participant perceptions of their development of ESP slides that minimize extraneous cognitive load and their Reported Principles in Practice Perception Scores, a Pearson correlation coefficient was computed. No significant correlation between what teachers perceived as their ability to develop high quality ESP slides and their stated practice of the principles was found, $r(200) = -.06$, $p = .40$. A second Pearson correlation test investigated the relationship between teachers' perceptions of their attempts to design ESP slides to reduce extraneous cognitive load and their implementation of recommended practices by analysis of ESP decks. No statistically significant correlation between what teachers perceived as their implementation of the principles and their observed implementation of the principles was found, $r(124) = -.04$, $p = .68$.

Predictor Variables

A multiple linear regression test was calculated as gender, content area, teaching level, education level, experience teaching, and experience teaching synchronous online classes as predictor variables. The *r* value of .24 appeared statistically significant. However, when squared, the resulting $r^2 = .06$ value indicated only a very small, impractical percentage of the variance was accounted for by predictor variables.

Summary

In summary, minimal adherence to the four CTML principles that reduce extraneous cognitive processing was found among participants. Similarly, no correlations between teachers' perceptions of their ability to reduce extraneous cognitive load and their implementation of the recommendations for each of the four design principles were detected. Few group differences for adherence were discovered for independent variables gender, content area, teaching level, education level, number of years' teaching experience, and number of years' experience teaching in an online synchronous K-12 environment. Nor did a combination of those variables predict adherence to the principles.

Chapter V

Discussion

Working as a teacher in the post-COVID world can be challenging and frustrating. Society has changed; the teaching profession is in flux. Working as a virtual K-12 teacher can be extremely discouraging. After all, if teaching in a virtual environment required the same skill set as teaching face-to-face in a brick-and-mortar learning environment, then learning outcomes should be relatively equal across schools because online teachers in both environments must meet the same licensure standards and requirements. But outcomes are not similar. The evidence appears hopelessly negative: K-12 students enrolled in virtual schools face significant academic risks compared to traditional, brick-and-mortar schools (Ahn, 2016; Ahn & McEachin, 2017; Barbour, 2015; Fitzpatrick et al., 2020; Molnar et al., 2019; Yllmaz & Keser, 2017; Zimmer et al., 2009, 2014).

Fitzpatrick et al. (2020) suggests poor academic outcomes of virtual K-12 students is not due to teacher competency but to something inherent in the virtual synchronous format that leads to learning failure. One possible explanation for the differences between brick-and-mortar and virtual school achievement is that virtual synchronous teachers are limited to communicating through multimedia messages (Martin et al., 2019; Pantazes, 2021). In other words, only two of the five senses are present to communicate with (visuals and sounds). But it is not just the senses of smell, taste, and touch that are missing. In my classes, most students decline to show themselves on the camera, and many prefer to type rather than speak on the microphone. Both students and teachers in a virtual class can feel like they are operating blindly. Faced with these challenges, even the most committed teachers can feel disheartened.

I was inspired to pursue this research after reading Mayer's 2020 book, *Multimedia Learning*, and I realized that I had (inadvertently, and with every good intention) created slide designs that appeared confusing and incoherent to my students. My goal was to find practical ways to improve learning outcomes for my own virtual K-12 students. I have no doubt the teachers at this academy are highly capable educators. Results of this research may appear to be negative, but that result is not a comment on the value of virtual teachers; instead, it points to an egregious lack of training and support for virtual teachers. Research into best practices in instructional slide design has long needed to catch up with online learning environments (Leacock & Nesbit, 2007). Professional development and teacher educator programs simply do not provide adequate tools or training in their current form.

Several studies determined that when CTML principles are applied to PPT design, there are significant improvements in understanding and retention of new knowledge (Issa et al., 2011, 2013; Nagmoti, 2017; Noyes et al., 2019; Pate & Posey, 2016). The current study investigated whether teachers in the academy know about or implement the principles that could improve instruction by designing ESP decks to minimize extraneous cognitive load. Historically, little has been known about K-12 virtual synchronous teachers, their practices, or online interaction characteristics (Black et al., 2009; DiPietro et al., 2008; Martin & Parker, 2014; Zweig & Stafford, 2016).

Descriptive Characteristics

To develop a baseline of knowledge about virtual teachers and their practices, participants were asked to report whether they create their own ESP decks; which software they use to create ESP decks; how often per week they teach virtual synchronous sessions; how many minutes those sessions last; how many students attend each session; and what characteristics germane to extraneous cognitive processing those students exhibit.

In this particular Ohio school district, the typical synchronous class session lasts 45 minutes, is attended by 40 students, and is conducted with ESP slides created by the teacher (Table 9) in PowerPoint (Table 10). The typical teacher is female (Table 4), holds ten synchronous classroom sessions per week (Table 25), and has a master's degree (Table 7). A majority of participants reported eleven to twenty years of experience teaching (51%) and one to ten years' experience working in a virtual K-12 school (75%) (Table 8). Of the students attending the classes that used these particular ESP slides, 20% were students whose first language is not English, 27% had a low working memory capacity, and 84% had low prior knowledge of content (Table 46).

ESP Slide Creation

Most participants in this study (74%) created their own ESP decks (Table 9). Teachers with only one to five years' virtual experience (Table 22) were more likely to rely on someone else to design their slides. New teachers at the school are usually assigned to a more experienced teacher for the first semester. Teachers commonly share slide decks with others on their team. It is reasonable to expect teachers with the least amount of experience to be less confident or capable as those with more experience,

A statistically significant difference was found between elementary and high school teachers, with high school teachers (Table 15) more often creating their own ESP decks. No explanation was found in the literature as to why elementary teachers might create their own slides at lower rates. It seems likely that new teachers would more often rely on others to create their slides, but the number of elementary teachers with only one-five years' experience (21%)

was not much higher than middle school (14%) or high school (17%) with the same amount of experience. There may be unknown administrative regulations or expectations in the individual schools that explain why elementary teachers do not prepare slide designs at the same rate as other teachers.

Number of Attendees

In a brick-and-mortar school, seats in a classroom are moderated by physical space, so teachers often present the same lesson several times in one day to smaller sections of students. State guidelines limit high school teachers to a roster with 200 students. This method ensures students regularly have a teacher’s attention in a relatively small group. For example, a high school teacher with 200 students might teach the same lesson six times in a day to groups of 30 or so students. The instructor has several opportunities to monitor and assess student learning over the course of a week. But sessions in this academy are recorded, so students who cannot attend are able to watch a recording. If only sixty students attend, the other 140 have access to a recording. Therefore, teachers can present a lesson once and spend time on other tasks. As predicted, high school teachers demonstrated statistically significantly higher numbers of students attend class than middle and elementary level teachers (Table 38). This difference is likely explained by state guidelines that govern the number of students assigned to teachers at different levels.

Results also showed a significant statistical difference in attendance rates between teachers according to experience. Teachers with the most experience teaching virtual synchronous K-12 classes (16-20 years) had much higher rates of attendance than the teachers in the two groups with the lowest number of years' experience: 1-5 years and 6-10 years (see Table 45). It is possible that the individual teachers in this study with the most experience in a virtual environment effectively motivate students to attend class at a higher rate. Another possibility could be that more experienced teachers are in positions of leadership and manage larger numbers of students.

Research Questions

This research focuses on characteristics of teachers who teach K-12 synchronous virtual classes and their perceptions and practices relative to designing their ESP slides according to proven principles known to reduce extraneous cognitive load. Results are presented in alignment with the study's research questions:

RQ1: To what extent do ESP designed by virtual K-12 teachers adhere to four CTML principles that reduce extraneous cognitive processing?

RQ2: Is there an association between virtual K-12 teachers’ perceptions of their ability to reduce extraneous cognitive load and their implementation of the design recommendations for these four principles?

RQ3: Are there group differences between virtual K-12 teachers’ adherence to the four target principles according to gender, content area, teaching level, education level, number of years teaching, or number of years’ experience teaching in an online synchronous environment?

RQ4: How much do gender, content area, teaching level, education level, number of years teaching, and number of years’ experience teaching synchronous online classes explain the variation in virtual K-12 ESP design adherence to the Cognitive Theory of Multimedia Learning principles?

Adherence to the CTML Principles

The results of this study demonstrate that although the practical skill of designing classroom instruction with ESP software is a common requirement for online instructors (Martin et al., 2019; Pantazes, 2021), participants in this school do not apply proven practices with that software. The results support the first hypothesis, which predicted there would be minimal adherence to the four CTML principles known to reduce extraneous cognitive load for learners. To be clear, there is no doubt the teachers at this school care very deeply for their students and work very hard to provide quality instruction and support. I did not come to hypothesize that teachers in the school are poor ESP designers nonchalantly. It was only after sustained research into the principles, years of observation, and the humbling revelation that I personally had confused my students with poor slide design that I made the prediction few teachers would implement the principles into their slide design. I am confident the teachers are simply unfamiliar with the research and honestly believe they are providing high quality ESP slides.

Coherence

Incoherent materials force learners to spend valuable cognitive resources sorting through unessential details rather than integrating new information into long-term schema (Mayer, 2014, 2021; Mayer & Moreno, 2003; Noyes, 2019; Sweller et al., 1998, 2019). Coherent multimedia messages do not include unrelated images or text (Mayer, 2020). Only 60% of the observed ESP decks adhered to the coherence principle (Table 74). This finding reflects coherence rates in studies reported in the literature (Noyes et al., 2020; Yue et al., 2013). While a small percentage (16%) of participants in this study admitted they often or always add text or images unrelated to the lesson material (Table 47), more than twice that number (37%) of ESP decks were considered incoherent by raters (Table 63). This discrepancy mimics Pantazes' study (2021) that showed instructors are not consistent in their implementation of the coherence principle and foreshadows a pattern of cognitive dissonance in this study's results.

It is improbable that teachers would intentionally create less than ideal circumstances for their learners if they were aware of how much damage seductive details can wreak on learning. However, although only 16% of teachers stated they add unrelated material to a slide (Table 47), a full 40% of slides contained images or graphics unrelated to the lesson, and an additional 14% included unrelated words, numbers, or text half or most of the time (Table 73).

Raters were asked to characterize the apparent intention of extraneous material. The predominant (81%) reason teachers added unnecessary material was to add visual interest for students (Table 64). The graphic in Figure 11 of a "Bitmoji" classroom image provides an illustration. Bitmoji is a recently popular virtual environment tool that can be used to create colorful classroom backgrounds and avatars that anyone can design and add to multimedia messages.

Raters also observed other reasons teachers included seductive details to their ESP decks: 40% were added to personalize slides for students; 29% were added to communicate reminders about the course, and last, 20% were used to add a social-emotional support message (Table 64). Whatever the reason may be, the literature shows any seductive details (interesting but off-topic images or text) can impede the selection, organization, and integration of new information (Mayer, 2020), particularly for students with low working memory capacity (Castro-Alonso et al., 2019a; Mayer, 2020).

Irrelevant background music is also considered a violation of the coherence principle because it can interfere with learner comprehension and transfer of knowledge into long-term memory (Lehmann & Seufert, 2017; Mayer, 2020; Mayer & Moreno, 2003). The effects of narration and background could not be observed in this study, but questionnaire participants disagreed about the efficacy of using background music during multimedia presentations. In fact, only 34% correctly stated that background music impedes multimedia learning, while 23% stated that it enhances learning. A large percentage (43%) neither agreed nor disagreed, proving teachers have an extensive lack of knowledge about how background music interferes with the cognitive process of forming new knowledge.

Signaling

Both visual and verbal signals direct attention to essential material and positively influence learning outcomes because they organize material logically (Mautone & Mayer, 2001; Mayer, 2014; Mayer, 2020; van Gog, 2014). Studies of ESP designs adhering closely to the cueing principle resulted in deeper learning (Garner & Alley, 2013; Issa et al., 2011, 2013; Nagmoti, 2017; Pate & Posey, 2016).

This study differentiated between visual and verbal signals, which are processed through separate senses and are influenced by different boundary conditions. Visual signals in a multimedia message include text effects common in PowerPoint such as highlighting, bolding, transparency, and font color variations. Visual signals are processed through a learner's sense of sight and are typically accompanied by a narrated explanation. Although they were not analyzed in this study, which was limited to static images, gestures such as pointing at important information and other physical movements are also considered visual signals (Mayer, 2020), helping learners select and organize new knowledge.

Verbal signals are processed through the ears. According to Mayer's CTML, when a learner reads words, they are not only using visual resources, but are also internally translating and filtering the letters and words they take in through their eyes as well as their internal sense of hearing. Words used in titles and headers can effectively grab learner attention by seeming to call out, "Hey, look at me! I am important!" Therefore, the theory considers titles, headers, labels and graphic organizers to be verbal signals (Castro-Alonso et al., 2019a; Liu et al., 2020; Mautone & Mayer, 2001; Mayer, 2020; Noyes et al. 2020; Richter & Scheiter, 2019; Schneider et al., 2018; Xie et al., 2019).

It's unclear why only 45% of observed ESP decks adhered to the signaling principle (Table 85). Approximately half contained verbal cues such as outlines, headings, or preview questions, but far fewer (26%) regularly included visual cues such as bold or highlighting (Table 84). The signaling effect is especially important in helping students with low prior knowledge organize and make sense of new ideas (Alpizar et al., 2020; Arslan-Ari, 2018; Johnson et al., 2015; Mautone & Mayer, 2001). Because 84% of students in attendance were estimated to have low prior knowledge, the lack of verbal and visual cues to direct attention on ESP decks is concerning.

Another area of concern is that sparing use of signals, particularly when learners have low working memory or prior knowledge, is recommended (Mayer, 2020). Yet, results of this study indicate 62% of ESP slide decks caused observers confusion because "There are so many items on a slide it is difficult to tell what is important" (Table 84) (see Figure 12 for an illustration).

Spatial Contiguity

Split-attention conditions can be caused by various designs or actions in a multimedia presentation. When two distinct pieces of information are both required to make sense of an idea, they are best presented simultaneously and close together (Mayer, 2020). If integrated elements are separated from each other, a split-attention condition is created. Learners must spend time and mental energy to reintegrate the separate pieces before they can make sense of the information (Chandler & Sweller, 1991; Ginns, 2006; Mayer, 2020; Sweller & Chandler, 1994;

Tarmizi & Sweller, 1988). CTML differentiates between split-attention conditions caused by separating crucial pieces of content in time (temporal) and by physical space on a slide (spatial). One limitation of this study was that temporal contiguity could not assessed because video recordings were not available for observation; therefore, discussion of the effect of contiguity on synchronous, virtual K-12 class sessions in this research is incomplete.

This study analyzed ESP decks for adherence to the spatial contiguity principle by determining how often text explanations and how often labels were located in close proximity to corresponding images. Overall, 65% of observed ESP decks adhered to the spatial contiguity principle (Table 99), which reflects results found in the literature analyzing animations with labels (Noyes et al., 2020; Yue et al., 2013).

The spatial contiguity principle was violated more often when text explanations accompanied images rather than when labels were present. Twenty-six percent of ESP decks adhered to the principle; i.e., text explanations were always or often placed in close proximity to the corresponding image. Learners were required to look in multiple places to integrate crucial information in 21% of cases (Table 97). Slides where teachers used labels had a much higher rate of adherence (53%); on those slides, images were accompanied by labels placed near to the corresponding image.

It is reasonable to assume that any ESP designer challenged with presenting complex material but limited to using only one standard sized PowerPoint slide at a time must be able to decide which information should be kept together and which pieces can be separated. This challenge is only one of those inherent to the use of PowerPoint as the teaching medium in online courses (Fitzpatrick et al., 2020; Garner & Alley, 2013; Kalyuga & Sweller, 2014) with the technology available today. Instructors and those who design ESP for learners must understand how the split attention effect can impact their learners and should have the skill to anticipate logical segmentation of material. The participants in this study did not indicate they understand these basic elements.

Redundancy

Redundant materials can take many forms, including diagrams, pictures, animations, or text (Kalyuga & Sweller, 2014). Theorists agree that when learners are presented identical material both verbally and visually, cognitive processing can be impaired. For example, when a teacher is narrating and identical text is added to the online screen, a negative competition for visual cognitive resources occurs (Castro-Alonso et al., 2019a; Kalyuga & Sweller, 2014; Mayer, 2020).

Redundancy effects are intensified when redundant materials are presented in combination with split-attention conditions or with seductive details. Other conditions interact with the redundancy principle but were not examined in this research, such as expert-reversal effects for students with high levels of prior knowledge, situations where the learner has control of pacing, and environments where large amounts of texts are read aloud. ESP designers must take into account many complex factors when preparing learning materials (Kalyuga et al., 1999; Kalyuga & Renkle, 2010; Kalyuga & Sweller, 2014; Yue & Bjork, 2017).

Adherence to the redundancy principle can reduce negative competition for mental resources. In this study, 55% of observed ESP decks adhered to the redundancy principle (Table 109). Because only static images could be observed, results are limited and do not evaluate a typically significant source of violations to the principle: narrative input. However, 67% of slides were determined to contain both a graphic and a large amount of text half or most of the time and 36% of slides contained more than one graphic demonstrating the same concept (Table 108). The low adherence rate and the low rates of prior knowledge among students found in this study indicate a need for teacher designer development.

Associations Between Perception and Adherence

The collected data in this study did not support hypothesis two, which stated there would be a moderate and statistically significant positive correlation between teachers' perceptions of their ability to implement the principles and their observed implementation of the principles. A majority (75%) of participants explicitly stated they create ESP decks that minimize extraneous cognitive load for learners, indicating most participants perceive they have the knowledge to design effective multimedia presentations. However, participants' reported adherence to the principles (RPPPS) scores, determined through a series of knowledge and application questions, were much lower (50%; Table 48).

Similarly, observed adherence scores for the four individual principles were also very different from participants' stated perceptions. Evaluation of submitted slide decks indicated 60% of participants design ESP demonstrating the coherence principle (Table 74); 45% use signaling effectively (Table 87); 65% implement spatial contiguity (Table 98); and 55% avoid redundancy (Table 109).

Results further confirmed there was no relationship between teachers' stated perceptions of their ability to design ESP that mitigate extraneous cognitive processing and actual knowledge of the stated principles. A second correlation showed there was no relationship between teacher perceptions of their implementation of the principles and their observed implementation of the principles. The lack of association is disappointing because it highlights a deficit in knowledge of the principles necessary to design quality instruction.

Group Differences in Adherence

Six hypotheses addressed group differences in adherence rates to each of the four principles under investigation. None of the 24 tests (0%) computed found statistically significant differences.

Hypothesis 3a predicted there would be no statistically significant group differences between genders regarding teachers' adherence to the four target principles. This prediction was made because only a few studies demonstrating differences were discovered in the literature review. According to Honebein and Honebein (2014), there are significant differences between what male and female instructional designers value as instructional methods, and according to Annetta et al. (2007), females integrate graphic more often into their designs. Results of this study did not indicate any differences between genders for ESP slide design practices.

The next three hypotheses were also confirmed. Hypothesis 3b anticipated no statistically significant group differences between content area (STEM-based or humanities-based) courses regarding teachers' adherence to the principles. Results confirmed the hypothesis and found no differences for adherence to coherency, signaling, spatial contiguity, or redundancy. Also as predicted, study results confirmed hypothesis 3c, finding no statistically significant group differences in adherence between teaching level (elementary, middle school, and high school). Hypothesis 3d was also confirmed, and no statistically significant group differences were apparent between teachers' highest education level regarding teachers' adherence to the four target principles. This negative result implies that no level of higher education emphasizes the importance of preparing instructional materials in accordance with proven cognitive science input.

When hypothesis 3e was tested, an interesting result was detected. The hypothesis predicted there would be no statistically significant group differences for number of years' teaching experience. However, participants with between eleven and fifteen years of experience adhered to the principle of signaling statistically significantly more often than the teachers with more than twenty years' teaching experience (Table 94). No clear explanation for this discrepancy was found in the literature, but a few thoughts might offer an explanation.

The signaling effect is influenced by prior knowledge of content (Alpizar et al., 2020; Arslan-Ari, 2018; Johnson et al., 2015; Kalyuga , 2007; Khacharem et al., 2020; Mautone & Mayer, 2001). Many studies of expert–novice differences demonstrate learner knowledge base is the single most important cognitive characteristic that influences learning and performance. It is reasonable to assume instructors with more than twenty years' experience are masters of the content they teach. Is it possible that the most experienced teachers could suffer from a version of the expertise reversal effect? Is it possible that mature teachers' ability to anticipate areas of confusion for students can diminish through the repetition of teaching? Yet, teachers with eleven to fifteen years of teaching experience can also be considered "experts" in their content, and this study showed that group used signals in their ESP designs more often and more effectively than those with even more experience. Perhaps teacher fatigue could explain the low use of signals in ESP deck design with the most experienced teachers.

Finally, tests confirmed hypothesis 3f. No statistically significant group differences between number of years teaching in an online synchronous environment regarding teachers' adherence to the four target principles were discovered. The negative hypothesis was made because no studies detailing practices of synchronous K-12 virtual teachers were located in the literature review, but the results are deeply disturbing. One could reasonably assume that practitioners with the most time in a learning environment would demonstrate greater skill navigating it. Instead, results of this study indicate an overall lack of knowledge and design is pervasive among all groups of virtual, synchronous K-12 teachers.

Predictors of Adherence

Results of this study demonstrate that no significant predictors for adherence to the four principles were detected. A multilinear regression statistic indicated a small, impractical percentage (approximately .06 of the variance) could be accounted for by the predictors. The predictors chosen for this study could be termed "typical" places to discern group differences in the field of education. From an analysis standpoint, these results are disappointing. Obviously, some participants do design their slides with cognitive processing in mind and as a result have high adherence scores in this study, but the indicators are not obvious. It is worthwhile to examine the results in search of other variables that could explain why some teachers attained higher adherence than others.

Special Populations and Boundary Conditions

This study did not investigate the learning outcomes of students taught with ESP decks, but results shed light on the fact that sub-optimal ESP slides are regularly used to teach three groups of students most at risk of cognitive overload: English Language Learners (20%), students with low working memory (27%) and students with low prior knowledge of the class teaching content (84%) (Table 46) (Alpizar et al., 2020; Arslan-Ari, 2018; Castro-Alonso et al., 2019a; Ginns, 2006; Johnson et al., 2015; Khacharem et al., 2020; Kalyuga, 2007; Kalyuga & Renkl, 2010; Mautone & Mayer, 2001; Mayer, 2020; Richter & Scheiter, 2019).

Because significant numbers of learners entered the virtual classroom with differences in prior knowledge, working memory capacity, and native language, one wonders if students with these conditions would be better served by attending classes specifically tailored to meet their individual needs. The CTML principles offer an opportunity to personalize ESP instruction that might result in higher comprehension and retention of knowledge. To present personalized instruction according to cognitive learning literature may, however, be at odds with current laws guaranteeing equal access to equal materials and instruction. Future research should investigate if there is a need to pursue this line of reasoning to better support all students.

Summary

- K-12 virtual schools served over 290,000 students in the 2019-2020 school year (U.S. Department of Education, 2020).
- Virtual online K-12 schools impose large and negative effects that persist over time, including low academic growth and graduation rates (Ahn, 2016; Ahn & McEachin, 2017; Barbour, 2015; Fitzpatrick et al., 2020; Molnar et al., 2019; Yllmaz & Keser, 2017; Zimmer et al., 2009; Zimmer et al., 2014).
- The negative academic outcomes of virtual online K-12 schools are likely not a result of teacher competency, but of the nature of virtual school itself (Azevedo et al., 2004; Cavanagh et al., 2004; Fitzpatrick et al., 2020).
- Virtual schools are unique because synchronous interactions between instructors and students occur nearly exclusively in a multimedia environment.
- CTML provides proven principles known to increase learning outcomes during multimedia lessons based on over 200 experimental studies (Beaulieu & Poyo, 2021: Mayer, 2014, 2020; Noyes et al., 2019).

- Many studies demonstrate improvement in student learning outcomes when the CTML principles are applied to ESP design (Issa et al., 2011, 2013; Nagmoti, 2017; Noyes et al., 2019; Pate & Posey, 2016).
- Teacher participants in this study demonstrated participants show little to no knowledge of or adherence to the CTML principles regarding their multimedia ESP design.

Significance of the Study

Results of this study contribute to the gap in knowledge we have about online virtual synchronous teachers' characteristics, such as gender, education level, number of years' experience teaching in total and in a synchronous, virtual K-12 environment. It's likely the 299 teachers at this school provide a good representation of all virtual K-12 teachers in the state of Ohio because the school serves approximately 22 thousand (85%) of the 26 thousand virtual K-12 students in the state (Ohio Virtual Academy, 2021a; Ohio Department of Education, 2021).

Results also contextualize previously unknown online virtual synchronous teacher practices such as whether they prepare their own ESP decks, which software they use to create their ESP decks, the number of students who attend each session, attendance rates, and specific details related to the length and frequency of virtual, synchronous class sessions.

The design of this study took into consideration a common criticism of CTML experiments: most of those were conducted in controlled lab environments, were largely limited to STEM materials, and relied on very short pieces of text. While not an experiment, this study attempted to evaluate authentic materials used in real K-12 virtual classrooms.

Most importantly, this study is significant because it presents evidence synchronous, virtual K-12 teachers in this school do not explicitly understand or implement CTML principles known to mitigate extraneous cognitive load into their multimedia ESP designs. It also highlights that a significant portion of students are at risk of cognitive overload, particularly those with known boundary conditions. These findings can be used to inform efforts to improve learning in K-12 synchronous virtual classrooms across the nation.

Recommendations

The lack of evidence found in this study to support the knowledge and implementation of proven practices known to reduce cognitive overload and improve learning outcomes is a call to action for teacher preparation and professional development programs, professional accreditation associations and institutions that recommend high-quality online school practices, virtual K-12 school management organizations, and school administrations. It is crucial that each of these groups address the problem of poor educational outcomes that may be the direct result of improperly designed ESP learning materials.

In light of the recent COVID-19 pandemic and the changing political landscape, it would be irresponsible to assume schools will never again face similar circumstances and be forced to provide instruction remotely. The current lull in pandemic-like circumstances provides the opportunity for US schools to focus on intentionally preparing for any possible future necessity of remote instruction. Sincere efforts to align teacher preparation programs and professional practices to the most recent research in cognition and neuroscience should be made, including a focus on competent online instruction skills for all teachers, no matter where they intend to teach. Explicit instruction for the design of digital learning materials incorporating the CTML principles should be taught, practiced, and mastered over the duration of pre-service courses. School districts and organizations that manage and provide virtual school services should take special interest in improving learning outcomes for their students; investing in research into best ESP practices would work to their benefit. Individual virtual K-12 schools should present the

CTML principles through professional development to raise teacher awareness of their importance and help teachers improve their ESP design skills.

Future Research

As online learning continues to expand, it is imperative researchers redouble efforts to find the best possible tools and practices to improve academic outcomes for hundreds of thousands of online students. This section lays out multiple suggestions for future research. Each idea aims to improve academic learning outcomes for virtual K-12 students, which might, in turn, level the significant differences found between traditional and virtual school state test scores, growth rates, and graduation numbers.

Replication and Expansion

Even though one intention of this study was to add knowledge about online K-12 instructors to the literature, much is still unknown. To confirm and expand findings, this study should be replicated in other K-12 virtual schools in other states and across the nation. It's entirely possible that teachers in other states have a different awareness of and adhere to the principles more often. The parameters should be widened to include the examination of other digital design practices. For example, non-linear presentation software such as Prezi might result in better learning outcomes. Blended and flipped learning environments might elicit different results. This research may have been hampered by the exclusion of audio and video analysis. Future studies should focus on the application of the CTML principles to text-heavy arts-based courses.

More in-depth studies should dig deeper into each of the principles known to reduce extraneous cognitive load, and others should widen the scope of investigation by including the other two groups of principles: those that facilitate essential and foster generative learning. In all future studies, special consideration should be given to determining effects on students who exhibit indicators of known cognitive load boundary conditions.

Other studies should determine which virtual K-12 schools hold synchronous classes and what their reasoning is. Perhaps asynchronous presentations result in better learning. What other digital learning materials do online K-12 virtual teachers design? What percentage of curricular materials are made by teachers or by professional curriculum designers provided by the school? If a school does provide digital resources, do the teachers choose to replace them? If so, why?

Asynchronous content interactions of virtual K-12 students should also be taken into account. It is unknown what percentage of content material virtual school students engage in outside the synchronous classroom, how much of that materially is designed in digital form by teachers, or how those materials might adhere to or violate proven cognitive processes. Findings might indicate a need for investigation into non-teacher designed materials and face-to-face, brick-and-mortar school students and their materials as well.

The CTML is based in part on CLT, which indicates average students can process about seven items at a time. Even if schools intentionally addressed cognitive overload during class sessions, the home environment also contributes to students' ability to pay attention. What distractions do students encounter in their physical learning spaces that might add to their cognitive overload, such as loud noises, other students engaging in different classes, etc. Unlike traditional schools, virtual schools rely significantly on parents ("Learning coaches"), particularly with younger students. Because teachers cannot always see or hear each student during a class session, learning coaches have valuable information about the specific engagement their student displays during a synchronous class. Information collected through surveys or case studies with learning coaches would fill in the gap about what a synchronous class session looks like from the family's perspective and provide valuable information for teachers and schools.

Continued Focus on CTML in K-12

The CTML is still developing, and it is possible that the principles that have proven effective in post-secondary and adult populations might not be as effective with K-12 learners. The efficacy of the CTML principles at the K-12 level should be confirmed. Quasi-experimental studies testing differences in learning outcomes when ESP decks are designed according to the CTML principles (similar to the redesign studies reported in the literature) should be conducted. To find generalizable data, multiple studies should be carried out using virtual K-12 courses and standardized tests across multiple school in multiple states. Mixed methods studies with standardized test comparisons in combination with qualitative analysis of teachers who participate in an intervention to learn and apply the CTML principles would yield powerful information. To build a more thorough base to examine differences and compare digital design practices, experimental designs should also be developed and conducted in brick and mortar schools.

Administrators and Policymakers

It is unknown whether school administrators are aware there is a need to create digital materials in a way that best aligns with cognitive processing, and if they are, what actions are taken to ensure students receive the highest quality materials as possible. Research should begin with determining awareness among administrators and discovering the unique insights they might have toward improving outcomes and providing resources for their teachers.

More questions than answers have been raised in this study. If negative academic outcomes of virtual online K-12 schools are not a result of teacher competency but of the nature of virtual school itself as this study and other research suggests (Azevedo et al., 2004; Cavanagh et al., 2004; Fitzpatrick et al., 2020), then the following questions should be addressed by administrators and policymakers through future research:

1. What percentage of learning outcomes can be attributed to synchronous learning sessions? What percentage of learning outcomes might be attributed to engagement outside synchronous sessions, with digital and/or paper materials?
2. What are the effects of "learn at your own pace on your own time" engagement policies on learning outcomes, and how does the format of synchronous and asynchronous curriculum contribute to those outcomes?
3. Should engagement policies replace outdated attendance policies for online students?
4. Does the role of online instructors need to change? What should online teachers be held accountable for?
5. Does the student-to-teacher ratio impact learning outcomes differently when instruction is virtual?
6. If students with boundary issues are disproportionately affected by violations to the CTML principles, should those students be provided with different curriculum, ESP, or learning environments?
7. What resources should school administrators invest in to provide teachers with training and tools for better teaching?

Teacher Preparation Programs

In accord with Mayer's (2020) stated intention of using the CTML to provide practical resources for practitioners, teacher preparation programs should include effective ways for teachers to improve the design of their ESP decks to minimize cognitive overload and maximize comprehension for students. Future research should include the development of instructional design courses or learning modules. As well, research should audit the contents of educational psychology courses to ensure future educators are provided up-to-date knowledge of CTML and other cognitive science principles.

Conclusion

In sum, this initial investigation into the perceptions and practices of virtual K-12 educators and their adherence to the CTML principles that mitigate extraneous cognitive overload has only scraped the surface. Many avenues for future research emerged.

References

Abrami, P., Bernard, R., Bures, E., Borokhovski, E., & Tamim, R. (2011). Interaction in distance education and online learning: using evidence and theory to improve practice. *Journal of Computing in Higher Education, 23*(2/3), 82–103. https://doi org/10.1007/s12528-011-9043-x

Adesope, O. O., & Nesbit, J. C. (2012). Verbal redundancy in multimedia learning environments: A meta-analysis. *Journal of Educational Psychology, 104*(1), 250–263. https://doi.org/10.1037/a0026147

Ahn, J. (2016). Enrollment and achievement in Ohio's virtual charter schools. *Fordham Institute*, *1*, 33–36. https://doi.org/10.1017/CBO9781107415324.004

Ahn, J., & McEachin, A. (2017). Student enrollment patterns and achievement in Ohio's online charter schools. *Educational Researcher, 46*(1), 44–57. https://doi.org/10.3102%2F0013189X17692999

Alpert, W. T., Couch, K. A., & Harmon, O. R. (2016). A randomized assessment of online learning. *American Economic Review*, *106*(5), 378-82. https://doi.org/10.1257/aer.p20161057

Alpizar, D., Adesope, O. O., & Wong, R. M. (2020). A meta-analysis of signaling principle in multimedia learning environments. *Educational Technology Research and Development, 68*(5), 2095-2119. https://doi.org/10.1007/s11423-020-09748-7

Anmarkrud, Ø., Andresen, A., & Bråten, I. (2019). Cognitive load and working memory in multimedia learning: Conceptual and measurement issues. *Educational Psychologist*, *54*(2), 61-83. https://doi.org/10.1080/00461520.2018.1554484

Annetta, L. A., Slykhuis, D., & Wiebe, E. (2007). Evaluating gender differences of attitudes and perceptions toward PowerPoint for preservice science teachers. *Eurasia Journal of Mathematics*, *3*(4), 297–304.

APA dictionary of psychology. (2022). American Psychological Association. https://dictionary.apa.org/

Archambault, L., & Kennedy, K. (2012, March). Situated online: Theoretical underpinnings of field experiences in virtual school settings. In *Society for Information Technology & Teacher Education International Conference* (pp. 3816-3823). Association for the Advancement of Computing in Education (AACE).

Azevedo, R., Cromley, J. G., & Seibert, D. (2004). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia? *Contemporary Educational Psychology*, *29*(3), 344-370. https://doi.org/10.1016/j.cedpsych.2003.09.002

Baceviciute, S., Lucas, G., Terkildsen, T., & Makransky, G. (2021). Investigating the redundancy principle in immersive virtual reality environments: An eye-tracking and EEG study. *Journal of Computer Assisted Learning*. https://doi.org/10.1111/jcal.12595

Bacolod, M., Mehay, S., & Pema, E. (2018). Who succeeds in distance learning? Evidence from quantile panel data estimation. *Southern Economic Journal*, *84*(4), 1129–1145. https://doi.org/10.1002/soej.1226

Baddeley, A. D. (1983). Working memory. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 311-324. https://doi.org/10.1098/rstb.1983.0057

Baddeley, A. D. (1992). Working memory: The interface between memory and cognition. *Journal of Cognitive Neuroscience*, *4*(3), 281-288. https://doi.org/10.1162/jocn.1992.4.3.281

Baddeley, A. D., & Hitch, G. (1974). Working Memory. *Psychology of Learning and Motivation*, (*8*)47–89. https://doi.org/10.1016/S0079-7421(08)60452-1

Baker, J. P., Goodboy, A. K., Bowman, N. D., & Wright, A. A. (2018). Does teaching with PowerPoint increase students' learning? A meta-analysis. *Computers and Education*, *126*, 376–387. https://doi.org/10.1016/j.compedu.2018.08.003

Barbour, M. K. (2015). Real-time virtual teaching: Lessons learned from a case study in a rural school. *Journal of Asynchronous Learning Network*, *19*(5), 54–68. http://dx.doi.org/10.24059/olj.v19i5.705

Barbour, M. K. (2017). K–12 online learning and school choice. *The Wiley handbook of school choice*, *3*, 421.

Barbour, M., Kinsella, J., Wicks, M. & Toker, S. (2009). Continuing change in a virtual world: Training and recruiting instructors. *Journal of Technology and Teacher Education*, *17*(4), 437–457. https://www-aace-org.ezproxy.liberty.edu:8888/

Barbour, M. K., Siko, J., Gross, E., & Waddell, K. (2013). Virtually unprepared: Examining the preparation of K-12 online teachers. In R. Hartshorne, T. Heafner, & T. Petty (Eds.), *Teacher education programs and online learning tools: Innovations in teacher preparation*, 60–81. IGI Global. https://doi.org/10.4018/978-1-4666-4502-8.ch011

Beaulieu, L. C., & Poyo, S. (2021, June 28). *Cognitive theory of multimedia principles of coherence and redundancy in educators' electronic slide presentation design: What do teachers know about cognitive science in slide design?* [Paper presentation]. International Society for Technology in Education ISTELive 21.

Bernard, R. M., Abrami, P. C., Lou, Y., Borokhovski, E., Wade, A., Wozney, L., Wallet, P. A., Fiset, M., & Huang, B. (2004a). How does distance education compare with classroom instruction? A meta-analysis of the empirical literature. *Review of Educational Research*, *74*(3), 379-439. https://doi.org/10.3102/00346543074003379

Bernard, R. M., Abrami, P. C., Wade, A., Borokhovski, E., & Lou, Y. (2004b). The effects of synchronous and asynchronous distance education: A meta-analytical assessment of Simonson's "Equivalency Theory." *Association for Educational Communications and Technology*.

Bettinger, E. P., Fox, L., Loeb, S., & Taylor, E. S. (2017). Virtual classrooms: How online college courses affect student success. *American Economic Review*, *107*(9), 2855–2875. https://doi.org/10.1257/aer.20151193

Black, E., DiPietro, M., Ferdig, R., & Polling, N. (2009). Developing a survey to measure best practices of K-12 online instructors. *Online Journal of Distance Learning Administration*, *12*(1), 13.

Bolkan, S. (2017) Instructor clarity, generative processes, and mastery goals: examining the effects of signaling on student learning, *Communication Education, 66*(4), 385-401, https://doi.org/10.1080/03634523.2017.1313438

Bolkan, S. (2019). Facilitating student attention with multimedia presentations: Examining the effects of segmented PowerPoint presentations on student learning. *Communication Education*, *68*(1), 61-79. https://doi.org/10.1080/03634523.2018.1517895

Bolliger, D. & Halupa, C. (2018). Online student perceptions of engagement, transactional distance, and outcomes. *Distance Education*, *39*(3), 299–316. https://doi.org/10.1080/01587919.2018.1476845

Borup, J., Graham, C. R., & Drysdale, J. S. (2014). The nature of teacher engagement at an online high school. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.12089

Bradley, B. (2020, November 23). K12 rebrands itself as Stride Inc., and announces two acquisitions. EDWEEK Market Brief. https://marketbrief.edweek.org/marketplace-k-12/k12-rebrands-stride-inc-announces-two-acquisitions/

Brasell, H. (1987). The effect of real-time laboratory graphing on learning graphic representations of distance and velocity. *Journal of Research in Science Teaching*, *24*(4), 385-395.

Butcher, K. R. (2014). The multimedia principle. In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (2nd ed., pp. 174–205). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.010

Çakiroğlu, Ü., & Aksoy, D. A. (2017). Exploring extraneous cognitive load in an instructional process via the web conferencing system. *Behaviour & Information Technology*, *36*(7), 713-725. https://doi.org/10.1080/0144929X.2016.1276964

Castro-Alonso, J. C., Ayres, P., & Sweller, J. (2019a). Instructional visualizations, cognitive load theory, and visuospatial processing. In *Visuospatial processing for education in health and natural sciences* (pp. 111-143). Springer, Cham. https://doi.org/10.1007/978-3-030-20969-8

Castro-Alonso, J. C., Wong, M., Adesope, O. O., Ayres, P., & Paas, F. (2019b). Gender imbalance in instructional dynamic versus static visualizations: A meta-analysis. *Educational Psychology Review*, *31*(2), 361-387.

Cavanaugh, C. S. (2001). The effectiveness of interactive distance education technologies in K-12 learning: A meta-analysis. *International Journal of Educational Telecommunications*, *7*(1), 73-88.

Cavanaugh, C., Gillan, K. J., Kromrey, J., Hess, M., & Blomeyer, R. (2004). The effects of distance education on k-12 student outcomes: A meta-analysis. *Learning Point Associates/North Central Regional Educational Laboratory (NCREL)*.

Center for Research on Education Outcomes (CREDO). (2019). *Charter School Performance in Ohio*. Stanford University. https://credo.stanford.edu/

Chandler, P. & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, *8*(4), 293–332. https://doi.org/10.1207/s1532690xci0804_2

Chen, C. C., & Shaw, R. (2006). Online synchronous vs. asynchronous software training through the behavioral modeling approach: A longitudinal field experiment. *International Journal of Distance Education Technologies, 4*(4), *88–102.*

Clark, J. M. & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review, 3*(3), 149–210.

Clark, R. E. (1994). Media will never influence learning. *Educational technology research and development*, *42*(2), 21-29.

Coleman, J. M., McTigue, E. M., & Dantzler, J. A. (2018). What makes a diagram easy or hard? The impact of diagram design on fourth-grade students' comprehension of science texts. *The Elementary School Journal*, *119*(1), 122-151. https://doi.org/10.1086/698819

Collis, B. (1996). *Tele-learning in a digital world: The future of distance learning*. London. International Thompson Computer Press.

Costley, J., & Lange, C. (2017). The effects of lecture diversity on germane load. *International Review of Research in Open and Distance Learning, 18*(2), 27–46. https://doi.org/10.19173/irrodl.v18i2.2860

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Progress in Brain Research, (169*)323-338. https://doi.org/10.1016/S0079-6123(07)00020-9

Craig, S. D., & Schroeder, N. L. (2017). Reconsidering the voice effect when learning from a virtual human. *Computers and Education*, (*114*)193–205. https://doi.org/10.1016/j.compedu.2017.07.003

Curtis, H., & Werth, L. (2015). Fostering student success and engagement in a K-12 online school. *Journal of Online Learning Research*, *1*(2), 163–190.

Davis, R. O., Vincent, J., & Park, T. J. (2019). Reconsidering the voice principle with non-native language speakers. *Computers and Education*, *140*. https://doi.org/10.1016/j.compedu.2019.103605

de Freitas, S., & Neumann, T. (2009). Pedagogic strategies supporting the use of synchronous audiographic conferencing: A review of the literature. *British Journal of Educational Technology*, *40*(6), 980–998. https://doi.org/10.1111/j.1467-8535.2008.00887.x

de Koning, B. B., Tabbers, H. K., Rikers, R. M., & Paas, F. (2007). Attention cueing as a means to enhance learning from an animation. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *21*(6), 731-746. https://doi.org/10.1002/acp.1346

Deming, D. J., Goldin, C., & Katz, L. F. (2012). The for-profit postsecondary school sector: Nimble critters or agile predators? *Journal of Economic Perspectives*, *26*(1), 139–164. https://doi.org/10.1257/jep.26.1.139

Deming, D. J., Yuchtman, N., Abulafi, A., Goldin, C., & Katz, L. F. (2016). The value of postsecondary credentials in the labor market: An experimental study. *American Economic Review*, *106*(3), 778-806. https://doi.org/10.1257/aer.20141757

D'Esposito, M., & Postle, B. R. (2015). The cognitive neuroscience of working memory. *Annual Review of Psychology, 66,* 115–142. https://doi.org/10.1146/annurev-psych-010814-015031

Dharani, K. (2015). Chapter 3—Memory. The biology of thought: A neuronal mechanism in the generation of thought: A new molecular model, 53-74. https://doi.org/10.1016/B978-0-12-800900-0.00003-8

Digital Learning Collaborative (2019). SNAPSHOT: *Keeping pace with digital learning: A review of K-12 online, blended, and digital learning.* https://www.digitallearningcollab.com/

DiPietro, M., Ferdig, R. E., Black, E. W., & Preston, M. (2008). Best practices in teaching K-12 online: Lessons learned from Michigan Virtual School teachers. *Journal of Interactive Online Learning, 7*(1), 10-35.

Dousay, T. A. (2016). Effects of redundancy and modality on the situational interest of adult learners in multimedia learning. *Education Tech Research Development*, *64*, 1251–1271. https://doi.org/10.1007/s11423-016-9456-3

Duncan, K., Kenworthy, A., & McNamara, R. (2012). The effect of synchronous and asynchronous participation on students' performance in online accounting courses. *Accounting Education, 21*(4), 431–449. https://doi.org/10.1080/09639284.2012.673387

Ferdig, R. E., Cavanaugh, C., DiPietro, M., Black, E. W., & Dawson, K. (2009). Virtual schooling standards and best practices for teacher education. *Journal of Technology and Teacher Education, 17*(4), 479-503. https://www.learntechlib.org/primary/p/30481/

Ferreira, C. M., Santos, A. I., & Serpa, S. (2018). Electronic Slideshow Presentations in the Higher Education Teaching and Learning Process. *Journal of Education and Training Studies*, *6*(2), 120-124.

Figlio, D., Rush, M., & Yin, L. (2013). Is it live or is it internet? Experimental estimates of the effects of online instruction on student learning. *Journal of Labor Economics*, *31*(4), 763-784. https://doi.org/10.1086/669930

Fish, L. A., & Snodgrass, C. R. (2019). Age and gender and their influence on instructor perspectives of online versus face-to-face education at a Jesuit institution. *Journal of Education for Business*, *94*(8), 531–537. https://doi.org/10.1080/08832323.2019.1595499

Fitzpatrick, B. R., Berends, M., Ferrare, J. J., & Waddington, R. J. (2020). Virtual illusion: Comparing student achievement and teacher and classroom characteristics in online and brick-and-mortar charter schools. *Educational Researcher*, *49*(3), 161-175. https://doi.org/10.3102/0013189X20909814

Florax, M., & Ploetzner, R. (2010). What contributes to the split-attention effect? The role of text segmentation, picture labelling, and spatial proximity. *Learning and Instruction, 20*(3), 216–224. https://doi.org/10.1016/j.learninstruc.2009.02.021

Friend, B. & Johnston, S. (2005). Florida virtual school: a choice for all students. In Z. L. Berge & T. Clark (Eds), *Virtual schools: Planning for success* (pp. 97–117). New York: Teachers College Press.

Gardner, H. (1993). *Multiple intelligences: The theory in practice.* Basic Books, HarperCollins Publishers.

Garner, J. K., & Alley, M. P. (2013). How the design of presentation slides affects audience comprehension: A case for the assertion-evidence approach. *International Journal of Engineering Education*, *29*(6), 1564–1579.

Gemin, B., Pape, L., & Evergreen Education Group. (2017). Keeping Pace with K-12 Online Learning 2016. In *Evergreen Education Group*. Evergreen Education Group.

Gill, B., Walsh, L., Wulsin, C. S., Matulewicz, H., Severn, V., Grau, E., Lee, A., & Kerwin, T. (2015). Inside online charter schools. A report of the national study of online charter schools. *Mathematica Policy Research, Inc.*

Ginns, P. (2005). Meta-analysis of the modality effect. *Learning and Instruction, 15*(4), 313–331. https://doi.org/10.1016/j.learninstruc.2005.07.001

Ginns, P. (2006). Integrating information: A meta-analysis of the spatial contiguity and temporal contiguity effects. *Learning and Instruction, 16*(6), 511-525. https://doi.org/10.1016/j.learninstruc.2006.10.001

Ginns, P., Martin, A., & Marsh, H. (2013). Designing instructional text in a conversational style: A meta-analysis. *Educational Psychology Review*, *25*(4), 445–472. https://doi-org.authenticate.library.duq.edu/10.1007/s10648-013-9228-0

Gligora Marković, M., Kliček, B., & Plantak Vukovac, D. (2014). The effects of multimedia learning materials quality on knowledge acquisition. In V. Strahonja, N. Vrček., D.

Plantak Vukovac, C. Barry, M. Lang, H. Linger, & C. Schneider (Eds.), *Information Systems Development: Transforming Organisations and Society through Information Systems (ISD2014 Proceedings).*

Gocognitive. (2010, November 5). *Alan Baddeley - Binding and the Episodic Buffer* [Video]. Youtube. https://youtu.be/tj_wwggiA68

Google Scholar. (2022). *Richard E. Mayer.* https://scholar.google.com/citations?user=o5doXYoAAAAJ&hl=en&oi=sra

Grech, V. (2018). The application of the Mayer multimedia learning theory to medical PowerPoint slide show presentations. *Journal of Visual Communication in Medicine, 41*(1), 36–41. https://doi.org/10.1080/17453054.2017.1408400

Guillén-Gámez, F. D., Mayorga-Fernández, M. J, Bravo-Agapito, J., & Escribano-Ortiz, D. (2021). Analysis of teachers' pedagogical digital competence: Identification of factors predicting their acquisition. *Technology, Knowledge and Learning*, *26*(3), 481–498. https://doi.org/10.1007/s10758-019-09432-7

Guo, D., McTigue, E. M., Matthews, S. D., & Zimmer, W. (2020a). The impact of visual displays on learning across the disciplines: A systematic review. *Educational Psychology Review*, *32*(3), pp. 627–656). https://doi.org/10.1007/s10648-020-09523-3

Guo, D., Wright, K. L., & McTigue, E. M. (2018). A content analysis of visuals in elementary school textbooks. *The Elementary School Journal*, *119*(2), 244-269. https://doi.org/10.1086/700266

Guo, D., Zhang, S., Wright, K. L., & McTigue, E. M. (2020b). Do you get the picture? A meta-analysis of the effect of graphics on reading comprehension. *AERA Open*, *6*(1), 2332858420901696. https://doi.org/10.1177/2332858420901696

Guo, D., Zimmer, W., Matthews, S. D., & McTigue, E. M. (2019). Critical analysis of research on the impact of visual literacy for learning: Strengths, weaknesses and recommendations for improvement. *Journal of Visual Literacy*, *38*(3), 181-198. https://doi.org/10.1080/1051144X.2019.1611702

Han, J., Zheng, Q., & Ding, Y. (2021). Lost in virtual reality? Cognitive load in high immersive VR environments. *Journal of Advances in Information Technology*, *12*(4). https://doi.org/10.12720/jait.12.4.302-310

Harp, S. F., & Maslich, A. A. (2005). The consequences of including seductive details during lecture. *Teaching of Psychology*, *32*(2), 100-103. https://doi.org/10.1207/s15328023top3202_4

Harp, S. F., & Mayer, R. E. (1998). How seductive details do their damage: A theory of cognitive interest in science learning. *Journal of Educational Psychology, 90*(3), 414–434. https://doi.org/10.1037/0022-0663.90.3.414

Hart, C. M., Friedmann, E., & Hill, M. (2018). Online course-taking and student outcomes in California community colleges. *Education Finance and Policy*, *13*(1), 42-71. https://doi.org/10.1162/edfp_a_00218

Hattie, J., & Clarke, S. (2018). *Visible learning: Feedback*. Routledge. https://doi.org/10.4324/9780429485480

Hitch, G. J., Allen, R. J., & Baddeley, A. D. (2020). Attention and binding in visual working memory: Two forms of attention and two kinds of buffer storage. *Attention, Perception, and Psychophysics, 82*(1), 280–293. https://doi.org/10.3758/s13414-019-01837-x

Honebein, P. C., & Honebein, C. H. (2014). The influence of cognitive domain content levels and gender on designer judgments regarding useful instructional methods. *Educational*

Technology Research and Development, *62*(1), 53–69. https://doi.org/10.1007/s11423-013-9322-5

Horvath, J. C. (2014). The Neuroscience of PowerPoint TM. *Mind, Brain, and Education*, *8*(3), 137–143. https://doi.org/10.1111/mbe.12052

Hu, L., Chen, G., & Li, P. (2021). Multimedia effect in problems solving: A meta-analysis. *Educational Psychology Review* (2021). https://doi.org/10.1007/s10648-021-09610-z

Huang, C. (2005). Designing high-quality interactive multimedia learning modules. *Computerized Medical Imaging and Graphics*, *29*(2-3), 223-233. https://doi.org/10.1016/j.compmedimag.2004.09.017

Huang, X., Chandra, A., DePaolo, C. A., & Simmons, L. L. (2016). Understanding transactional distance in web-based learning environments: An empirical study. *British Journal of Educational Technology*, *47*(4), 734–747. https://doi.org/10.1111/bjet.12263

Huang, Y., Zhao, C., Shu, F., & Huang, J. (2017, December). Investigating and analyzing teaching effect of blended synchronous classroom. In *2017 International Conference of Educational Innovation through Technology (EITT)* (pp. 134-135). IEEE. https://doi.org/10.1109/EITT.2017.40

IBM Corp. (2020). IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp

Issa, N., Mayer, R. E., Schuller, M., Wang, E., Shapiro, M. B., & Darosa, D. A. (2013). Teaching for understanding in medical classrooms using multimedia design principles. *Medical Education, 47*(4), 388–396. https://doi.org/10.1111/medu.12127

Issa, N., Schuller, M., Santacaterina, S., Shapiro, M., Wang, E., Mayer, R. E., & DaRosa, D. A. (2011). Applying multimedia design principles enhances learning in medical education. *Medical Education*, *45*(8), 818-826. https://doi.org/10.1111/j.1365-2923.2011.03988.x

Jahng, N., Krug, D., & Zhang, Z. (2007). Student achievement in online distance education compared to face-to-face education. *European Journal of Open, Distance and E-Learning, 10*(1).

Johnson, A. M., Ozogul, G., & Reisslein, M. (2015). Supporting multimedia learning with visual signalling and animated pedagogical agent: Moderating effects of prior knowledge. *Journal of Computer Assisted Learning*, *31*(2), 97-115. https://doi.org/10.1111/jcal.12078

Kalyuga, S. (2005). Prior knowledge principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 325–337). Cambridge University Press. https://doi.org/10.1017/CBO9780511816819.022

Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review*, *19*(4), 509–539. https://doi-org.authenticate.library.duq.edu/10.1007/s10648-007-9054-3

Kalyuga, S. (2014). The expertise reversal principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 576–597). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.028

Kalyuga, S., Chandler, P., & Sweller, J. (1998). Levels of expertise and instructional design. *Human Factors, 40*(1), 1–17. https://doi.org/10.1518/001872098779480587

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *13*(4), 351-371. https://doi.org/10.1002/(SICI)1099-0720(199908)13:4<351::AID-ACP589>3.0.CO;2-6

Kalyuga, S., Chandler, P., & Sweller, J. (2004). When redundant on-screen text in multimedia technical instruction can interfere with learning. *Human Factors*, *46*(3), 567-581.

Kalyuga, S., & Renkl, A. (2010). Expertise reversal effect and its instructional implications: Introduction to the special issue. *Instructional Science*, *38*(3), 209-215.

Kalyuga, S., & Sweller, J. (2014). The redundancy principle in multimedia learning. *The Cambridge handbook of multimedia learning*.

Kanellopoulou, C., Kermanidis, K. L., & Giannakoulopoulos, A. (2019). The dual-coding and multimedia learning theories: Film subtitles as a vocabulary teaching tool. *Education Sciences, Vol. 9*. https://doi.org/10.3390/educsci9030210

Kartal, G. (2010). Does language matter in multimedia learning? Personalization principle revisited. *Journal of Educational Psychology*, *102*(3), 615–624. https://doi.org/10.1037/a0019345

Keegan, D. (2013). *Foundations of distance education.* Routledge.

Kester, L., Kirschner, P. A., & van Merrienboer, J. J. G. (2004). Timing of information presentation in learning statistics. *Instructional Science, 32*(3), 233–252.

Khacharem, A., Trabelsi, K., Engel, F. A., Sperlich, B., & Kalyuga, S. (2020). The effects of temporal contiguity and expertise on acquisition of tactical movements. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.0041

Killian, C. M., Kinder, C. J., & Woods, A. M. (2019). Online and blended instruction in K–12 physical education: A scoping review. *Kinesiology Review, 8*(2), 110-129.

Kirschner, P. A., Sweller, J., Kirschner, F., & Zambrano, J. R. (2018). From cognitive load theory to collaborative cognitive load theory. *International Journal of Computer-*

Supported Collaborative Learning, 13(2), 213–233. https://doi.org/10.1007/s11412-018-9277-y

Klepsch, M., Schmitz, F., & Seufert, T. (2017). Development and validation of two instruments measuring intrinsic, extraneous, and germane cognitive load. *Frontiers in Psychology, 8*, 1997. https://doi.org/10.3389/fpsyg.2017.01997

Kosslyn, S. M., Kievit, R. A., Russell, A. G., & Shephard, J. M. (2012). PowerPoint® presentation flaws and failures: a psychological analysis. *Frontiers in Psychology*, *3*, 230. https://doi.org/10.3389/fpsyg.2012.00230

Lawson, A. P., & Mayer, R. E. (2021). Benefits of writing an explanation during pauses in multimedia lessons. *Educational Psychology Review*, 1-27.

Leacock, T. L., & Nesbit, J. C. (2007). A framework for evaluating the quality of multimedia learning resources. *Journal of Educational Technology & Society*, *10*(2), 44-59.

Lehmann, J. A. M., & Seufert, T. (2017). The influence of background music on learning in the light of different theoretical perspectives and the role of working memory capacity. *Frontiers in Psychology*, *8*, 1902. https://doi.org/10.3389/fpsyg.2017.01902

Lemak, D. J., Shin, S. J., Reed, R., & Montgomery, J. C. (2005). Technology, transactional distance, and instructor effectiveness: An empirical investigation. *Academy of Management Learning & Education*, *4*(2), 150–159. https://doi.org/10.5465/amle.2005.17268562

Leslie, K. C., Low, R., Jin, P., & Sweller, J. (2012). Redundancy and expertise reversal effects when using educational technology to learn primary school science. *Educational Technology Research and Development*, *60*(1), 1–13. https://doi.org/10.1007/s11423-011-9199-0

Levasseur, D. G., & Kanan Sawyer, J. (2006). Pedagogy meets PowerPoint: A research review of the effects of computer-generated slides in the classroom. *The Review of Communication, 6(*1-2), 101-123. https://doi.org/10.1080/15358590600763383

Levinson, A. J. (2010). Where is evidence-based instructional design in medical education curriculum development? In *Medical Education* (Vol. 44, Issue 6, pp. 536–537). https://doi.org/10.1111/j.1365-2923.2010.03715.x

Liu, X., Liu, C. H., & Li, Y. (2020). The effects of computer-assisted learning based on dual coding theory. *Symmetry, 12*(5). https://doi.org/10.3390/SYM12050701

Machtmes, K., & Asher, J. W. (2000). A meta-analysis of the effectiveness of telecourses in distance education. *American Journal of Distance Education*, *14*(1), 27-46.

Mahajan, R., Gupta, K., Gupta, P., Kukreja, S., & Singh, T. (2020). Multimedia instructional design principles: Moving from theoretical rationale to practical applications. *Indian Pediatrics, 57*(6), 555–560. https://doi.org/10.1007/s13312-020-1854-2

Malinovski, T., Vasileva, M., Vasileva-Stojanovska, T., & Trajkovik, V. (2014). Considering high school students' experience in asynchronous and synchronous distance learning environments: QoE prediction model. *The International Review of Research in Open and Distributed Learning*, *15*(4). https://doi.org/10.19173/irrodl.v15i4.1808

Martin, F., Ahlgrim-Delzell, L., & Budhrani, K. (2017). Systematic review of two decades (1995 to 2014) of research on synchronous online learning. *American Journal of Distance Education, 31*(1) 3–19. https://doi.org/10.1080/08923647.2017.1264807

Martin, F., Budhrani, K., Kumar, S., & Ritzhaupt, A. (2019). Award-winning faculty online teaching practices: Roles and competencies. *Online Learning Journal*, *23*(1), 184–205. https://doi.org/10.24059/olj.v23i1.1329

Martin, F., & Carr, M. (2015). An exploratory study on K-12 teachers' use of technology and multimedia in the classroom. *I-Manager's Journal of Educational Technology*, *12*(1), 7–14.

Martin, F., & Parker, M. A. (2014). Use of synchronous virtual classrooms: Why, who, and how. *MERLOT Journal of Online Learning and Teaching*, *10*(2), 192-210.

Mautone, P. D., & Mayer, R. E. (2001). Signaling as a cognitive guide in multimedia learning. *Journal of Educational Psychology*, *93*(2), 377–389. https://doi.org/10.1037//O022-O663.93.2.377

Mayer, R. E. (2001). *Multimedia learning*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139164603

Mayer, R. E. (2005). Principles of multimedia learning based on social cues: Personalization, voice, and image principles. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 201–212). Cambridge University Press. https://doi.org/10.1017/CBO9780511816819.014

Mayer, R. E. (2010). Applying the science of learning to medical education *Medical Education*, *44*(6), 543-549.

Mayer, R. E. (Ed.). (2014). *The Cambridge handbook of multimedia learning* (2nd ed). Cambridge University Press.

Mayer, R. E. (2019). Thirty years of research on online learning. *Applied Cognitive Psychology*, *33*(2), 152–159. https://doi.org/10.1002/acp.3482

Mayer, R. E. (2020). *Multimedia learning* (3rd ed). Cambridge University Press. https://doi:10.1017/9781316941355

Mayer, R. E., & Fiorella, L. (2014). Principles for reducing extraneous processing in multimedia learning: Coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles. In The Cambridge Handbook of Multimedia Learning, Second Edition. https://doi.org/10.1017/CBO9781139547369.015

Mayer, R. E., Griffith, E., Jurkowitz, I. T. N., & Rothman, D. (2008). Increased interestingness of extraneous details in a multimedia science presentation leads to decreased learning. *Journal of Experimental Psychology: Applied*, *14*(4), 329–339. https://doi.org/10.1037/a0013835

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 43–52. https://doi.org/10.1207/S15326985EP3801_6

McBrien, J. L., Jones, P., & Cheng, R. (2009). Virtual spaces: Employing a synchronous online classroom to facilitate student engagement in online learning. *International Review of Research in Open and Distance Learning*, *10*(3), 1–17. https://doi.org/10.19173/irrodl.v10i3.605

McClanahan, B. J., & Nottingham, M. (2019). A suite of strategies for navigating graphic novels: A dual coding approach. *Reading Teacher, 73*(1), 39–50. https://doi.org/10.1002/trtr.1797

McKenney, S., Kali, Y., Markauskaite, L., & Voogt, J. (2015). Teacher design knowledge for technology enhanced learning: An ecological framework for investigating assets and needs. *Instructional Science, 43*(2), 181–202. https://doi.org/10.1007/s11251-014-9337-2

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies.* U.S. Department of Education.

Miller, G. A. (1994). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *101*(2), 343–352.

Molnar, A., Miron, G., Elgeberi, N., Barbour, M. K., Huerta, L., Shafer, S. R., & Rice, J. K. (2019). *Virtual schools in the U.S.* National Education Policy Center. http://nepc.colorado.edu/ publication/virtual-schools-annual-2019

Moore, M. G. (1973). Toward a theory of independent learning and teaching. *The Journal of Higher Education*, *44*(9), 661-679.

Moore, M. & Kearsley, G. (1996). *Distance education: A systems review*. Belmont: Wadsworth Publishing Company.

Moore, M. G., & Kearsley, G. (2011). *Distance education: A systems view of online learning*. United States: Cengage Learning.

Moreno, R., & Mayer, R. E. (2000). A coherence effect in multimedia learning: The case for minimizing irrelevant sounds in the design of multimedia instructional messages. *Journal of Educational Psychology*, *92*(1), 117–125. https://doi.org/10.1037/0022

Murphy, E., & Rodríguez-Manzanares, M. (2008). Revisiting transactional distance theory in a context of web-based high-school distance education. *Journal of Distance Education*, *22*(2), 1–14.

Murphy, E., Rodríguez-Manzanares, M. A., & Barbour, M. (2011). Asynchronous and synchronous online teaching: Perspectives of Canadian high school distance education teachers. *British Journal of Educational Technology, 42*(4), 583–591. https://doi.org/10.1111/j.1467-8535.2010.01112.x

Nagmoti, J. M. (2017). Departing from PowerPoint default mode: Applying Mayer's multimedia principles for enhanced learning of parasitology. *Indian Journal of Medical*

Microbiology, 35(2), 199–203. https://doi.org/10.4103/ijmm.IJMM

National Center for Education Statistics (NCES), U.S. Department of Education (2021a). *Fast Facts: Back-to-school statistics.* https://nces.ed.gov/fastfacts/display.asp?id=372#College-distancelearning

National Center for Education Statistics (NCES), U.S. Department of Education (2021b). *Identifying Virtual Schools Using the Common Core of Data (CCD).* Common Core of Data America's Public Schools.

National Center for Education Statistics (NCES), U.S. Department of Education (2021c). *The condition of education 2021*: *Characteristics of public school teachers.* https://nces.ed.gov/programs/coe/indicator/clr

Nguyen, G. N. H., & Bower, M. (2018). Novice teacher technology-enhanced learning design practices: The case of the silent pedagogy. *British Journal of Educational Technology*, *49*(6), 1027–1043. https://doi.org/10.1111/bjet.12681

Noyes, J. A., Carbonneau, K. J., Gotch, C. M., & Matthew, S. M. (2020). Is a picture worth a thousand words? Evaluating the design of instructional animations in veterinary education. *Journal of Veterinary Medical Education*, *47*(1), 69-77. https://doi.org/10.3138/jvme.0118-002r

Ohio Department of Education. (2021). *Enrollment Data: Fall Enrollment (Headcount).* http://education.ohio.gov/Topics/Data/Frequently-Requested-Data/Enrollment-Data

Ohio Virtual Academy. (2021a). *Annual Report 2020-2021.* https://www.k12.com/content/dam/mps-refresh/ohva/files/Annual_Report_2020-2021.pdf

Ohio Virtual Academy. (2021b). *School Handbook 2021-2022.* https://sites.google.com/view/ohvahandbook/home

Ollerenshaw, A., Aidman, E., & Kidd, G. (1997). Is an illustration always worth ten thousand words? Effects of prior knowledge, learning style, and multimedia illustrations on text comprehension. *International Journal of Instructional Media, 24*, 227–238

Olson, J. S., & McCracken, F. E. (2014). Is it worth the effort? The impact of incorporating synchronous lectures into an online course. *Online Learning*, *19*(2). https://doi.org/10.24059/olj.v19i2.499

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. M. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychologist, 38*(1), 63–71. https://doi.org/10.1207/S15326985EP3801_8

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology/Revue Canadienne de Psychologie, 45*(3), 255–287. https://doi.org/10.1037/h0084295

Paivio, A. (2014). Intelligence, dual coding theory, and the brain. *Intelligence*, *47*, 141-158.

Paivio, A., & Csapo, K. (1971). Short-term sequential memory for pictures and words. *Psychonomic Science, 24*(2), 50–51. https://doi.org/10.3758/BF03337887

Paivio, A., Rogers, T. B., & Smythe, P. C. (1968). Why are pictures easier to recall than words? *Psychonomic Science, 11*(4), 137–138. https://doi.org/10.3758/BF03331011

Pantazes, T. C. (2021). Online instructors’ use of the Cognitive Theory of Multimedia Learning design principles: A mixed methods investigation [Doctoral dissertation, West Chester University]. https://digitalcommons.wcupa.edu/all_doctoral/81

Park, B., Korbach, A., & Brünken, R. (2015). Do learner characteristics moderate the seductive-details-effect? A cognitive-load-study using eye-tracking. *Journal of Educational Technology & Society, 18*(4), 24–36.

Park, E., Martin, F., & Lambert, R. (2019). Examining predictive factors for student success in a hybrid learning course. *Quarterly Review of Distance Education*, (2), 11-74.

Parker, I. (2001). Absolute PowerPoint. *The New Yorker*. https://www.newyorker.com/magazine/2001/05/28/absolute-powerpoint

Passig, D., & Levin, H. (1999). Gender interest differences with multimedia learning interfaces. *Computers in Human Behavior*, *15*(2), 173–183. https://doi.org/10.1016/S0747-5632(99)00016-3

Pate, A., & Posey, S. (2016). Effects of applying multimedia design principles in PowerPoint lecture redesign. *Currents in Pharmacy Teaching and Learning, 8*(2), 235–239. https://doi.org/10.1016/j.cptl.2015.12.014

Pausch, R., Proffitt, D., & Williams, G. (1997, August). Quantifying immersion in virtual reality. In *Proceedings of the 24th annual conference on computer graphics and interactive techniques* (pp. 13-18).

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction, 12*(1), 61–86. https://doi.org/10.1016/S0959-4752(01)00016-0

Pulham, E., Graham, C., & Short, C. (2018). Generic vs. modality-specific competencies for K-12 online and blended teaching. *Journal of Online Learning Research*, *4*(1), 33-52.

Quality Matters (2022). *The national standards for quality online teaching*. https://www.nsqol.org/

Rabinovich, T., Berthon, P., & Fedorenko, I. (2017). Reducing the distance: Financial services education in web-extended learning environments. *Journal of Financial Services Marketing*, *22*(3), 126. https://doi-org.authenticate.library.duq.edu/10.1057/s41264-017-0030-9

Raes, A., Detienne, L., Windey, I., & Depaepe, F. (2020). A systematic literature review on synchronous hybrid learning: Gaps identified. *Learning Environments Research, 23*(3), 269–290. https://doi.org/10.1007/s10984-019-09303-z

Rey, G. D. (2012). A review of research and a meta-analysis of the seductive detail effect. *Educational Research Review, 7*(3), 216–237. https://doi.org/10.1016/j.edurev.2012.05.003

Rey, G. D., & Buchwald, F. (2011). The expertise reversal effect: Cognitive load and motivational explanations. *Journal of Experimental Psychology: Applied, 17*(1), 33-48. http://dx.doi.org/10.1037/a0022243

Rey, G. D., Beege, M., Nebel, S., Wirzberger, M., Schmitt, T. H., & Schneider, S. (2019). A meta-analysis of the segmenting effect. *Educational Psychology Review, 31*(2), 389-419.

Rhim, H. C., & Han, H. (2020). Teaching online: Foundational concepts of online learning and practical guidelines. *Korean Journal of Medical Education*, *32*(3), 175. https://doi.org/10.3946/KJME.2020.171

Rice, K. L. (2006). A comprehensive look at distance education in the K–12 context. *Journal of Research on Technology in Education*, *38*(4), 425-448.

Richter, J., & Scheiter, K. (2019). Studying the expertise reversal of the multimedia signaling effect at a process level: Evidence from eye tracking. *Instructional Science*, *47*(6), 627–658. https://doi.org/10.1007/s11251-019-09492-3

Roberts, K. L., & Brugar, K. A. (2017). The view from here: Emergence of graphical literacy. *Reading Psychology*, *38*(8), 733-777.

Roberts, K. L., Norman, R. R., & Cocco, J. (2015). Relationship between graphical device comprehension and overall text comprehension for third-grade children. *Reading Psychology*, *36*(5), 389-420.

Roblyer, M. D., Freeman, J., Donaldson, M. B., & Maddox, M. (2007). A comparison of outcomes of virtual school courses offered in synchronous and asynchronous formats. *The Internet and Higher Education, 10*(4), 261-268.

Russell, M., Bebell, D., O'Dwyer, L., & O'Connor, K. (2003). Examining teacher technology use: Implications for preservice and inservice teacher preparation. *Journal of Teacher Education*, *54*(4), 297–310. https://doi.org/10.1177/0022487103255985

Sadoski, M., & Paivio, A. (1994). A dual coding view of imagery and verbal processes in reading comprehension. In R. B. Ruddell, M. R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading* (pp. 582–601). International Reading Association.

Salkind, N. (2012). Causal-Comparative Design. In *Encyclopedia of Research Design*. SAGE Publications, Inc. https://doi.org/10.4135/9781412961288.n42

Savoy, A., Proctor, R. W., & Salvendy, G. (2009). Information retention from PowerPoint™ and traditional lectures. *Computers & Education*, *52*(4), 858–867. https://doi.org/10.1016/J.COMPEDU.2008.12.005

Scheiter, K., & Eitel, A. (2017). Learning from multimedia: Cognitive processes and instructional support. In S. Schwan & U. Cress (Eds.), *The psychology of digital learning: Constructing, exchanging, and acquiring knowledge with digital media* (pp. 1–205). https://doi.org/10.1007/978-3-319-49077-9

Schneider, S., Beege, M., Nebel, S., & Rey, G. D. (2018). A meta-analysis of how signaling affects learning with media. *Educational Research Review*, *23*, 1–24. https://doi.org/10.1016/j.edurev.2017.11.001

Schrader, P. G., & Rapp, E. E. (2016). Does multimedia theory apply to all students? The impact of multimedia presentations on science learning. *Journal of Learning and Teaching in Digital Age*, *1*(1), 32-46.

Schrader, C., Reichelt, M., & Zander, S. (2018). The effect of the personalization principle on multimedia learning: The role of student individual interests as a predictor. *Educational Technology Research and Development*, *66*(6), 1387–1397. https://doi.org/10.1007/s11423-018-9588-8

Schroeder, N. L., & Cenkci, A. T. (2018). Spatial contiguity and spatial split-attention effects in multimedia learning environments: A meta-analysis. *Educational Psychology Review*, *30*(3), 679–701. https://doi.org/10.1007/s10648-018-9435-9

Schroeder, N. L., & Cenkci, A. T. (2019). Do measures of cognitive load explain the spatial split-attention principle in multimedia learning environments? A systematic review. *Journal of Educational Psychology, 112*(2), 254–270. https://doi.org/10.1037/edu0000372

Schüler, A., Scheiter, K., & van Genuchten, E. (2011). The role of working memory in multimedia instruction: Is working memory working during learning from text and pictures? *Educational Psychology Review*, *23*(3), 389-411. https://doi.org/10.1007/s10648-011-9168-5

Qualtrics Security Statement. (2021, April 23). Retrieved September 30, 2021 from https://www.qualtrics.com/security-statement/

Shachar, M., & Neumann, Y. (2003). Differences between traditional and distance education academic performances: A meta-analytic approach. *International Review of Research in Open and Distributed Learning*, *4*(2), 1-20.

Shamim, M. (2018). Application of cognitive theory of multimedia learning in undergraduate surgery course. *International Journal of Surgery Research and Practice*, *5*(1), 2–7. https://doi.org/10.23937/2378-3397/1410065

Shin, N. (2003). Transactional presence as a critical predictor of success in distance learning. *Distance Education*, *24*(1). https://doi.org/10.1080/01587910303048

Smith, R., Clark, T., & Blomeyer, R. L. (2005). *A synthesis of new research on K-12 online learning*. Naperville, IL: Learning Point Associates. http://www.ncrel.org/tech/synthesis/synthesis.pdf

Smith, G. G., Sorensen, C., Gump, A., Heindel, A. J., Caris, M., & Martinez, C. D. (2011). Overcoming student resistance to group work: Online versus face-to-face. *The Internet and Higher Education*, *14*(2), 121–128. https://doi.org/10.1016/J.IHEDUC.2010.09.005

Sorden, S. D. (2013). The cognitive theory of multimedia learning. In B. J. Irby, G. Brown, R. Lara-Alecio, & S. Jackson (Eds.), The handbook of educational theories (pp. 155–167). https://doi.org/10.3102/0091732X09358129

StackCommerce. (2021, April 10). Over 1 billion people worldwide use a MS Office product or service: *MS Office skills pay off in the job field.* Financial Post. https://financialpost.com/personal-finance/business-essentials/over-1-billion-people-worldwide-use-a-ms-office-product-or-service

Stein, D., Wanstreet, C. Clavin, J., Overtoom, C., and Wheaton, J.E. (2005) Bridging the Transactional Distance Gap in Online Learning Environments, *American Journal of Distance Education, 19*(2), 105-118, https://doi.org/10.1207/s15389286ajde1902_4

Stiller, K. D., & Jedlicka, R. (2010). A kind of expertise reversal effect: Personalisation effect can depend on domain-specific prior knowledge. In *Australasian Journal of Educational Technology, 26,* 133-149. https://doi.org/10.14742/AJET.1107

Stride Learning. (2021). https://investors.stridelearning.com/esg/default.aspx

Stride Newsroom. (2020, August 25). K12 announces updated enrollment for managed public schools of 170 thousand students [Press release]. http://news.stridelearning.com/k12-announces-updated-enrollment-for-managed-public-schools-of-170-thousand-students-2/

Sundararajan, N. K., & Adesope, O. (2020). Keep it coherent: A meta-analysis of the seductive details effect. *Educational Psychology Review*, *32*(3), 707–734. https://doi.org/10.1007/s10648-0`20-09522-4

Sung, E., & Mayer, R. E. (2012). When graphics improve liking but not learning from online lessons. *Computers in Human Behavior*, *28*(5), 1618-1625.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*, 275–285. https://doi.org/10.1016/0364-0213(88)90023-7

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*(4), 295–312. https://doi.org/10.1016/0959-4752(94)90003-5

Sweller, J. (2010a). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational Psychology Review, 22*(2), 123–138. https://doi.org/10.1007/s10648-010-9128-5

Sweller, J. (2010b). Cognitive load theory: Recent theoretical advances. In J. L. Plass, R. Moreno, & R. Brünken (Eds.), *Cognitive load theory* (pp. 29–47). Cambridge University Press. https://doi.org/10.1017/CBO9780511844744.004

Sweller, J., & Chandler, P. (1991). Evidence for cognitive load theory. *Cognition and Instruction*, *8*(4), 351–362. https://doi.org/10.1207/s1532690xci0804_5

Sweller, J. & Chandler, P. (1994). Why some material is difficult to learn. *Cognition and Instruction*, *12*(3), 185–233. https://doi.org/10.1207/s1532690xci1203

Sweller, J., van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*. https://doi.org/10.1023/A:1022193728205

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review, 31*, 261–292. https://doi.org/10.1007/s10648-019-09465-5

Tabbers, H. K., Martens, R. L., and van Merriënboer, J. J. G. (2004). Multimedia instructions and cognitive load theory: Effects of modality and cueing. *British Journal of Educational Psychology, 74*(1) 71–81. https://doi.org/10.1348/000709904322848824

Tang, B., Coret, A., Qureshi, A., Barron, H., Ayala, A., & Law, M. (2018). Online Lectures in Undergraduate Medical Education: Scoping Review. *JMIR Medical Education, 4*(1), e11. https://doi:10.2196/mededu.9091

Tarmizi, R. A., & Sweller, J. (1988). Guidance during mathematical problem solving. *Journal of Educational Psychology*, *80*(4), 424-436. https://doi.org/10.1037/0022-0663.80.4.424

Thalheimer, W. (2004). Bells, whistles, neon, and purple prose: When interesting words, sounds, and visuals hurt learning and performance-a review of the seductive-augmentation research. https://www.worklearning.com/ wp-content/uploads/2017/10/Review_Seductive_Augmentations_ 2009.pdf

United States Securities and Exchange Commission. (2017). *Exhibit 99.1.* https://www.sec.gov/Archives/edgar/data/1157408/000155837019007293/lrn-20190630x10k.htm

van Gog, T. (2014). The signaling (or cueing) principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 263–278). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.014

van Merriënboer, J. J. G., Kester, L., & Paas, F. (2006). Teaching complex rather than simple tasks: Balancing intrinsic and germane load to enhance transfer of learning. *Applied Cognitive Psychology, 20*(3), 343–352. https://doi.org/10.1002/acp.1250

van Merriënboer, J. J., & Kirschner, P. A. (2018). *Ten steps to complex learning: A systematic approach to four-component instructional design.* Routledge.

Wang, Z., Ardasheva, Y., Carbonneau, K., & Liu, Q. (2021). Testing the seductive details effect: Does the format or the amount of seductive details matter? *Applied Cognitive Psychology*, *35*(3), 761. https://doi-org.authenticate.library.duq.edu/10.1002/acp.3801

Wedemeyer, C. A. (2010*). Learning at the back door: Reflections on non-traditional learning in the lifespan*. IAP.

Wengrowicz, N., & Offir, B. (2013). Teachers' perceptions of transactional distance in different teaching environments. *American Journal of Distance Education*, *27*(2), 111–121. https://doi.org/10.1080/08923647.2013.773701

Wittrock, M. (1992). Generative learning processes of the brain. *Educational Psychologist*, *27*(4), 531–541.

Wittrock, M. C., & Farley, F. (2010). Learning as a generative process. *Educational Psychologist, 45*(1), 40–45. https://doi.org/10.1080/00461520903433554

Wong, M., Castro-Alonso, J. C., Ayres, P., & Paas, F. (2015). Gender effects when learning manipulative tasks from instructional animations and static presentations. *Journal of Educational Technology & Society, 18*(4), 37–52.

Xie, H., Mayer, R. E., Wang, F., & Zhou, Z. (2019). Coordinating visual and auditory cueing in multimedia learning. *Journal of Educational Psychology*, *111*(2), 235–255. https://doi.org/10.1037/edu0000285

Xie, H., Wang, F., Hao, Y., Chen, J., An, J., Wang, Y., & Liu, H. (2017). The more total cognitive load is reduced by cues, the better retention and transfer of multimedia learning: A meta-analysis and two meta-regression analyses. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0183884

Xu, D., & Jaggars, S.S. (2014). Performance gaps between online and face-to-face courses: Differences across types of students and academic subject areas. *The Journal of Higher Education 85*(5), 633-659. https://doi:10.1353/jhe.2014.0028

Yllmaz, R., & Keser, H. (2017). The impact of interactive environment and metacognitive support on academic achievement and transactional distance in online learning. *Journal of Educational Computing Research*, *55*(1), 95–122. https://doi.org/10.1177/0735633116656453

Yue, C. L., & Bjork, E. L. (2017). Using selective redundancy to eliminate the seductive details effect. *Applied Cognitive Psychology*, *31*(5), 565. https://doi-org.authenticate.library.duq.edu/10.1002/acp.3348

Yue, C., Kim, J., Ogawa, R., Stark, E., & Kim, S. (2013). Applying the cognitive theory of multimedia learning: An analysis of medical animations. *Medical Education, 47*(4), 375–387. https://doi.org/10.1111/medu.12090

Zander, S., Wetzel, S., Kühl, T., & Bertel, S. (2017). Underlying processes of an inverted personalization effect in multimedia learning–An eye-tracking study. *Frontiers in Psychology, 8*, 2202.

Zhang, J., Yen, S. H., Liu, T. C., Sung, Y. T., & Chang, K. E. (2022). Studies on learning effects of AR-assisted and PPT-based lectures. *The Asia-Pacific Education Researcher*, *31*(1), 1–10. https://doi.org/10.1007/s40299-020-00533-x

Zhao, Y., Lei, J., Yan, B., Lai, C., & Tan, H. S. (2005). What makes the difference? A practical analysis of research on the effectiveness of distance education. *Teachers College Record, 107*(8), 1836–1884.

Zimmer, R., Gill, B. P., Attridge, J., & Obenauf, K. (2014). Charter school authorizers and student achievement. *Education Finance and Policy, 9*(1), 59–85.

Zimmer, R., Gill, B., Booker, K., Lavertu, S., & Witte, J. (2009). Charter schools in eight states: Effects on achievement, attainment, integration, and competition. RAND Corporation.

Zucker, A. & Kozma, R. (2003). *The virtual high school: Teaching generation V*. New York: Teachers College Press.

Zweig, J. S., & Stafford, E. T. (2016). Training for online teachers to support student success: Themes from a survey administered to teachers in four online learning programs. *Journal of Online Learning Research*, *2*, 399–418.

Appendix A

Formal Request of School District

Dr. Kristen Stewart
kstewart@k12.com
Head of School
Ohio Virtual Academy
1690 Woodlands Drive, Suite 200
Maumee, OH 43537

Dear Dr. Stewart:

I am presently pursuing a doctoral degree in Instructional Technology and Leadership at Duquesne University. I am interested in determining the extent to which online K-12 virtual teachers use proven design strategies to minimize students' cognitive load when they create their lesson slides. I hope to improve my own online teaching and perhaps aid others as well. The study includes a 23-question questionnaire for K-12 teachers and asks participants to anonymously share a lesson slide deck they created for use in their virtual, synchronous classroom.

The online questionnaire has been created in Qualtrics, a software that uses Transport Layer Security encryption (TLS), also known as HTTPS, to protect data and mask IP addresses. (A copy of the questionnaire is attached.) The questions will not appear until participants agree to give their informed consent. If they choose to leave the survey incomplete, no data will be recorded.

Some questions will gather demographic information, while others concern general slide use, boundary conditions known to affect the principles under investigation, and teacher perceptions about their slides in relation to extraneous cognitive load. Within the questionnaire there is a link to a separately housed collection tool in Qualtrics for those participants willing to share a lesson slide deck.

The submitted lesson slide decks will be analyzed using a rubric to determine to what extent they adhere to the redundancy, coherence, signaling, and spatial contiguity principles as proposed by Richard Mayer in *Multimedia Principles* (2021). (A copy of the rubric is attached.) To ensure anonymity, Ms. Brenda Heslet, my OHVA high school English department instructional lead, has agreed to collect the slide decks through the separate Qualtrics tool and remove any personal identifiable information before forwarding the lesson slide links to me for examination.

As an incentive, I will provide 12 gift cards worth $25 each to be included in three raffles: one for the Elementary, one for the Middle School, and one for the High School. Ms. Katie Halpin, another of my ENG403 team members, has agreed to conduct the raffles with the use of a random number generator and distribute the gift cards to the 12 winners (4 from each of the three schools within OHVA's academy). When participants share their lesson slide deck, they will be prompted to leave their name and OHVA email address if they want to be included in the raffle. Only Ms. Heslet and Ms. Halpin will have access to their names and email addresses.

To conduct this research, I would like permission to have an email distributed to all teachers at OHVA. A copy of the email is attached. The email contains an explanation of the informed consent process, the purpose of the study, and an invitation to participate. The link to the questionnaire is also included in the email. Once you grant permission, I will forward the letter to the principals at each school and ask that the email letter be sent to all teachers in their schools unless you recommend a different process.

I would also ask the principals to post a reminder announcement in their weekly update newsletters the Monday before the questionnaire expires. The period for the research is two weeks, from April 25 - May 6, 2022.

Feel free to contact me if you have any questions. Your approval will be very much appreciated.

Thank you for your time and consideration.

Respectfully,

Lisa Cartin Beaulieu
Researcher
OHVA HS English Teacher
740-346-5720
x5277
lbeaulieu@ohva.org
beaulieul@duq.edu

Appendix B

Request for School Principals to Distribute Email to Teachers

To: Ohio Virtual Academy principals

Dr. Debbie Wotring, K-2 principal
Ms. Amy Helm-Borchers, 3-5 principal
Ms. Laura House, Middle School principal
Ms. Marie Mueller, 9th grade principal
Ms. Andrea Zawisza, 10th grade principal
Mr. Andrew Smerekanich, 11th grade principal
Ms. Megan Daley, 12th grade principal

Dear OHVA principals:

Dr. Kristen Stewart has granted permission for me to conduct research for my dissertation at all three schools in the OHVA Academy. I am interested in determining the extent to which online K-12 virtual teachers use proven design strategies to minimize students' cognitive load when they create their lesson slides. I hope to improve my own online teaching and perhaps aid others as well. The anonymous study includes a 23-question questionnaire for K-12 teachers and asks participants to share a lesson slide deck they created for use in their virtual, synchronous classroom.

The online questionnaire takes about 10 minutes to complete the 23 questions in part one and a few more minutes to upload a slide set and register for the raffle in the second part.

As an incentive to participate, I am providing a total of 12 gift cards worth $25 each for four teachers who participate from the Elementary, four teachers from the Middle School, and four teachers from the High School. Ms. Katie Halpin, my British Literature ENG403 colleague, has agreed to conduct the raffles with the use of a random number generator and distribute the gift cards to the winners.

On **Monday, April 25,** will you please distribute the attached email to all your teachers (including specialists - anyone who teaches anything with students in the virtual classroom)?

On **Monday, May 2,** will you please post a reminder announcement in your weekly update? newsletters the Monday before the questionnaire expires. The collection period expires Friday, May 6, at midnight.

Feel free to contact me if you have any questions. Your assistance will be very much appreciated.

Respectfully,

Lisa Cartin Beaulieu

Researcher and OHVA HS English Teacher
740-346-5720 x5277
lbeaulieu@ohva.org
beaulieul@duq.edu
Attached: Dr. Stewart's permission statement

Appendix C

Email Request to Teachers to Participate in Questionnaire

Monday, April 25, 2022

Subject: Teacher Questionnaire

Hello, OHVA teacher colleagues!

I am writing to ask for your help. I am pursuing a doctoral degree in Instructional Technology and Leadership at Duquesne University, and my dissertation research focuses on how online K-12 teachers design their lesson slides to reduce cognitive overload for their students. Your response to this questionnaire will help determine to what extent design principles proven to help students learn more easily and deeply are used in our school. The results will help us know where we excel and where there could be improvement for our students. All teachers, including specialists (anyone who teaches any subject or level) are invited to participate.

The questionnaire has 23 questions and takes about 10 minutes. A second, optional task is for you to share a slide deck you created and taught your students in a synchronous (students in the room with you at the time) virtual classroom this school year. You can link it or upload it inside the questionnaire.

I know your time is valuable, and so I have included 12 gift cards to Amazon worth $25 each as an incentive. Names of 4 participant teachers from the Elementary, 4 teachers from the Middle School, and 4 teachers from the High School will be drawn. Winners will be mailed their Amazon gift card. Please click the link to open the survey (or copy and paste the link into your Internet browser). **Link**

Your participation is completely voluntary and anonymous. Once you open the link, you will see a detailed informed consent section. The software used for the survey portion masks IP addresses and encrypts all the data. If you decide to upload a set of slides in addition to the survey, you can enter your name for the drawing. You will have to click the button inside the questionnaire that will take you to a separate collection site. There you can leave your name and OHVA address. Some of my colleagues on the HS English British Literature team are making sure there is no personally identifiable information on the slides you submit before I see them, and they will also hold the raffles and distribute the gift cards. You can contact Ms. Brenda Heslet, HS English Instructional Lead bheslet@ohva.org with questions ensuring anonymity or the raffles.

The Duquesne University Institutional Review Board has approved this questionnaire. If you have any comments or questions, feel free to contact me at lbeaulieu@ohva.org, school extension x5277, or 740-346-5720. The link expires in two weeks, on May 6, 2022.

I am extremely grateful for your time and cooperation.

Sincerely,

Lisa Cartin Beaulieu
Researcher
OHVA High school English teacher
lbeaulieu@ohva.org

Appendix D

Teacher Questionnaire

DEMOGRAPHICS

Which grade level do you teach?

- Elementary K-5
- Middle school 6-8
- High school 9-12

Which content area do you teach this year? (Choose all that apply.)

- Science
- Math
- English
- History
- Art
- Music
- Health and Physical Education
- World Languages
- Intervention Specialist
- Career Readiness
- Counselor
- Advisor
- Other:________

Including this year, how many years in total have you been a teacher? (Please respond numerically. For example, use the number 5 if you have taught for five years.)

Including this year, how many years in total have you been a teacher in an online, virtual environment? (Please respond numerically. For example, use the number 7 if you have taught in an online, virtual environment for seven years.)

What is the highest level of education you have completed?

- Bachelor Degree
- Master Degree
- Specialist License
- Doctorate Degree

What is your gender?

- Male
- Female
- Other

GENERAL SLIDE USE

The next questions ask about your class

Which is true most of the time?

- I design my own presentation slides
- I use slides prepared by someone else

About how long does a typical class last? Please answer in number of minutes. For example, if your class is 55 minutes long, write 55.

About how many students attend a typical learning session? Please answer numerically.

How many slide presentations do you usually present synchronously (in real time with students present) each week? Please answer in number of slide presentations.

Display this question

If GENERAL SLIDE USEThe next questions ask about your class Which is true most of the time? I design my own presentation slides Is Selected

Which software do you most often use to create your class slide presentations?

- PowerPoint
- Google Slides
- Other:

LEARNERS

The next four questions ask you to think about the lesson session connected to the slides you will upload and the students who attended.

Was the slide deck used to teach learners whose first language is not English?

- Yes
- No

Do you consider the content in this course (the course from which the slides you will share came) to be more arts-based (humanities) or more process-based (STEM)? (If you teach more than one subject, but you will submit a slide deck from a math class, please choose STEM.)

- The course content is arts-based (humanities).
- The course content is process-based (STEM).

Please think about the working memory of the students who attended this lesson. Which statement is most accurate?

- Most of the students have **low** working memory capacity.
- Most of the students have **average** working memory capacity.
- Most of the students have **high** working memory capacity.
- Attendees included a mix of students with low, average, and high working memory capacity.

Again, think about the students who attended this lesson. Which statement is more accurate?

- Most of the students had **low** prior knowledge of the content before the class
- Most of the students had **high** prior knowledge of the content before the class

PRACTICES

The last section asks you to share your typical practices when you design and teach with electronic slide presentations. To what extent do you agree or disagree?

I develop presentation slides that minimize extraneous cognitive load for my learners.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I create elaborate and detailed slides. (Coherence)

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Including background music enhances multimedia lesson learning. (Coherence)

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I only include background music if it is directly related to the content. (Coherence)

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

It is important to present a concept in more than one way on a slide. (Redundancy)

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

How often do you add text or images that are unrelated to the content being presented? (Coherence)

- Never

- Rarely
- Sometimes
- Often
- Always

How often do you show both an image and a paragraph or more of text on one slide? (Coherence)
- Never
- Rarely
- Sometimes
- Often
- Always

When showing a slide with text, how often do you or someone else read the material aloud word-for-word? (Redundancy)
- Never
- Rarely
- Sometimes
- Often
- Always

Thank you for submitting a slide deck from a virtual lesson you created and taught in a live classroom this school year. To ensure anonymity, please be sure to remove any personal identification before you submit. For your convenience, there are two ways to submit. Here, you can upload a document.

Drop files or click here to upload

Or, you can paste a link to your slide set here if you prefer.

End of Survey Message:

Thank you for your time!
Open the
Raffle Entry Form

Research Raffle Entry Form

If you would like to be considered for the raffle, please provide your OHVA email address. A random number generator will be used to select winners. To ensure anonymity, please be sure to remove any personal identification before you submit. Ms. Brenda Heslet, Instructional Lead for the High School English department, is collecting the slide sets to confirm there is no personal information in the slides. She will send them to the researcher and hold three raffles for $25 Amazon gift cards. Four teacher emails will be drawn from the Elementary, four from the Middle School, and four from the High School.

I completed the survey. Please enter my name for the raffle for one of 12 gift cards to Amazon. *
We will inform the winners through OHVA email and ask for mailing addresses at that time.
Enter email here:

Short answer text

Which is your school level? *

- ◯ K-5
- ◯ 6-8
- ◯ HS

Appendix E

Informed Consent

INVESTIGATOR
Lisa Cartin Beaulieu | Duquesne University | beaulieul@duq.edu

ADVISOR
Dr. Joseph Kush | Duquesne University | School of Education, Department of Instruction and Leadership | 412-313-3862 | kushj@duq.edu

SOURCE OF SUPPORT
This study is being performed as partial fulfillment of the requirements for the doctoral degree in Instructional Technology and Leadership at Duquesne University.

STUDY OVERVIEW
This study examines ways virtual K-12 school instructors design presentation slides in accordance with the Cognitive Principles of Multimedia Learning. A 23-question online survey will be used to collect participant data. Your participation is voluntary, and if you choose to participate, you can opt out at any time. All teaching staff will be given the opportunity to participate.

PURPOSE
I am interested in understanding your implementation of four cognitive principles of multimedia that are known to reduce cognitive load for learners. In order to participate, you must teach synchronously at a completely online virtual school.

PARTICIPANT PROCEDURES
For the first part of this study, you will be asked to answer some questions about yourself, your class, the slides you create and use in your class, and your perceptions of reducing cognitive load for learners.

In the second part of the questionnaire, you will be asked to submit an electronic slide presentation deck (PowerPoint or similar) from a class you taught synchronously (in real time with students).

Your responses will be kept completely confidential.

RISKS AND BENEFITS
There are minimal risks associated with participating in this study, but no greater than those encountered in everyday life. The benefits of participating in this study include contributing to the improvement of teacher-designed presentation best practices. Implications for pre-service and professional development programs may result.

COMPENSATION
Participants have the option of submitting their name and contact information for a drawing of one of twelve $25 Amazon.com gift cards. Your participation is voluntary.

CONFIDENTIALITY
The researcher values your privacy and will make every effort to protect all participants' personal information. Submitted ESP slide sets will be pre-analyzed by a third party so any personal information can be removed before the researcher or the two volunteer ESP evaluators receives the slide decks. It is unlikely but possible that the research team may be able to identify a participant. In that rare circumstance, the information will be kept confidential.

After the third party forwards the electronic slide decks, they will be kept on the researcher's password-protected computer and shared only with the two volunteer ESP evaluators.

Questionnaire data is collected using an anonymous password-protected Qualtrics survey. The Qualtrics survey and data platform uses Transport Layer Security encryption (TLS), also known as HTTPS. No email address, IP address, or any other electronic information is requested or recorded. The data will be kept confidential and stored on a password-protected computer. Responses to the questionnaire will be kept secure as per the Qualtrics security statement found here: https://www.qualtrics.com/security-statement/

The raw data will be kept for three years following the close of the study. At the conclusion of the three years, the data will be destroyed/deleted. In addition, any publications or presentations about this research will only use data that is combined together with all subjects; therefore, no one, including the researcher, will be able to determine how you responded.

RIGHT TO WITHDRAW
You are under no obligation to start or continue this study. You can withdraw at any time without penalty or consequence by not completing the survey. If you change your mind about participating while taking the survey and exit, your responses will not be recorded. Any partial responses will be deleted one week after the survey was opened. You will not be able to re-open the survey after that time.

SUMMARY OF RESULTS
A summary of the results of this study will be provided at no cost. You may request this summary by contacting the researcher and requesting it. The information provided to you will not be your individual responses, but rather a summary of what was discovered during the research project as a whole.

FUTURE USE OF DATA
Any information collected that can identify you will have the identifiers removed and not be kept for use in future related studies, and/or provided to other researchers to further investigate teacher use of technology-enhanced presentation tools.

VOLUNTARY CONSENT

I have read this informed consent form and understand what is being requested of me. I also understand that my participation is voluntary and that I am free to withdraw at any time, for any reason without any consequences. Based on this, I certify I am willing to participate in this research project.

I understand that if I have any questions about my participation in this study, I may contact Lisa Beaulieu (beaulieul@duq.edu). If I have any questions regarding my rights and protections as a subject in this study, I can contact Dr. David Delmonico, Chair of the Duquesne University Institutional Review Board for the Protection of Human Subjects at 412.396.1886 or at irb@duq.edu. This project has been approved/verified by Duquesne University's Institutional Review Board.

Please note that this survey will be best displayed on a laptop or desktop computer. Some features may be less compatible for use on a mobile device. The survey should take you about 10 minutes.

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are 18 years of age, and you are aware that you may choose to terminate your participation in the study at any time and for any reason.

I consent, begin the study

I do not consent, I do not wish to participate