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?

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Abstract

This exploratory study examines educators' knowledge of and adherence to two principles of the Cognitive Theory of Multimedia Principles (Coherence and Redundancy) in their role as designers. The purpose of the study was to answer the following two questions: 1) To what extent do educators have a working knowledge of the Cognitive Theory of Multimedia Principles of coherency and redundancy, and 2) To what extent do educators apply the research-based multimedia principles of coherency and redundancy in their electronic slide design? The study implemented an anonymous online survey method. Descriptive data from 112 professional educators in face-to-face, virtual synchronous, and asynchronous environments across k-adult levels who use electronic slide presentation software such as PowerPoint are reported. Results show that educators have low knowledge of and low adherence to the principles of redundancy and coherence in their electronic slide design. The study has implications for educators and administrators who make decisions about professional development in their schools and for teacher preparation programs.

Keywords: ISTE standards, Design, Electronic Slide Presentations, Cognitive Load Theory, Cognitive Theory of Multimedia Learning, Coherence Principle, Redundancy Principle

Cognitive Theory of Multimedia Principles of Coherence and Redundancy in Educators' Electronic Slide Presentation Design

The use of Electronic Slide Presentation (ESP) software such as PowerPoint® is pervasive in face-to-face and virtual learning environments (Bolkan, 2019; Ferreira, et al., 2018; Kosslyn, et al., 2012, Martin, et al., 2019). Higher education students expect its use across the curriculum (Bolkan, 2019; Levasseur & Kanan Sawyer, 2006), and k-12 classrooms rely heavily on it (Martin and Carr, 2015). In fact, the ability to design and use PowerPoint® is considered a basic competency for online instructors (Martin, et al., 2019) even though research indicates there is very little evidence that slide software tools contribute to student learning (Baker, et al., 2018; Bolkan, 2019; Savoy, et al., 2009). However, there is a growing body of evidence that the design and use of ESP tools does impact students' depth of understanding and retention of new information (Baker, et al., 2018). Ferreira, et al. (2018) emphasize the need for instructors to apply proven pedagogical practices as guides rather than as prescriptive rules when using tools such as PowerPoint®. Baker, et al. (2018) encourage face-to-face educators to consider how and why they use ESP software and how intentionally they direct students to interact during class with the tool.

The International Society for Technology in Education (ISTE) has developed seven standards to help educators empower student learning. These standards indicate that educators should act as 1) Learners: Educators continually improve their practice by learning from and with others and exploring proven and promising practices that leverage technology to improve student learning; 2) Leaders: Educators seek out opportunities for leadership to support student empowerment and success and to improve teaching and learning; 3) Citizens: Educators inspire students to positively contribute to and responsibly participate in the digital world; 4) Collaborators: Educators dedicate time to collaborate with both colleagues and students to improve practice, discover and share resources and ideas, and solve problems; 5) Designers: Educators design authentic, learner-driven activities and environments that recognize and accommodate learner variability; 6) Facilitators: Educators facilitate learning with technology to support student achievement of the ISTE Standards for Students; and 7) Analysts: Educators understand and use data to drive their instruction and support students in achieving their learning goals (International Society for Technology in Education, 2017).

For the purposes of this study, we focused primarily on one indicator of ISTE Standard 5 Designer (5c): "Explore and apply instructional design principles to create innovative digital learning environments that engage and support learning." This standard aligns with the Cognitive Theory of Multimedia Principles (CTMP) (Mayer, 2014) as we seek to describe current practices of educators in designing instruction. This research emphasizes the art of using scientific principles of both learning and multimedia to design instruction for maximum student learning outcomes.

Design

Research into best practices in multimedia learning material design for educators has not kept pace with the increasing diversity in learning environments or the use of technology in virtual and face-to-face classrooms (Leacock & Nesbit, 2007). Many educators create their own learning materials (or adapt easily found materials of differing quality) without the benefit of relevant psychological or educational research (Nguyen & Bower, 2018). McKenney, et al. (2015) argued that because educators are increasingly creating their own technology-enhanced learning (TEL) materials, more needs to be done to develop their design expertise.

Designing effective learning activities is a "complex, non-linear, ill-structured, and yet generative, creative process requiring the understanding and implementation of a range of skills and knowledge domains to construct artifacts for human purposes" (Mishra, 2020). A helpful lens through which to understand the process is to turn to the Technology, Pedagogy and Content Knowledge (TPACK) framework (Mishra & Koehler, 2006). This model emphasizes that educators should understand each element in a learning activity (the content to learn, the technology used as a vehicle for learning, and the pedagogical method of instruction) as well as the complex intersections between each of the elements to design technology-enhanced lessons well (Nguyen & Bower, 2018, p. 1029).

Conceptual Framework

Electronic slide design sits at the intersection of technology and pedagogy. Educators should be familiar with how the brain processes new information and take steps to mitigate potential interference. The Cognitive Theory of Multimedia Learning (CTML) offers a comprehensive evidence-based set of guidelines for effective multimedia design (Mayer, 2014; Noyes, et al., 2019). Many studies show marked improvement in student learning when these principles are applied to PowerPoint slide design (Issa, et al., 2013; Nagmoti, 2017; Noyes, et al., 2019; Pate & Posey, 2016).

Mayer's development of the CTML principles grew out of Cognitive Load Theory (CLT) (Sweller, et al., 2019), which was in turn based on a three-part model of working memory. The Working Memory theory states that information is taken in through the ears (a phonological loop) and/or the eyes (a visuospatial sketchpad), and both of these channels are moderated by a central executive component (Baddeley, 1992). This model has since become a central tenet in neuroscience and cognitive psychology (D'Esposito and Postle, 2015).

CLT categorizes three levels of cognitive load that might interfere with learning: intrinsic, extraneous, and germane (Sweller, et al., 1998). Intrinsic load refers to the complexity of the new information to be learned, with complexity referring to the number of interacting elements (Çakiroğlu & Aksoy, 2017). de Jong (2020) notes that the inherent complexity of a task or an idea to be learned cannot be changed by the instructor. On the other hand, extraneous load refers to things that might distract or interfere with a student's ability to generate new information into their memory (Mayer, et al., 2008). Extraneous load can be manipulated by the instructor to make learning easier or, inadvertently, more difficult (Noyes, et al., 2019; Sweller, et al., 1998; Sweller, et al., 2019). The third element central to CLT is germane load, which is defined as "working memory resources devoted to dealing with intrinsic cognitive load" (Kirschner, et al., 2018). It is not considered to add to the overall cognitive load, but rather acts as a mediator of sorts: Germane cognitive load "redistributes working memory resources from extraneous activities to activities directly relevant to learning by dealing with information intrinsic to the learning task" (Sweller, et al., 2019).

Mayer applied the CLT cognitive processing model to the educational setting of multimedia learning and developed the multimedia learning hypothesis, the idea that people earn more from both pictures and words than from words alone (Mayer, 2014). Table 1 presents a summary of the multimedia principles.

Table 1

Summary of the Multimedia Principles

Purpose	Principle	People learn better in this condition	Rather than this condition
Minimize Extraneous Load: Eliminate extraneous processing	Redundancy principle	Narration and graphics	Narration, graphics, and text
	Coherence principle	All media related to topic of learning	Extra, unrelated media is included
	Signaling principle	Most important elements are pointed out	All elements are given same weight or emphasis
	Spatial contiguity principle	Related text and images are near each other	Related text and images are separated
	Temporal contiguity principle	Related text and images are presented simultaneously	Related text and images are presented consecutively
Manage Intrinsic Load: Facilitate essential processing	Modality principle	Narration and graphics	Written text and graphics
	Pre-training principle	Basic concepts are pre-taught	Basic and advanced concepts are presented together
	Segmenting principle	Information is chunked into meaningful parts	Information is long and continuous
Maximize Germane Load: Enable deep synthesis of new information	Multimedia principle	More than one media is used	Only one media is used
	Voice principle	Material is presented in a human voice	Material is presented in a computerized voice
	Personalization principle	Material is presented in a conversational tone	Material is presented in a formal tone

Note. Adapted from Mayer, 2014 and Noyes, et al., 2019.

The two multimedia principles under investigation in this study are redundancy and coherence, both of which work to minimize extraneous distractions and help learners process new information more effectively (Mayer & Johnson, 2008). According to the CTML, the redundancy effect states that learners will more easily learn from a combination of graphics and narration rather than from a slide that contains graphics, narration, and written text (Mayer, 2014). Hovarth (2014) posited that when a learner's attention is divided between two things that require visual processing (graphics plus text), then comprehension of both items is reduced. Text on a slide, even if it is exactly the same in meaning as the narration, is considered a redundant distraction (Adesope & Nesbit, 2012; Mayer & Johnson, 2008; Mayer & Moreno, 2003; Nowak, et al., 2016; Penciner, 2013).

According to the CTML, the coherence principle states that people learn better when all the media being presented directly pertains to the topic being taught (Mayer, 2014). Therefore, any unrelated information becomes a threat to the student's ability to process the new information. Moreno and Mayer (2000) found that "students achieve better transfer and retention when extraneous sounds are excluded rather than included" and explain that music and narration might compete with each other in the audio channel of working memory (p. 124).

Learning designers at all levels — from those who work with the youngest children to those who design instruction for mature adults — should consider cognitive load and grapple with how to minimize extraneous load, manage essential processing, and maximize germane learning of difficult subjects (Baker, et. al., 2018; Leacock & Nesbit, 2007; Martin & Carr, 2015; Mayer & Moreno, 2003; Merrild & Buras, 2021).

Purpose of the Pilot Study

Instructor implementation of the Cognitive Theory of Multimedia Principles (CTMP) helps students learn more deeply (Mayer, 2014; Noyes, et al., 2019; and Sweller, et al., 2019). In this pilot study, we investigated educators' understanding of and adherence to two evidence-based cognitive principles proven to mitigate extraneous mental processing (coherency and redundancy) in their design and use of ESP slides.

Research Questions

We used a quantitative survey research approach to answer the following questions: 1) To what extent do educators have a working knowledge of the Cognitive Theory of Multimedia Principles of coherency and redundancy, and 2) To what extent do educators apply the research-based multimedia principles of coherency and redundancy in their electronic slide design?

Method

A non-experimental, non-probabilistic, exploratory quantitative research approach was used to collect data through a combination of convenience and voluntary response sampling in the spring of 2020. The study is considered convenient because we directly sent invitations to potential respondents affiliated with the researchers' organizations, including a large online public charter k-12 school and a small private university, both located in the Midwest United States. We also sent requests for voluntary participation to colleagues on professional networking sites as well as social media. Individuals who responded were encouraged to forward the invitation to peers. The study is also considered voluntary response sampling because the authors do not know every respondent. Walters (2021) points out that because some people are more likely to voluntarily respond to an online survey than others, there is a chance of bias. Because there is no way to tell if this sample is representative of the entire educator population, the results are not generalizable.

One goal was to determine to what extent educators understand the Cognitive Theory of Multimedia principles of coherence and redundancy as defined by Mayer and Moreno (2003). A second goal was to explore educators' implementation of this learning theory in their electronic slide presentation design. The researchers used the web-based survey tool Qualtrics to create questions that aligned with the two study questions. Each research question was addressed multiple times. The survey asked Likert scaled questions concerning teacher knowledge and implementation of the coherence and redundancy principles to reduce extraneous extrinsic cognitive load. Data was collected from a small group representative of a wide population of educators who work with students at any level.

Instrument

For the purposes of this paper, we are reporting the results from 22 questions. The first eight questions were demographic in nature and screened potential participants to ensure they were professional educators who regularly use PowerPoint or some other form of ESP software to create lesson slides. The demographic questions also asked respondents to identify their age, gender, years of teaching experience, level of school taught, and learning environments. Table 2 shows the demographic questions.

Table 2

8 Demographic Questions

8 Demographic Questions
Are you a professional educator?
Do you use presentation software (PowerPoint, Prezi, Keynote, etc.) to prepare instructional materials for your students?
What is your gender?
As of today, what is your age?
How many total years of teaching experience do you have?
At which school level(s) do you have the most experience using presentation software? Check all that apply.
In which academic subject(s) do you have the most experience using presentation software? Check all that apply.
Which learning environment best describes your experience designing and teaching with presentation software? Check all that apply.

The next seven questions, a combination of true or false and multiple choice, focused on knowledge of and adherence to the coherency principle as defined by Mayer and Moreno (2003). Four questions centered on knowledge of the principle, and three concerned participants' design of their own ESP slides according to the coherency principle. Table 3 shows the specific questions.

Table 3

7 Coherency Principle Questions

Focus	7 Coherency Principle Questions	Type
Knowledge	Students learn better when interesting but extraneous graphics are excluded.	True or False
	Students learn better when pleasant but unnecessary background sounds are included.	True or False
	The coherence principle states that in order to keep students' working memory from being overloaded, we should eliminate extraneous material from our presentations.	True or False
	From which of the following slides will students learn more deeply? (Water cycle)	Multiple choice
Adherence	How often do images on your slides directly illustrate the concept you are teaching?	Multiple choice
	How often do you include several images per slide?	Multiple choice
	How often do you include entertaining text or graphics unrelated to the content on your slides?	Multiple choice

The last seven survey questions concentrated on knowledge of and adherence to the redundancy principle as defined by Mayer and Moreno (2003). Again, four questions targeted knowledge of the principle and three concerned whether the participant designed their own ESP slides according to the redundancy principle as articulated in CTML. Table 4 shows the specific questions.

Table 4

7 Redundancy Principle Questions

Focus	7 Redundancy Principle Questions	Type
Knowledge	Students learn better when the slide has all three elements: written text + graphics + teacher narration.	True or False
	Students learn better when narration is accompanied by graphics rather than when the teacher narrates the printed text on the screen word for word.	True or False
	The redundancy principle implies the reason presenters should not read their slides aloud is that words we read are processed in both auditory and visual channels, which can cause students to comprehend less.	True or False
	From which of the following slides will students learn more deeply? (Bees)	Multiple choice
Adherence	When showing a slide with a full paragraph or more of text, how often do you read the paragraph to the students?*	Multiple choice
	When showing a slide with a full paragraph or more of text, how often do you give students time to read the paragraph in silence?*	Multiple choice
	How often do you combine an image with a full paragraph or more of text?	Multiple choice

Note. *It was (correctly) pointed out by one respondent that these are bad questions because they assume the respondents would show a slide with a full paragraph. As a result, the responses to these questions were not included in the final ratings.

The questions reported here focused on only two of the CTMP principles: redundancy and coherence. There are two reasons only these two principles out of twelve were chosen. First, because this is a pilot study intended to explore the gap between educators' knowledge and adherence to these proven methods of designing ESP slides for deeper cognition, essentially preparing the way to explore the possibility that there may or may not be any differences between educators in different learning environments' understanding of and implementation of the principles in their slide design, a small sample was sufficient; there was no need in this situation to conduct an extensive survey questioning all twelve of the multimedia principles.

Second, to make the survey short enough to elicit a reliable number of responses through voluntary response sampling, the researchers surmised that educators with a deep understanding of *all* the principles — from minimizing extraneous distractions through managing essential processing to maximizing synthesis of new information — would correctly identify redundancy and coherency as basic elements of multimedia principles. In other words, we hypothesized that if an educator was familiar with these two basic principles and worked to adhere their slide design to them, it would be logical that those same respondents would be more likely to implement all twelve principles. Conversely, it seemed reasonable that respondents who obviously did not understand or implement these two principles would probably not have a deep knowledge of the other principles.

Participants

In March of 2020, we recruited respondents through online sources. 119 people responded to the survey, but seven were eliminated by the Qualtrics software because in order to participate in the study, contributors had to indicate they were professional educators who regularly use PowerPoint®, Prezi®, Keynote®, or other presentation software in their classrooms. Final participants included professional educators (n = 112) who teach three different age group levels (elementary school, n = 48; secondary school, n = 44; post-secondary school, n = 20). Table 5 presents the frequency and percentage of grade levels taught by the participants.

Table 5

Grade Levels Taught

Grade Level	Frequency	Percentage
Elementary	48	43%
Secondary	44	39%
Post-secondary	20	18%
Total	112	100%

Of the participating educators, 13% identified as male (*n* = 14), 87% identified as female (*n* = 97), and one identified as other gender (*n* = .9%). The mean age of participants was 43.98 years, with a standard deviation of 10.37 years. Two respondents did not indicate their age. The average of all respondents' teaching experience was 15.76 years. These demographics generally conform to the average and median distribution of public school teachers published by the U.S. Department of Education (2018).

More than twelve subject areas were represented, including Arts (Performing and Visual) (*n* = 9), Computer Science/Technology (*n* = 9), Education (*n* = 8), English Language Arts (*n* = 33), Foreign Languages (*n* = 7), Health Care/Nursing (*n* = 4), History/Social Studies (*n* = 15), Law/Political Science (*n* = 1), Math/Statistics *n* = 20), Philosophy/Religious Studies (*n* = 5), Science: Biology/Chemistry/Physics (*n* = 19), Psychology (*n* = 2), and Other (*n* = 9). Table 6 displays the frequency and percentage of subject areas taught by participants.

Table 6

Subject Areas Taught

Subject Area	Frequency	Percentage
Arts (Performing and Visual)	9	8%
Computer Science/Technology	9	8%
Education	38	34%
English Language Arts	33	30%
Foreign Languages	7	6%
Health Care, Nursing	4	4%
History or Social Studies	15	13%
Law, Political Science	1	1%
Math, Statistics	20	18%
Philosophy, Religious Studies	5	5%
Science: Biology, Chemistry, Physics	19	17%
Psychology	2	2%
Other	9	8%
Total	112	100%

Contributors brought a total of 1,749 years' teaching experience (*M* =15.76 years, *SD* = 8.78) to the study. In addition, many respondents had experience using ESP software to design lesson slides in more than one learning environment. A total of 72 (64%) of educators used ESP software in face-to-face in a brick-and-mortar classrooms; 44 (39%) used ESP software in a distance, online, or virtual asynchronous environment, where students access material on their own time; and 64 (57%) used ESP software in distance, online, or virtual synchronous classrooms, where they worked in real time with students. Table 7 demonstrates the variety of learning environments represented by participants.

Table 7

Experience using ESP Software in Different Learning Environments

Learning Environment	Frequency	Percentage
Face-to-face, brick-and-mortar	72	64%
Distance, online, or virtual asynchronous	44	39%
Distance, online, or virtual synchronous	64	57%

Results

Knowledge of the Principles

Knowledge of the Coherency Principle Results

To answer the first research question, "To what extent do educators have a working knowledge of the Cognitive Theory of Multimedia Principles of coherency and redundancy," we coded responses that correctly corresponded with the principle as "1" and interpreted that score as high knowledge of the principle. Incorrect responses and *I do not know* responses were coded with "0" and interpreted as low knowledge of the principle. Participants as a group scored fairly low on the knowledge of coherency principle *(M* = .59, *SD* = .255), although the individual responses to the knowledge of the coherence principle conflict with each other. A majority (*n* = 69, 62%) did not identify students learn better when extraneous graphics are excluded, yet most (*n* = 78, 70%) did understand that unnecessary background sounds negatively affect learning. When asked, "The coherence principle states that in order to keep students' working memory from being overloaded, we should eliminate extraneous material from our presentations," 53% (*n* = 59) correctly responded affirmatively, and only 5% (*n* = 6) disagreed. However, a large portion of respondents (*n* = 47, 42%) stated they did not know the answer. It is unclear whether the wording of the question confused them, or if they did not know that extraneous material hurts cognition. Most (*n* = 86, 77%) correctly identified the "coherent" slide image as the one from which students would learn more deeply. Table 8 displays the four questions concerning knowledge of the multimedia principle of coherence as well as the coding key and responses.

Table 8
Knowledge of the Coherency Principle Results

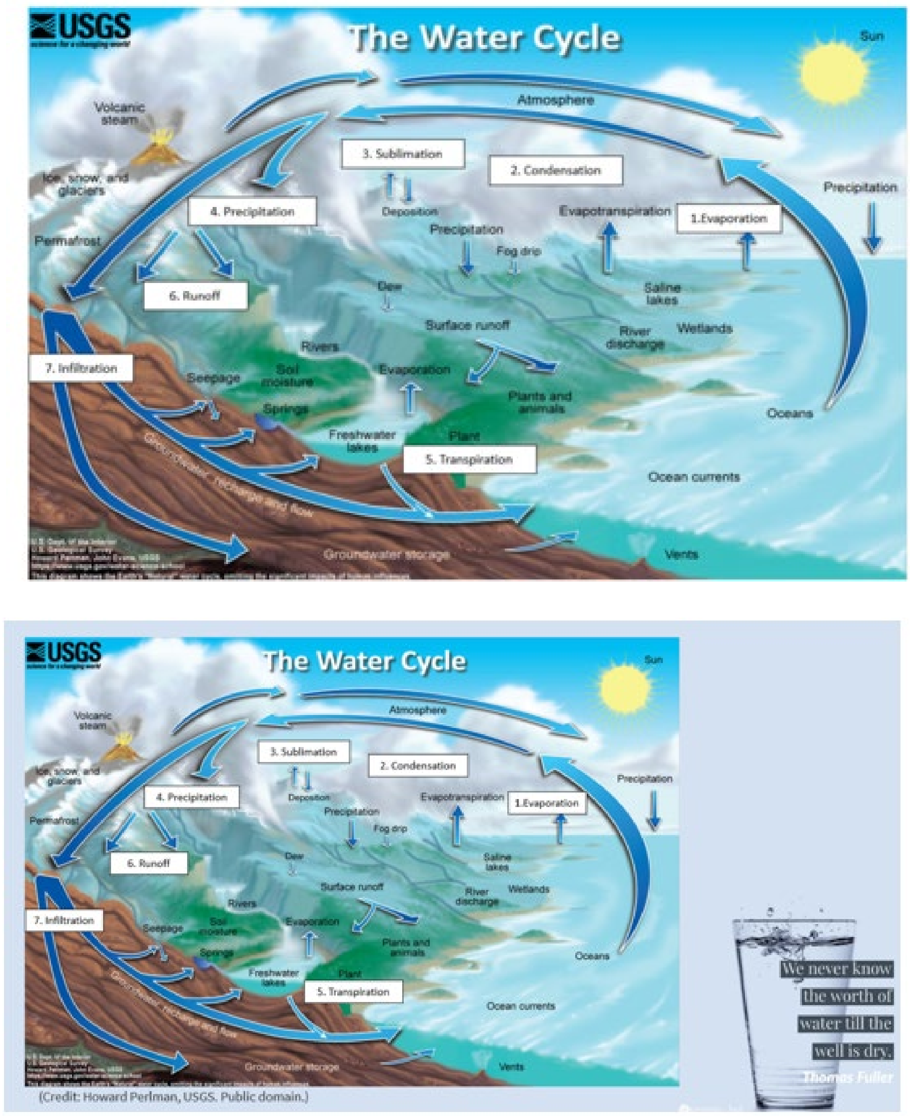
Question	Response	*n*	%
Students learn better when interesting but extraneous graphics are excluded.	True (High Knowledge)	43	38%
	False (Low Knowledge)	35	35%
	I do not know (Low Knowledge)	34	34%
Students learn better when pleasant but unnecessary background sounds are included.	True (Low Knowledge)	10	9%
	False (High Knowledge)	78	78%
	I do not know (Low Knowledge)	24	21%
The coherence principle states that in order to keep students' working memory from being overloaded, we should eliminate extraneous material from our presentations.	True (High Knowledge)	59	53%
	False (Low Knowledge)	6	5%
	I do not know (Low Knowledge)	47	42%
From which of the following slides will students learn more deeply? (Water cycle)	Correct, coherent image (High Knowledge)	86	77%
	Incorrect, incoherent image (Low Knowledge)	26	23%

Note. Correct responses indicating high knowledge of the coherence principle are highlighted.

One of the knowledge of coherence questions asked respondents to choose the ESP design from which students would learn more deeply. Of the two nearly identical slides featuring an image from the U.S. Geological Survey (USGS), one contained an element that could lead to learner cognitive overload according to the CTMP. An incoherent detail (an extraneous, unnecessary image that violates the principle of coherence) was added to one slide option. According to the CTML as articulated by Mayer and Moreno (2003), the coherence principle states that students learn better when interesting but extraneous graphics are excluded. The incoherent slide exhibits a glass of water along with an inspirational statement about conserving water. The glass of water and accompanying text are interesting, but not necessary to understand the water cycle. Most participants *(n* = 86, 77%) correctly chose the first, coherent slide as the image from which students would learn more deeply. Figure 1 presents images of the two coherency slide options.

Figure 1

Knowledge of the Coherence Principle Slide Choices



Note. The survey question read as follows: "From which of the following two slides will students learn more deeply?"

Knowledge of the Redundancy Principle Results

Responses to the four questions about the redundancy principle were coded and calculated in the same manner. Answers that correctly corresponded with the redundancy principle were coded with a "1" and interpreted as high knowledge of the principle. Incorrect responses and *I do not know* responses were coded with "0" and interpreted as low knowledge of the principle. Participants as a group scored low on the knowledge of redundancy principle (*M* = .35, *SD* = .238). Table 9 displays the responses and questions regarding knowledge of the multimedia principle of redundancy.

Table 9

Knowledge of the Redundancy Principle Results

Question	Response	*n*	%
Students learn better when the slide has all three elements: written text + graphics + teacher narration.	True (Low Knowledge)	90	80%
	False (High Knowledge)	13	12%
	I do not know (Low Knowledge)	9	8%
Students learn better when narration is accompanied by graphics rather than when the teacher narrates the printed text on the screen word for word.	True (High Knowledge)	68	61%
	False (Low Knowledge)	19	17%
	I do not know (Low Knowledge)	25	22%
The redundancy principle states presenters should not read their slides aloud because words we read are processed in both auditory and visual channels, which can cause students to comprehend less.	True (High Knowledge)	19	17%
	False (Low Knowledge)	33	29.5%
	I do not know (Low Knowledge)	60	53.6%
From which of the following slides will students learn more deeply? (Bees)	Correct, no redundant element	57	51%
	Incorrect, redundant text	55	49%

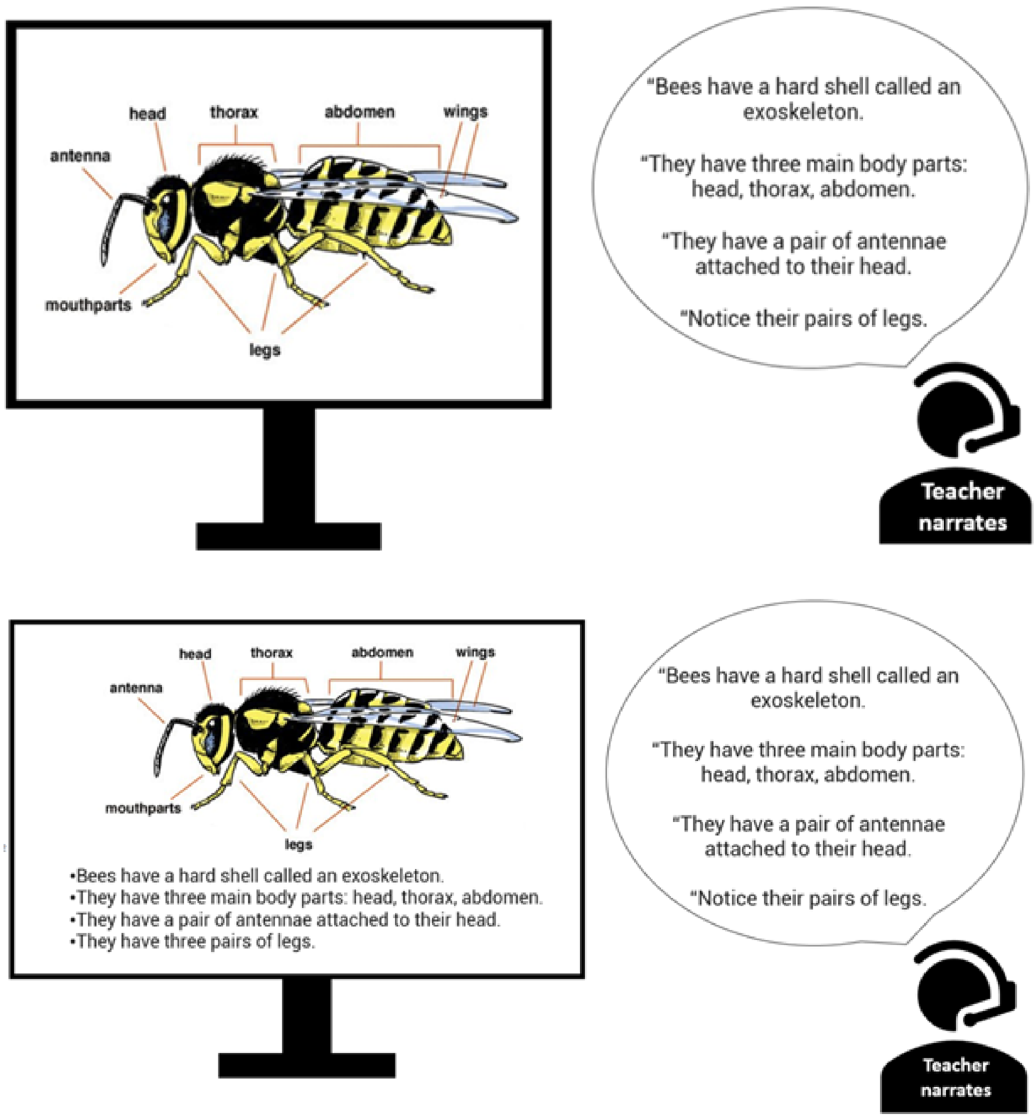
Note. Responses indicating high knowledge of the redundancy principle are highlighted.

Once again, educators were presented with a choice of ESP slides and asked to decide from which students would learn more deeply. In this second set of choices, designed to gauge knowledge of the redundancy principle, a repetitive detail — the visual repetition of narrated text — was added to one of the slide choices. The redundancy principle states that students learn better when narration is accompanied by graphics rather than when the teacher narrates the printed text on the screen word-for-word (Adesope & Nesbit, 2012). In their exploration of verbal redundancy, Yue, et al. (2013)

confirmed that simultaneous, identically narrated and written on-screen text causes learners to use more mental energy than necessary**.** To test educator knowledge, the second slide option is identical to the first except that in addition to showing the instructor narrate the slide, it also displays the exact text the teacher used in written form. Only half of the respondents correctly identified the slide that did not present redundant information (n = 57, 51%). Figure 2 presents the two redundancy principle image options.

Figure 2

Knowledge of the Redundancy Principle Slide Choices



Note. The survey question read as follows: "From which of the following two slides will students learn more deeply?"

Adherence to the Coherency and Redundancy Principles in ESP Practice

To answer the second research question, "To what extent do educators apply the research-based multimedia principles of coherency and redundancy in their electronic slide design?" we asked six questions with four possible responses: *Always*, *Most of the time*, *Sometimes*, and *Never*. Again, we used a binary system, as we did with the knowledge questions, to code the responses. Responses that displayed better adherence to the practice of implementing the multimedia principles of coherence and redundancy were coded "1." Responses that did not indicate adherence to the principle were assigned a score of "0."

Adherence to the Coherence Principle in Slide Design Results

A strong majority of participants' responses rated high adherence to the coherence principle in electronic slide design (*M* =. 81, SD = .218). Most respondents *(n* = 100, 89%) said they never or only sometimes include unrelated graphics or text. 82% *(n* = 92) said that images illustrate the concept they are teaching always or most of the time. Very few participants (n = 21, 28%) said they often include several images per slide. Table 10 charts the responses.

Table 10

Adherence to the Coherence Principle in Slide Design Results

Question	Response	*n*	%
How often do images on your slides directly illustrate the concept you are teaching?	Always (High Adherence)	40	35.7%
	Most of the time (High Adherence)	52	46.4%
	Sometimes (Low Adherence)	20	17.9%
	Never (Low Adherence)	0	0%
How often do you include several images per slide?	Always (Low Adherence)	5	4.5%
	Most of the time (Low Adherence)	26	23.2%
	Sometimes (High Adherence)	75	67%
	Never (High Adherence)	6	5.4%
How often do you include entertaining text or graphics unrelated to the content on your slides?	Always (Low Adherence)	2	1.8%
	Most of the time (Low Adherence)	10	8.9%
	Sometimes (High Adherence)	61	54.5%
	Never (High Adherence)	39	34.8%

Note. Responses indicating high adherence to the coherence principle in ESP design are highlighted.

Adherence to the Redundancy Principle in Slide Design Results

Overall, the three questions in this section indicate that educators' slide design slightly adheres to the CTML principle of redundancy (*M* = .52, *SD* = .315*).* However, of the three questions asked in this section, two were criticized by one respondent for assuming that an educator would show a slide with a full paragraph of text. The first was "When showing a slide with a full paragraph or more of text, how often do you read the paragraph to the students," and the results were fairly even (*M* = .51, *SD* = .502.) 51% (*n* = 57) were rated as high adherence, and 49% (*n* = 55) were rated low adherence. The second flawed question was, "When showing a slide with a full paragraph or more of text, how often do you give students time to read the paragraph in silence," (*M* = .34, *SD* = .475). Grouped together, only 34% (*n* = 38) responded that they allow students to read slides on their own. Most respondents answered with a low adherence rating *(n* = 74, 66%).

Instead of considering those two imprecise questions, it may give better insight to participants' overall adherence to the redundancy principle to consider only the overall response to the question, "How often do you combine an image with a full paragraph or more of text" (*M* = .71, *SD* = .457). Most participants (*n* = 79, 70.5%) were rated as having high adherence to the redundancy principle in this question. Table 11 demonstrates how each response was coded and displays the responses.

Table 11

Adherence to the Redundancy Principle in Slide Design Results

Question	Response	*n*	%
When showing a slide with a full paragraph or more of text, how often do you read the paragraph to the students?*	Always (Low Adherence)	31	28%
	Most of the time (Low Adherence)	24	21%
	Sometimes (High Adherence)	41	37%
	Never (High Adherence)	16	14%
When showing a slide with a full paragraph or more of text, how often do you give students time to read the paragraph in silence?*	Always (High Adherence)	16	14.3%
	Most of the time (High Adherence)	22	19.6%
	Sometimes (Low Adherence)	41	36.6%
	Never (Low Adherence)	33	29.5%
How often do you combine an image with a full paragraph or more of text?	Always (Low Adherence)	5	4.5%
	Most of the time (Low Adherence)	28	25%
	Sometimes (High Adherence)	46	41%
	Never (High Adherence)	33	29.5%

Note. Responses indicating high adherence to the redundancy principle in ESP design are highlighted.
* This question was criticized by a respondent for assuming an educator would show a slide with a full paragraph of text.

Discussion

In this study, we explored educator's understanding of and coherence to the Cognitive Theory of Multimedia Principles of coherency and redundancy in their electronic slide presentation design. We investigated the extent to which teachers understand the principles and the extent to which they design their slides according to those principles. Results of this study suggest that educators do not have a deep understanding of the CTML principles of coherency and redundancy, although there is evidence they may have a better knowledge of the coherency principle than the redundancy principle. Similarly, this study suggests that educators apply the coherency principle to their slide design more consistently than the redundancy principle.

It is worth noting that many respondents chose "I do not know" for several knowledge questions. These results indicate that educators may intuitively understand the concept while not necessarily understanding the terms, because the data implies they are slightly better at identifying which slides will better for student learning. It might be worthwhile to investigate the other ten principles of CTML. Although this study would seem to indicate otherwise, it is possible that some educators apply design principles without formal training.

The fact that many educators do not know about or implement two basic tenets of CTML principles to their ESP design is concerning. This study only focused on two evidence-based cognitive principles proven to help mitigate cognitive overload in multimedia instruction by minimizing extraneous load; there are ten more principles improve management of essential processing and maximize germane learning of difficult subjects. In other words, this study merely scratches the surface. Yet, it appears from the results that educators have not yet learned the concepts and might not understand how they could improve their instruction.

Implications for Practice

Given the experience educators have had this past year due to the pandemic and having to pivot to online and/or face-to-face and virtual environments at the same time, it is possible that educator's knowledge of the CTMP principles grew since this survey, which ended right as the COVID pandemic closed schools. Perhaps educators are more aware of these principles now. Or is it necessary that intentional instruction of these principles must occur for educators to gain awareness and perspective during reflection of their instruction particularly as it is related to student learning? Professional development and teacher preparation programs would benefit by considering how to implement proven practices of electronics slide design as learning environments continue to change and develop.

Limitations of this Study

One purpose of this pilot study was to gather data to use as a springboard for future study concerning CTML principles and ESP design, particularly at the k-12 level, where there is a dearth of research information. This study has succeeded for the researchers, and one important reason is because it quickly became apparent that the language of some questions must be clarified. Specifically, two questions concerning the adherence of the redundancy principle in ESP design were not clear, leaving only one question to indicate adherence. While this non-probabilistic survey design cannot lead to valid generalizations, the loss of data for these two questions is disappointing.

Recommendations for Future Research

Researchers and leaders in the fields of cognitive psychology and education are aware that the need to better prepare and enable educators to use technology effectively. Further studies should investigate practical ways to implement multimedia principles in electronic slide design in all learning environments. More empirical research should be conducted on different groups of educators and learning environments, especially at the k-12 level.

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