

# Principles of Accessible Multimedia Learning

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Accessibility

Instructional Design

Multimedia

Cognition

Presentation Styles



*Multimedia presentations have been shown to benefit learners; as a result, multiple theories have been advanced to guide the presentation design process. This opinion paper addresses the most widely used of these theories, Mayer's Cognitive Theory of Multimedia Learning (CTML), advancing that CTML as well as cognitivism itself may work in opposition to the provision of accessible instruction. A review of literature finds Sweller's decision to highlight threats to learners' cognitive capacity for processing audio and visual stimuli to be a problematic choice that, in combination with the medical neuroscience lens used by learning scientists, engenders discrimination against students with disabilities. In response, this paper proposes a novel alternative cognitivism framework which positions cognition as driven by learners' analysis of verbal and symbolic data, based on a return to Paivio's depiction of cognition as based on the interpretation of verbal and symbolic signs. This alt cog approach is offered as an explanation for Mayer's observation of boundary conditions for the redundancy principle, then used to recast multiple CTML theories as a set of principles for the design and development of instruction through accessible multimedia learning.*

## Introduction

From overhead transparencies and filmstrips through videocassettes and YouTube, the use of multimedia principles has been shown to benefit learning processes (Adesope & Nesbit, 2012; Alpizar et al., 2020; Schroeder & Cenkci, 2018; Takacs et al., 2015). Multimedia presentations incorporate at least two categories of media, e.g., static visuals and audio. During instructor-led face-to-face or synchronous online classes, the instructor's voice combines with simultaneously presented visual content to form a "live" multimedia presentation; such presentations can also be recorded and stored online for later viewing. The plummeting cost of software for content creation and its increasing ease of use have brought the production of multimedia within reach of nearly everyone. Today, educators are able to develop their own customized multimedia content for inclusion in classroom or online lessons. Even those instructors who prefer hands-on constructivist lesson plans often choose to incorporate multimedia, e.g., the use of recorded multimedia presentations to inform students of an activity's scope, parameters, or procedures prior to in-class activities (Bergmann & Sams, 2012).

As a learning designer and university instructor, I seek out tools, methods, and frameworks that support equitable pedagogical approaches. Reflecting on my process for designing new courses or modules, my preference has been for experiential learning – but even those activities are supported and scaffolded through multimedia presentations. While developing courseware, I have relied on cognitivist theories to guide the design of my presentations; however, a growing unease with many of the assumptions underlying our current framing of cognitivism have left me yearning for a new approach. As I've accrued deeper experience with issues of disability and access, my classroom experiences of watching cognitivist guidelines fail to adequately address the needs of disabled and disadvantaged students has inspired me to seek a framework that could be more social and less discriminatory. This opinion paper will provide observations towards that end, including revised guidelines for multimedia development.

Instructional designers seeking guidance in the preparation of multimedia often rely on Mayer's (2002) Cognitive Theory of Multimedia Learning (CTML). This compendium of established and novel principles has been an influential force in the practice and study of instructional design (Moore, 2006), shaping the field's view of what constitutes proper design and implementation of multimedia. For instructional content designers who embrace a humanist pedagogical perspective, however, the cognitivist orientation of CTML's principles may be problematic. To understand the basis for that concern requires consideration of how cognitivists "see" learners, including their priorities when considering experimental results.

In research and teaching, a lens is a perspective informed by a particular set of values and beliefs. As one example, Foucault's (1973) *The Birth of the Clinic* renewed attention on the "medical gaze" doctors use when considering the question, "What is negatively impacting the health of this recipient?" By positioning hurdles to perfect health as sicknesses in need of cure, the medical gaze serves as a lens that allows physicians to view patients' bodies as separate from their socially constructed personhood. Similarly, Sweller's (1988) cognitive load theory typifies cognitivist's use of a neuroscience lens when thinking and writing about the interactions between learners and instruction. Instructional researchers who use a neuroscience lens ask, "What is impeding a perfect response from this recipient?" and then search for a variable they can adjust to "fix" observed problems with performance. Such a diagnosis of learning deficiency is usually made when the participant fails to achieve an average outcome on an assessment. Using this pathology model (Walker, 2020) to position deviations from averaged outcomes as problematic and in need of elimination, cognitive theorists seek instructional approaches that improve overall performance as evidenced by mean test scores.

The neuroscience lens employed by cognitivists dovetails with their focus on measurement; an important but seldom-asked question is whether useful things are being measured. Since the advent of Sweller's influential cognitive load theory, cognitivists have been interested in learners' capacity to receive and comprehend stimuli presented in visual and auditory forms, taking care to avoid overwhelming these audio and visual processing centers. Could this focus be misplaced? Prior to Sweller et al.'s (1998) definition of cognitive load, Paivio (1986) recommended a more humanistic approach that foregrounded the processing of information as separated into verbal and non-verbal signs (Saussure & Riedlinger, 1983). This position paper explores this dramatic yet unheralded shift in priorities, then presents a rationale for de-emphasizing the processing of auditory and visual inputs in favor of a return to focusing on the interpretation of words and symbols.

One benefit of moving from an audio/visual orientation to a word/symbol focus is that such a shift embraces multiple means of representation to deliver instruction (Rose et al., 2006); another is its allowance for the consideration of external social and emotional factors. In contrast, to portray human cognition as primarily driven primarily by the successful processing of visual and audio stimuli defines learners with visual or auditory disabilities as defective in ways that would impair cognition. Learners with substantial barriers to access, e.g., vision impairment, hearing impairment, cognitive impairments, or low language proficiency have traditionally been overlooked in research on multimedia learning, but together they comprise a substantial, growing portion of the student body. The success of learners who find a deep understanding of instruction through processes that do not fit cognitivism's inputs-centric neuroscience lens belies the need to treat such learners as "less than." Research on accessible, inclusive classroom practices (Allman et al., 2019; Rose et al., 2005) show that these non-standard learners are able to fully appreciate and benefit from instruction – if the instruction can be accessed.

# Purpose

The framework of this position paper embraces theories of disability and accessibility, employing them in critique of early twenty-first century cognitivism. I take the position that cognitivism's current emphasis on examining audio and visual processing ignores the needs of students for whom such processing is impaired, and that cognitivism itself should be revised to enable more inclusive and useful applications of theory.

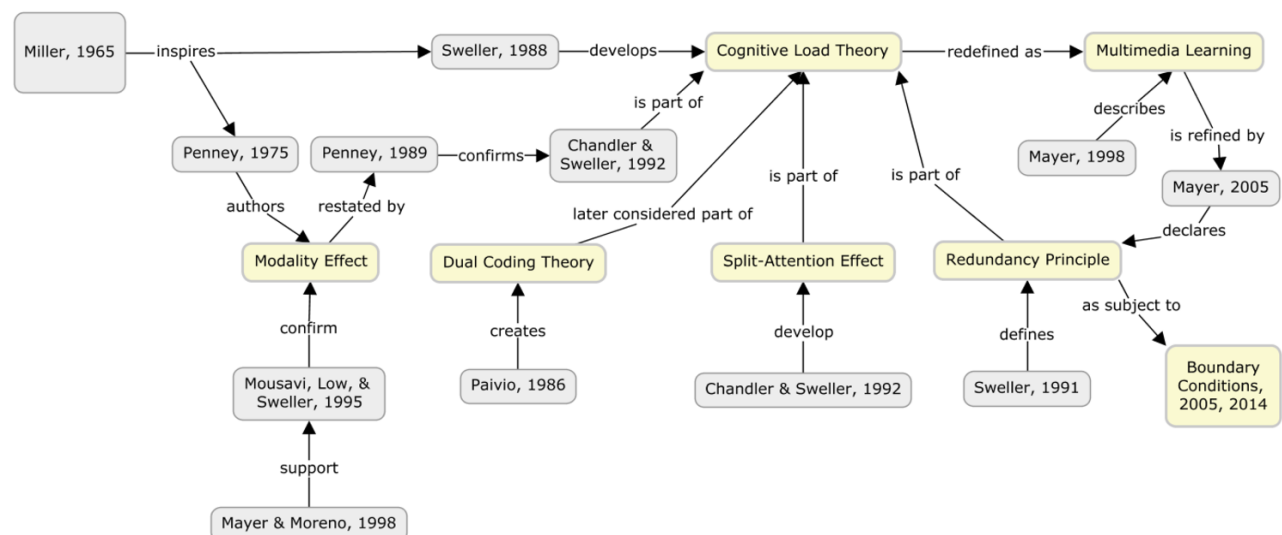
To serve as one example of such a modification, this position paper introduces a new approach: an alternative cognitivism ("alt cog") that returns to the humanist ideas at the heart of Paivio's (1986) dual-coding theory. Capping more than a decade of research that became foundational to cognitivism, Paivio's foundational work on dual-coding theory describes the process of human cognition as reliant on separate processing centers for verbal input, i.e., language, both spoken and written, and symbolic input, e.g., photos, charts, diagrams. By focusing on learner's understanding of words and symbols rather than their capacity to accept visual and auditory input, Paivio portrayed human understanding as a complex construct that includes social factors as well as individual abilities. The current paper explains how an alt cog focus on learners' verbal/symbolic processing can provide improved insights into learner cognition while explaining documented inconsistencies in CTML's redundancy principle (Mayer & Johnson, 2008). The ideas proposed within this paper will benefit instructional/learning designers who wish to improve students' comprehension of words and symbols in service of knowledge development while foregrounding the need for more inclusive, accessible guidelines and practices.

# Literature

A recognized force by the late 1980s, cognitivism leverages insights attributed to neuroscience to recommend that instruction be tailored around the cognitive learning processes of students. This innovative idea was advanced by a cluster of new theories that Mayer (2002) would eventually gather under the CTML umbrella. These concepts included dual coding theory, cognitive load theory, the modality effect, and the redundancy principle (Figure 1). This paper considers these concepts chronologically in their original forms to better understand the relationships between CTML's component principles.

**Figure 1**

*Concept Map of Related Cognitive Theories*



Among the first to posit methods of human cognition from a neuroscience perspective, Paivio's (1986) dual coding theory diagrammed interaction between processing centers for language and nonverbal stimuli. He surmised that the

human brain processes verbal and nonverbal information independently but that these systems could operate in parallel, with each input processing system able to stimulate activity in the other. Paivio believed that together these dual systems could build the complex representational structures needed for concept formation and information retrieval (Paivio, 1986, p. 54). Paivio defined presentation modalities as verbal, i.e., language, or nonverbal, i.e., symbolic, noting that both types of content carry their own ramifications for student learning. By diagramming a logical path for learning, Paivio's dual coding theory differed from the prevailing pre-cognitivist belief that only the essential concepts within instruction were of note. Prior to the acceptance of dual coding theory, modality was considered theoretically unimportant, so choice of delivery method was devalued.

Two years later, Sweller (1988) theorized that students' learning strategies could directly influence the load, i.e., stress, placed on their cognitive processes (p. 275). Treating the human mind's processing of cognitive problems as akin to a computer circuit board, he felt that human problem-solving capabilities could be diagrammed as a production model. Sweller defined a learner's total cognitive load as consisting of (1) intrinsic load, i.e., the effort required to understand the primary learning task; (2) extraneous load, i.e., the undesirable additional stress incurred by poorly formed instructions; and (3) germane load, e.g., the effort involved in fixing new information within long-term memory. While the principles of cognitive load theory have been widely accepted, instructional design researchers typically overlook that subsequent explanations of Sweller's widely heralded theory pushed aside Paivio's focus on verbal and symbolic processing in order to focus on the human brain's discrete, limited capacity for processing visual and auditory information. Sweller et al. (1998) cautioned against overloading the brain's ability to process sounds and visuals in order to preserve learners' mental capacity for acquiring problem-solving schemas and transferring them into long-term memory.

Employing a scientific lens for their analysis, Sweller et al. (1998) ignored the influence of social factors to concentrate on the enhancement of individual performance through maximization of learners' ability to process audio and visual inputs. Having once used the term "audio-visual" to describe itself, the field of instructional design embraced Sweller's focus on human sensory inputs as the engines of cognition whose extraneous load must be kept at a minimum to leave capacity for the processing of instruction.

The popular acceptance of cognitive load theory greatly influenced other research that Mayer later subsumed into CTML, e.g., the modality effect, the redundancy principle, split-attention effect, and multimedia learning theory. Penney (1989) had first researched the modality effect in 1975, but then returned to the subject with a new analysis (Penney, 1989) that brought her findings into alignment with Sweller's influential cognitive load theory. Her research into modality proposed a model for the structure of short-term memory which included a separate-streams hypothesis: that the brain's short-term memory processes auditorily presented verbal items separately from visually presented items. Penney (1989) found benefits when audio processing is used for receiving instruction, as learners were better able to retain the sequential characteristics of verbal input, i.e., remember lists.

As the advent of microcomputers and desktop publishing increasingly allowed authors to add graphics and audio to their instruction, Chandler and Sweller (1991) formulated a redundancy principle, claiming that redundant material decreases the intelligibility of instruction by overloading learners' processing capacity. This research featured six quantitative experiments, none of which involved an auditory component – their tests utilized printed booklets in which explanatory text and legends were positioned either adjacent to or separately from a series of diagrams. Significantly and despite their assertion, Chandler and Sweller emphasized that they "were not engaged in a theory validation exercise" and that "direct tests of, for example, attentional or cognitive load factors were not carried out" (p. 329). This view of redundancy, as incorporated into Mayer's omnibus theory, should be of limited applicability to multimedia learning due to their experiment's lack of audio testing.

Mayer's first exposition (Mayer et al., 1996) of what would grow to become CTML focused on an instructional technique combining visuals, captions, and detailed written explanations in an annotated illustration which Mayer et al. called a multimedia summary. Their study detailed the multimedia summary's rationale for selecting, organizing, and combining words and images in ways that promote the retention and transfer of technical scientific information by reducing students' cognitive load in accordance with Sweller's model.

Research from Mayer and Moreno (1998) was among the first to site questions of cognitive load and student instruction within a computer-mediated environment. This research focused on the question of what should accompany an illustration for learners to receive the most benefit; as Penney (1989) as well as Chandler and Sweller (1992) predicted, the findings favored audio narration over on-screen text explanations. “The most important new practical implication of this study is that animations should be accompanied by auditory narration rather than by on-screen text,” they wrote. “These results cast serious doubts on the implicit assumption that the modality of words is irrelevant when designing multimedia lessons with pictures and words” (Mayer & Moreno, 1998, p. 318-319). It is important to note that this study examined the use of animations with explanatory audio as compared to animations accompanied by explanatory text, providing no basis for using these results to reach conclusions on the efficacy of using text and narration simultaneously, i.e., verbally redundant text and narration.

In 2002, Mayer provided a definition of multimedia learning based on an initial nine key principles (Mayer, 2002, p. 133), later updated to 12 principles (Mayer, 2017). Foremost among these was the multimedia principle, described as, “People can learn more deeply when they receive an explanation in words and pictures rather than words alone” (emphasis added; Mayer, 2002, p. 105). This initial focus on verbal/symbolic processing was complicated a few years later when Mayer (2005) described three primary assumptions for multimedia learning: that visual and auditory stimuli are processed separately using dual channels; that the amount of information these channels can process is circumscribed due to the limited capacity of human cognition; and that active processing, i.e., attending to, organizing, and integrating information, leads to meaningful learning. Mayer’s 2005 language aligning CTML’s focus with Sweller et al.’s (1998) emphasis on audio-visual processing had the effect of codifying this distinction into widespread practice.

Even prior to CTML’s expansion in 2017, its core principles were subject to redefinition, sometimes through empirical results that challenged Mayer’s previously held positions as well as the findings of other researchers. In Mayer and Johnson’s (2008) announcement of what would come to be known as a boundary condition for the redundancy effect, the authors noted that when spoken narration matches the on-screen text, there can be an unexpected decrease in learners’ cognitive load if the text is also revealed synchronously. They specified that verbally redundant on-screen text, which CTML’s redundancy principle had always described as a negative influence on learning, can instead be helpful in specific circumstances, e.g., when the narration is complex or contains unfamiliar words, when the narration is not in the learner’s native language, when the pace of presentation is slow or learner-controlled, or when the audience is composed of low-knowledge learners (Mayer & Johnson, 2008). This boundary condition for redundancy, sometimes referred to as a reverse redundancy effect, has been confirmed by other research (Mayer, 2005; Mayer & Fiorella, 2014; Mayer & Johnson, 2008).

The preceding survey of major cognitivist theories detailed our field’s move away from Paivio’s proposal that human cognition is dependent upon learners’ ability to interpret words and symbols, not just the successful reception of audio and visual data. Instead, the broad acceptance of cognitive load theory and Sweller et al.’s (1998) focus on audio and visual streams shifted the focus of cognitive inquiry onto students’ ability to receive and comprehend separate streams of auditory and visual input. The remainder of this paper considers key principles from Mayer’s (2002) CTML and asks how they may be revised to support a return to Paivio’s focus on words and symbols rather than Sweller’s emphasis on the reception of sights and sounds.

## Discussion

Revisiting CTML from the alt cog perspective proposed by this paper indicates the possibility for reforms beyond a return to Paivo’s verbal/symbolic orientation. Cognitivism’s self-selected label as a learning science has been criticized (Lynch, 2019) as well as the connotation that its theories are not simply inspired by, but are in fact explicitly supported by, data collected through cognitive science (Watson & Coulter, 2008).

## Scope Reduction

The experiments used to support CTML's constituent theories are said to provide validation for the primacy of audio and visual processing, but without the support of precise, concrete neurological data these tests simply indicate better average outcomes from certain delivery methods and presentation styles as sited within specific instructional contexts. As such, the alt cog approach is to prefer interpretations which are not dependent on narrowly defined neuroscience-derived rationales:

- It is possible to respect the accumulated empirical evidence supporting the benefits of multimedia instruction without attributing those benefits to specific neurological processes.
- We can affirm the substantial evidence that human capacity for information processing is limited (Marois & Ivanoff, 2005) without having to specify a concern over auditory and visual inputs; simply restating cognitive load as the belief that learning is impacted when cognitive processing occurs under duress justifies acting to conserve learners' limited processing power.

## Coherence and Contiguity

In this light, the benefits of CTML's coherence principle are readily apparent and extend to all learners on all platforms: instruction should avoid irrelevant words, pictures, and sounds in order to minimize cognitive load. Similarly, this position also supports CTML's spatial contiguity principle in that the positioning of labels, legends, and other explanatory text in close physical proximity to the material they explain can reduce the cognitive effort, e.g., searching, required for their integration.

## Demystifying Boundary Conditions

More pointedly, an alt cog perspective with its accompanying orientation towards verbal/symbolic processing can better explain Mayer's observed boundary conditions for the redundancy effect, a phenomenon that is also closely tied to CTML's principles of modality and temporal contiguity. Mayer (2008) notes that CTML's modality and redundancy principles both indicate that verbally redundant text and narration should negatively impact learners by overwhelming their limited capacity for cognitive processing, specifically those processes involved in the discrete acceptance and comprehension of auditory and visual stimuli. Over time, however, empirical data from multiple studies (Mayer, 2005; Mayer & Fiorella, 2014; Mayer & Johnson, 2008) led to the proposal of boundary conditions for redundancy due to the observed benefits of redundant text. Such research includes Toh et al.'s (2010) finding that "redundant synchronized on-screen text did not impede learning; rather it reduced the cognitive load and thereby enhanced learning" (p. 988).

Viewing this same phenomenon through Paivio's verbal/symbolic path to cognition removes the supposed conflict between redundancy and comprehension. Paivio tells us that presenting words via both auditory and visual channels reinforces meaning and aids meaning-making because these systems operate in parallel to develop the germane cognitive load needed for successful learning. Paivio's word/symbol approach obviates concerns over redundancy as a waste of cognitive resources in situations when the presentation is temporally contiguous, thereby allowing the processing of similar spoken and written words to occur in tandem. This perspective reveals why Mayer and others observed a boundary condition for redundancy: delivering redundant content with visual and auditory elements that are temporally contiguous is supported by Paivio's decision to focus on verbal content as a single unit rather than as separate components of sight and sound. Sweller et al.'s (1998) formative decision to emphasize auditory and visual processing as independent entities has left cognitivist theorists without the tools to discern situations where visual and auditory processing are coordinated to reduce cognitive load.

## Accessibility as a Component of Cognition

Perhaps most importantly, shifting cognitivism's focus to the interpretation of words and symbols rather than the reception of sights and sounds better suits the needs of learners who cannot see or hear. When we think of meaning as resulting from the interpretation of words and symbols, the function of media becomes simply to deliver that verbal and symbolic content. When we recognize instruction as dependent on the communication and interpretation of these



signs, then the question of media becomes not which, but how many. An alt cog perspective views multiple media as a matter of course, favoring accessible, reflowable formats that can accommodate every type of learner. For disabled learners who are limited in various forms of sensory input, redundancy is a critical method of guaranteeing access – provided that the redundant content’s format is compatible with assistive technologies.

The empirical studies behind most foundational cognitivist research from the 1980s and 1990s relied on sample populations drawn from classrooms where disabilities were not represented. As a cognitivist theory, CTML is unconcerned with accessibility. Cognitivists synthesize individual cases into homogenous patterns of processing and interpretation that supersede all differences in age, gender, race, or other demographics. Their interest is in accurately defining the process of human cognition in order to recommend a single best way to communicate instruction (Campbell, 2020). Finding this apex can mean driving the best possible outcomes from top performers, as opposed to pedagogies that prioritize compatibility with assistive technologies (McNicholl, 2021).

Rather than striving for accessibility for all learners, some cognitivists have been open about privileging the ideal learner. Notably, Sweller (2005) advocated against the use of fully redundant text and narration as a waste of precious cognitive resources yet has also acknowledged that “information that is redundant for one person may be essential for another” (Sweller, 2005, p. 165). Despite this admission, Sweller’s work maintains that “information should be presented in a single form only, i.e., with all other versions and all unnecessary explanation eliminated” (p. 167). Such prescriptions discriminate against populations that diverge from cognitivism’s assumed norms. Omission of non-standard, e.g., disabled, audiences from consideration should be a major concern for education researchers, especially in light of positive results from accessible course designs (Seok et al., 2018). For example, when Mayer and Johnson (2008) spoke of redundancy’s benefits for low-knowledge learners in their initial declaration of boundary conditions, they did not make a connection to learners whose challenges to comprehension may have resulted from barriers to access such as physical or cognitive disabilities.

CTML contains other principles that can be seen as enabling improved access for all learners, including Mayer’s (2017) more recently added principles of pretraining, signaling, and personalization; however, these principles are not discussed in this position paper.

## Conclusion

Grounded in the previously described theories, this paper recommends a subset of modified CTML principles as guidance for instructional designers on the development of accessible multimedia learning initiatives. This modified CTML subset can be referred to as the principles of Accessible Multimedia Learning (AML):

**Multimedia principle:** Provide instruction through all necessary media. When spoken words and displayed text are accompanied by meaningful graphics during the delivery of instructional content, knowledge transfer is improved (subject to the remaining two principles). The benefits of multimedia should be available to all learners, so alternative media, e.g., closed captions, transcripts, should be included in multimedia presentation designs.

**Coherence/spatial contiguity principle:** Only provide what is needed, and make it easy to find. Limited human capacity for the processing of instruction indicates the need to preserve cognitive resources by minimizing the distance between diagrams and their labels while excluding irrelevant audio, text, or graphics. (However, this should not be misinterpreted as recommending only sparse on-screen text in the presence of narration, per the final principle.)

**Verbal Redundancy/Temporal Contiguity principle:** Narration should be fully or nearly redundant with displayed text, and that text should be revealed in synchronization with the redundant narration. When spoken narration is closely related to on-screen text, there can be a decrease in learners’ cognitive load if the text is revealed synchronously. Learners’ coordinated processing of temporally contiguous and verbally redundant text can reduce extraneous cognitive load.

AML’s recommendations extend to multiple forms of multimedia instruction, whether delivered as PowerPoint slides to accompany a stand-up lecture or made available asynchronously in accessible formats such as webtexts or EPUBs. The

implications of this research are numerous and widespread, as the number of students who identify as disabled in some form continues to rise (Greenberg, 2022). Learners without relevant disabilities can also benefit from instruction prepared in accordance with this paper's recommendations.

While Mayer's (2002) cognitive theory of multimedia learning has been recognized as a cornerstone of instructional design, its complexity and malleability make its relationship to issues of accessibility difficult to fully summarize. Additionally, this position paper has been limited by my personal advocacy for universal access to instruction, especially in higher education.

To that end, I call for more research into the comprehension of accessible multimedia courseware in real-world learning environments. Such research should incorporate significant numbers of participants from special populations such as non-native English speakers as well as learners who face a range of physical and cognitive challenges, e.g., low vision, deafness, dyslexia, attention deficit disorder. Future scholarly work in this area should include empirical research, both quantitative and qualitative, to clarify whether these proposed principles of accessible multimedia can help improve learning outcomes for all learners.

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