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The Effects of Seductive Details in an Inflatable Planetarium

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COLLEGE OF EDUCATION

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2013

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Doctoral Study Submitted in Partial Fulfillment

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Abstract

Astronomy is becoming a forgotten science, which is evident by its relatively low enrollment figures compared to biology, chemistry, and physics. A portable inflatable planetarium brings relevance back to astronomy and offers support to students and educators by simulating realistic astronomical environments. This study sought to determine if learning is improved in an inflatable planetarium by adhering to the design principles of the cognitive theory of multimedia learning (CTML), specifically the coherence principle, in an authentic classroom. Two groups of 5^{th} grade students of similar ability were purposefully assigned using a 1-teacher-to-many-students format with mean lesson lengths of 34 minutes. The experimental group was differentiated with *seductive details*, defined as interesting but irrelevant facts that can distract learning. The control group (n = 28), with seductive details excluded, outperformed the experimental group (n = 28), validating the coherence principle and producing a Cohen's effect size of medium practical significance (d = 0.4). These findings suggest that CTML, when applied to planetarium instruction, does increase student learning and that seductive details do have a negative effect on learning. An adult training project was created to instruct educators on the benefits of CTML in astronomy education. This study leads to positive social change by highlighting astronomy education while providing educators with design principles of CTML in authentic settings to maximize learning, aid in the creation of digital media (astronomical simulations/instructional lessons for planetariums) and provide valuable training for owners of inflatable planetariums with the eventual goal of increasing student enrollment of astronomy courses at the local level.

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Dedication

This doctoral dissertation is dedicated to my wife and three children. I would like to thank them for listening patently while I told them all about the world of astronomy education and inflatable planetariums, which only I seemed to be excited about. They have waited patiently for me to complete this project, with that I would like to express my love.

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Section 1: The Problem

Introduction

Astronomy is a neglected course of study in the United States (Bishop, 2003). This trend began in the late 19th century when the Committee of Ten (1894) labeled high school astronomy as an elective during its mandate to standardize high school courses across the United States for college admissions. This trend does not appear to be reversing (Krumenaker, 2010). The national education standards being adapted by California, known as The Common Core, further deemphasize astronomy in science education (California Department of Education, 2012a). New technologies and methodologies designed to support astronomy education provide the opportunity to shift astronomy back into the classroom (Deustua, Noel-Storr, & Foster, 2009). Planetariums offer an environment directly related to astronomy instruction with the hope of inspiring scientific investigation (Perhoniemi, 2006), but it is unclear what instructional strategies are most effective in a planetarium (Brazell & Espinoza, 2009).

The planetarium has undergone an evolution in delivery (Yo, Chaplin, & Goldsworth, 2011). No longer do planetariums use analog projectors to display the stars, but rather use complicated digital projectors to create immersive cosmic environments on a grand scale using a multimedia format of images, video, sound, and narration (Rosenfield et al, 2010). Several questions arise from the use of these new methods of display. Does this new method of delivery provide a benefit to the audience? Are the strategies employed to instruct the audience effective? Which strategies, if any, deliver optimal learning conditions?

Richard Mayer (2009) developed 12 principles of multimedia learning, known as the cognitive theory of multimedia learning or CTML, for dealing with learning based on the plethora of modern electronic delivery choices. The focus of this study will attempt to determine if seductive details (interesting, but irrelevant information – part of the coherence principle of CTML) applied to a portable inflatable planetarium environment will help or hurt the learning taking place in the planetarium. This first section will describe a definition of the problem, a rationale of why the problem needs solutions, unique definitions pertaining to this project study, the significance of the problem, guiding research questions, implications, and conclude with a review of the literature on this topic.

Definition of the Problem

A review of the literature has revealed that local students are not enrolled in astronomy courses (California Department of Education, 2011a) due to difficulties associated with teaching astronomy (Guimarães, 2009; Krumenaker, 2009b; Plummer & Zahm, 2010; Trundle & Bell, 2010). Four existing points have been discovered that support this problem. First, astronomy education standards are not on par with other science standards such as biology, chemistry, and physics; it is represented but often times positioned under earth sciences with fewer requirements (California Department of Education, 2009; Krumenaker, 2009b; California Department of Education, 2012a). Second, existing high school astronomy courses offer insufficient benefit for graduation or college entrance and are often identified as an elective without a true laboratory component such as with biology, chemistry, or physics (California Department of Education, 2012b; California State University, 2012; Krumenaker, 2009b; Krumenaker, 2009c; University of California, 2012). Third, misconceptions of the nature of the cosmos are prevalent among teachers and students (Bailey, 2011; Lelliott & Rollnick, 2010). Finally, high school astronomy courses need funding for hands-on activities, similar to labs for biology, chemistry, and physics (Krumenaker, 2009a; Krumenaker, 2009c; Krumenaker, 2010). This study will focus on promoting the planetarium as a viable hands-on activity for teaching observational astronomy, with the expectation of elevating astronomy education and creating demand for rigorous astronomy courses.

The problem of students not enrolling in astronomy courses is a trend that can be spotted at the local level and across the United States, where astronomy is absent from the curriculum (California Department of Education, 2011a). Widening the scope to include the state of California observes that the state does not have the facilities to teach astronomy to the entire student population (California Department of Education, 2011b; Go-Astronomy, 2011; Krumenaker , 2008; Loch Ness Productions, 2011). The rest of the United States does not fare any better. Astronomy does not have the weighted prestige of other science courses due to a reduction of significance that occurred in the late 19th century (Bishop, 2003; Committee of Ten on Secondary Studies, 1894). Astronomy is considered an elective course with no laboratory component (Sadler, 1992) and provides no benefit to standardized test scores (Krumenaker, 2009a).

Being the forgotten science (Krumenaker, 2009a), astronomy has many unique instructional difficulties. Three-dimensional astronomical observations are difficult to replicate in the classroom (Guimarães, 2009) and nighttime observations are generally impractical during the school day (Trundle & Bell, 2010). Due to the aforementioned problems, the opportunity for students to participate in astronomy courses does not exist in secondary school (Krumenaker, 2009b) and if it does, students typical spend less than one-third of the school year studying astronomy (Plummer & Zahm, 2010).

A planetarium can solve many of the problems associated with true astronomical observations (Brazell & Espinoza, 2009). Planetariums simulate a nighttime environment and accelerate the motion of the stars, allowing experiences in minutes rather than hours (Perhoniemi, 2006). The planetarium is the most effective environment for teaching observational astronomy to K-12 students (Brazell, 2009). Guimarães (2009) and Larsen (2011) argued that for the purposes of teaching astronomy, three dimensions, such as what a planetarium replicates, are better than two. Guimarães stated "It is much easier to understand how eclipses are caused by the tilt of the Moon's orbital plane in relation to the Earth and Sun in three-dimensions than in two" (p. 196). The planetarium affords that all-important third dimension.

Rationale

If real teaching and learning is to take place in the planetarium, then research must be conducted to identify different teaching methods and strategies to use in the planetarium that can have an impact on student experiences (Brazell, 2009; Mayer, 2009; Perhoniemi, 2006). The goal of this research project is to further the development of instructional techniques that provide maximum learning within the limited amount of student instructional time under the planetarium dome (Plummer & Small, 2011).

In order to develop methodologies and techniques that add to the understanding of planetarium instruction, educators need to align instruction and research with models of cognitive growth (Plummer, Wasko, & Slagle, 2011). CTML provides a framework for understanding how students learn in a digital multimedia environment (Mayer, 2009).

Using Mayer's (2009) cognitive theory of multimedia learning as the theoretical foundation, how can planetarium lessons be designed to benefit the learner? Specifically, this project will focus on testing the coherence principle and whether seductive details (interesting, but irrelevant facts embedded in a planetarium lesson) hinder learning in the planetarium environment.

Contrary to most CTML investigations, this study was performed in an authentic classroom (one teacher/many students) where normal distractions and interruptions are common. Most seductive detail studies have determined that seductive details have a detrimental effect on learning and have been performed in a laboratory setting that tightly controls experimental variables (Bryant, 2010; Lehman, Schraw, McCrudden, & Hartley, 2007; Lusk, 2008; Mayer, 2008; McCrudden & Corkill, 2010; Rowland et al., 2008; Rowland-Bryant, Skinner, C. H., Skinner, A., Saudargas, Robinson, & Kirk, 2009; Verkoeijen & Tabbers, 2009). A small number of studies implemented in authentic classrooms have revealed that perhaps these seductive details improve the learning within authentic classrooms (Lusk, 2008; Muller, Lee, & Sharma, 2008; Ozdemir, 2009; Towler, 2009; Towler & Kraiger, 2008). By testing seductive detail in an authentic classroom, the research knowledge pertaining to CTML can be further extended.

Another underlying purpose of this project study was to provide research to assist astronomy instructors, both inside the classroom and the planetarium, on how best to plan planetarium lessons and uncover methodologies that improve student learning in a planetarium. Brazell (2009) performed a meta-analysis of past planetarium studies (1966 – 2007) that compared the planetarium to the classroom, and determined that the planetarium is the better environment for teaching observational astronomy. The intent was to further Brazell's (2009) research and ascertain which techniques provide an optimal learning environment.

The increased use of digital technology within the planetarium allows for an unlimited and unhindered representation of the night sky (Yu, 2011). The data that has been collected by telescopes can now be presented in a digital planetarium simulation (Rosenfield et al., 2010). With this plethora of possibilities comes the responsibility of structure. Large institutions, which house planetariums, have invested considerable effort to provide a full dome digital environment (Loch Ness Productions, 2010). Full-scale immersive movies have the ability to transport and awe an audience (Yu, 2011), but are these experiences maximizing the audience's cognitive understanding?

Evidence of the Problem at the Local Level

The perceived impracticality of teaching astronomy has manifested itself in the local public schools, with two local comprehensive high schools in the High Desert region of Southern California not offering astronomy as a science course (California Department of Education, 2011a). In the state of California there are approximately 63 fixed dome planetariums, with 43 serving community colleges or universities, and only seven dedicated to K-12 institutions (Go-Astronomy, 2011; Loch Ness Productions, 2011). As of the 2010-2011 school year, California has over 6 million students enrolled in K-12 (California Department of Education, 2011b). This means that the vast majority of K-12 students in California have limited access to a planetarium. Krumenaker (2008) reported that less than 4% of high school students take astronomy courses. According to Plummer (2009) most children will not learn celestial motion without proper instruction that can be achieved in a planetarium.

The difficulties of teaching astronomy are present at school districts across the country (Krumenaker, 2008). In the United States, astronomy is not taught with the same rigor as other sciences (Bishop, 1996; Krumenaker, 2009b;). In 1892 the National Education Association, or NEA, formed the Committee of Ten to standardize college admission standards (Bishop, 2003). This committee recommended that biology, chemistry, and physics be taught as possible science entrance requirements for colleges nationwide. Astronomy was relegated to an elective course (Committee of Ten on Secondary Studies, 1894). This caused a decline in astronomy education that was reversed during the space race in the 1950s. (Marché, 1999) Since then astronomy education has declined, possibly due to a lack of hands-on learning (Sadler, 1992) The last 5 years has seen a further decrease in astronomy education attributed to standardized education, which favors test scores in mathematics and language arts (Krumenaker, 2009a).

Evidence of the Problem from the Professional Literature

The planetarium is the best-suited environment for teaching astronomy concepts (Brazell, 2009; Brazell & Espinoza, 2009). The planetarium education community has progressed from comparing the effectiveness of the planetarium to the effectiveness of the classroom and has moved towards testing effective teaching techniques within the planetarium (Brazell & Espinoza, 2009; Perhoniemi, 2006). This maturing of the industry has allowed researchers the opportunity to test successful planetarium teaching strategies (Plummer, 2011). One such strategy is the coherence principle, part of CTML (Mayer, 2010). Using this principle as a framework to develop effective planetarium instructional techniques, the problem develops into correctly removing extraneous materials used in a planetarium to provide positive learning strategies that maximize the limited time students spend studying astronomy in a planetarium.

According to Mayer (2010) CTML supports the notion that people learn better from pictures and words than words alone. Specifically, the coherence principle postulates that extraneous material should be removed from a lesson in order to maximize learning (Austin, 2009). Interesting, but irrelevant, material that can be removed is referred to as seductive details (Park, Moreno, Seufert, & Brünken, 2011) Examples include salacious pictures or alluring stories, such as pictures or stories of people struck by lightning during a lesson on lightning formation. In this case, the learner may focus finite cognitive energy on the more interesting seductive details and not provide enough cognitive processing to correctly create a mental model about lightning formation (Mayer, 2009). Details like these provide no extra information that aids the student in understanding the main idea of the lesson (Mayer, 2010).

Most studies testing multimedia learning within the context of the coherence principle and seductive details have reported that the inclusion of seductive details harm learning (Bryant, 2010; Lehman et al., 2007; Lusk, 2008; Mayer et al., 2008; McCrudden & Corkill, 2010; Rowland et al., 2008; Rowland-Bryant et al., 2009; Verkoeijen & Tabbers, 2009). These studies share similar common elements, they were all performed on college students, in a controlled laboratory, and testing occurred on a one-to-one basis. Recent speculation has surfaced that perhaps the seductive detail effect does not transfer to an authentic classroom and that the interest generated by the seductive details outweighs any impairment generated (Harskamp, Mayer, & Suhre, 2007; Muller et al., 2008; Towler, 2009; Towler & Kraiger, 2008).

Definitions

Authentic classroom; A learning environment with one instructor and many students where everyday distraction impact comprehension (Muller et al., 2008)

Cognitive theory of multimedia learning (CTML); Theory that people learn better from pictures and words than words alone (Mayer, 2009)

Coherence principle; One of many design principles describing CTML. The coherence principle states that people learn better when irrelevant information is removed from a lesson (Mayer, 2010).

Multimedia; A combination of media used for instruction, including pictures, sounds, video, narration, and text (Clark & Mayer, 2011).

Seductive details; Interesting and irrelevant information contained in a lesson designed to attract the attention of the learner (Park et al., 2011).

Planetarium; A domed theater for viewing stellar formations in the night sky (Perhoniemi, 2006).

Portable inflatable planetarium; A collapsible planetarium designed to be taken directly to the learner, the inside curvature of the dome is achieved by using high-powered fans. (Sumners, Reiff, & Weber, 2008).

Planetarian or planetarium professionals; Anyone responsible for the design, planning, and implementation of a planetarium lesson (Croft, 2008; Small & Plummer, 2010). The term ‘planetarian’ was first used in 1971 by Norman Sperling of the International Society of Planetarium Educators (ISPE), later renamed the International Planetarium Society (IPS; 2013), to address the need for a job title (Marché, 1999).

Significance

The maturation of the planetarium industry has caused researchers to conclude that planetariums are better for astronomy instruction than a classroom (Baxter & Preece, 2000; Brazell, 2009; Brazell & Espinoza, 2009; Dean & Lauck, 1972; Edoff, 1982; Hayward, 1975; Palmer, 2007; Ridky, 1975; Sonntag, 1981; Tuttle, 1966; Twiest, 1989; Wright 1968; Yee, Baer, & Holt, 1971). It is now time to determine what sort of instruction is most effective within the planetarium environment (Perhoniemi, 2006). One possible strategy may be Mayer's (2009) cognitive theory of multimedia learning. Since the planetarium has demonstrated to be the better medium (Brazell, 2009), it is now time to evaluate which sort of instruction best suits the needs of planetarians (Plummer et al., 2011).

Guiding/Research Questions

Two research questions guided this study:

1. Does the cognitive theory of multimedia learning (CTML), when applied to planetarium instruction, improve student learning?
2. Do seductive details have a negative or positive effect, on children's understanding of astronomy concepts, in an authentic classroom environment?

In terms of question 1, *Does the Cognitive Theory of Multimedia Learning (CTML), when applied to planetarium instruction, improve student learning?* CTML was used to explain how people learn in a modern digital society (Mayer, 2009). Using CTML as the theoretical foundation of this research project and adhering to the coherence principle should improve the student's performance in the planetarium (Mayer, 2010).

Research question 2, *Do seductive details have a negative or positive effect, on children's understanding of astronomy concepts, in an authentic classroom environment?* With the establishment of the planetarium in learning institutions, planetarians are seeking methodologies to increase the effectiveness of the teaching material (Brazell, 2009). A criticism of seductive detail studies is that a majority of tests confirming the negative influence of seductive details, known as the seductive detail effect, were performed in a controlled laboratory situation on adult learners (Bryant, 2010; Lehman et al., 2007; Lusk, 2008; Mayer et al., 2008; McCrudden & Corkill, 2010; Rowland et al,, 2008; Rowland-Bryant et al., 2009; Verkoeijen & Tabbers, 2009). It is unclear if these laboratory conditions predict what will occur in authentic classrooms filled with children (Harskamp et al., 2007; Muller et al., 2008).

Review of the Literature

This review of the literature will consist of three sections. First, an overview of multimedia learning will provide a framework for this study. Second, an in-depth portrayal of the coherence principle will be presented along with how seductive details help or harm learning. Finally, a historical analysis will allow understanding of what planetariums are, how they came into being, what instructional strategies work best, and where planetarium development is headed.

Cognitive Theory of Multimedia Learning

Designers of instruction and curriculum have a plethora of options available to them; they can choose to create written material with graphics, instructional videos, computer-based learning, or PowerPoint type lessons. A common theme running through each lesson type is that they are all multimedia instruction. Mayer (2008) defined multimedia instruction as lessons containing words and pictures meant to promote learning. This term is the basis for CTML, a set of design principles meant to provide the maximum learning potential for students. It marries research-based learning theories with evidence-based instruction design principles (Mayer, 2008).

Learning theory. CTML assumes that "people learn better from words and pictures than from words alone" (Mayer, 2009, p. 1). It was founded on the science of learning, which is a change in knowledge based on experience (Mayer, 2008). Learning is comprised of three cognitive processes; (a) selecting relevant material, (b) organizing the material into understandable models, and (c) integrating the material with prior knowledge (Lusk, 2008).

CTML supposes three design elements. First, humans process material using dual-channels (Ozdemir, 2009); humans have one incoming channel for visual information and another for verbal information (Austin, 2009). Secondly, humans have limited capacity for processing information while learning (Mayer et al., 2008). Think of each channel as a pipe. Each pipe has only a certain diameter through which material can pass through. If too much information is pushed through the pipe, the human mind rejects the extra material, and it is never learned. Finally, humans engage in active processing. Active processing depends on the learner's cognitive function (selecting, organizing, and integrating) at the time of learning (Harskamp et al., 2007).

Figure 1 represents CTML. On the left the learner is presented with a multimedia presentation using words and pictures. These words and pictures are initially funneled into the brain using one or both channels, as either pictures or words. Pictures are processed through the visual channel and words can be processed through the auditory or visual channel, depending on whether the words are spoken as sounds or seen as symbols.

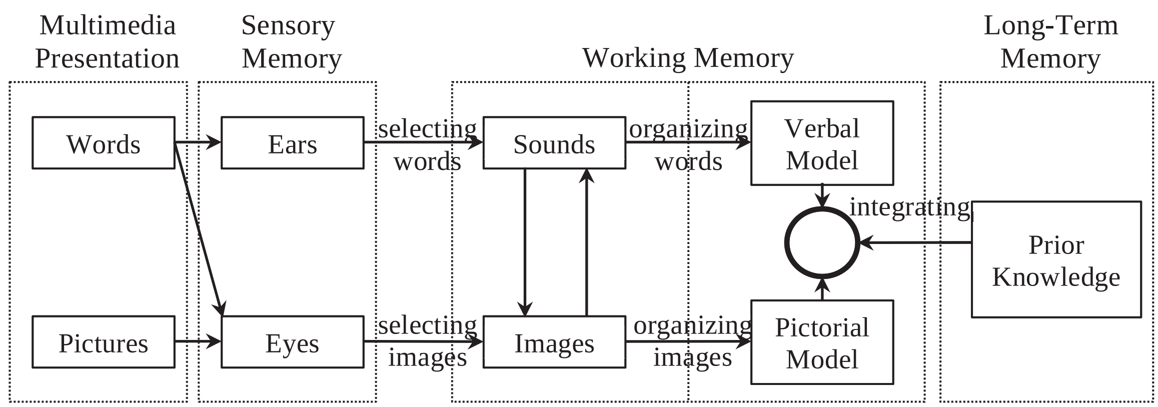

Figure 1 Cognitive theory of multimedia learning (Mayer, 2010)

In the second column the information is imprinted in sensory memory. The auditory channel (ears) handles spoken words and the visual channel (eyes) handles printed words and/or pictures. Meaningful words and images are selected by the learner and passed to working memory.

Working memory tries to organize the information. On the left half of the working memory column the learner may select some sounds for further processing in the auditory channel and some images for further processing in the visual channel. At this point some printed words may be converted into spoken text. According to CTML, each channel has a limited capacity for processing; but information may simultaneously pass through both channels, which is why CTML postulates that people learn best through pictures and words as opposed to words alone. Spoken words can jam the auditory channel, but related information, in the form of pictures, can simultaneously enter through the visual channel.

On the right side of the working memory column the learner organizes the words and pictures into either a verbal or pictorial model. At this point prior knowledge is integrated with the existing models and the learning is stored in long-term memory.

Instructional design. Mayer (2010) defined instruction as an instructor's intentional manipulation of the learning environment to change the learner's knowledge. Prior to instruction being delivered the instructor has an objective. This objective is a clear description of the intended learning outcome (Mayer, 2008). After the learning has taken place the outcome (tests) measure the learner's change in knowledge due to the instruction (Mayer, 2009).

Two methods of testing common in multimedia instruction are retention and transfer tests (Mayer, 2010). Retention tests are referred to as recall exams, in other words, what the learner can remember from the instruction. Most recall exams common in CTML testing involve asking the learner to write down, from memory, everything they can remember. Transfer tests ask the learner to apply what they have learned towards a new scenario.

In order for instruction to be effective it needs to fulfill three goals to reduce cognitive load (Harskamp et al., 2007). Cognitive load is the stress, placed on the learner, to acquire the new knowledge and is limited by the available resources (Lusk, 2008). First, the instruction needs to reduce extraneous processing (Mayer et al., 2008). Any extra processing within the human mind does not aid in the creation of mental models. Focusing on the relevant material provides less crowding of the dual channels involved in cognitive processing. Second, essential processing (the main concepts being taught) needs to be managed effectively and presented with successful strategies (Park et al., 2011). The greater number of elements that need to be learned in a lesson, the higher the essential cognitive load. Finally, generative processing needs to be encouraged. Generative processing is the mind's ability to make sense, organize, and integrate new material [schema acquisition] (Harskamp et al., 2007). Generative processing, sometimes referred to as germane processing, is influenced by presentation design and focuses the learner to create mental models of the material (Lusk, 2008).

According to CTML, extraneous processing is reduced by five design principles (Mayer, 2009). The coherence principle recommends excluding extraneous details from the material (Mayer et al., 2008). The signaling principle advocates highlighting essential material (Ozcelik, Arslan-Ari, Cagiltay, 2009). The redundancy principle suggests adding on-screen text to narrated animation (Mayer & Johnson, 2008). This principle maximizes both the visual and auditory channel, allowing similar material to be processed redundantly. The spatial contiguity principle dictates that printed text be placed adjacent to any corresponding images (Johnson & Mayer, 2012). Finally, the temporal contiguity principle requires that narration and animation be presented simultaneously (Schüler, Scheiter, Rummer, & Gerjets, 2012).

Essential processing is managed by segmenting, pre-training, and the modality principle (Mayer, 2010). Segmenting is a design principle where the learner controls the pace of the learning segments (Florax & Ploetzner, 2010). It is the learner who chooses when to continue based on their cognitive processing. Pre-training is achieved when the instructor presents the absolute essential material (typically in an outline format) prior to the planned instructions (Nelson & Erlandson, 2008). The modality principle presents text as spoken words rather than printed words, again shifting processing to the auditory channel instead of relying solely on the visual channel (Austin, 2009).

To assist in the creation of correct mental models, generative processing is fostered by the multimedia principle and the personalization principle (Mayer, 2010). The multimedia principle suggests that words and pictures be presented instead of words alone, maximizing the dual channel concept (Evans & Gibbons, 2007). Personalization principle suggests than spoken words are presented in conversation style as opposed to a formal style (Katal, 2010).

Coherence Principle

The coherence principle states that all unnecessary material should be excluded in order to decrease demands on cognitive functioning in multimedia lessons (Mueller et al., 2008). This unnecessary material is referred to as seductive details. An example of seductive details is the inclusion of unnecessary music played while a lesson is being taught. According to the coherence principle the music causes a tax on the auditory channel and impairs other information trying to enter the brain (Mayer, 2009). Limited cognitive functions are diverted to comprehend the music. This leaves less cognitive ability to grasp the intended lesson. The term ‘seductive detail’ was first defined by Garner et al. (1989). Seductive details refer to irrelevant details that remain interesting, but unimportant (Garner et al., 1989). Park et al. (2011) defined seductive details as interesting material that provides added information that is irrelevant to the learning goals.

Most studies report that adding seductive details to a lesson decreases the amount of learning achieved by the student (Bryant, 2010; Lehman et al., 2007; Lusk, 2008;

Mayer et al., 2008; McCrudden & Corkill, 2010; Rowland et al., 2008; Rowland-Bryant et al., 2009; Verkoeijen & Tabbers, 2009). Garner et al. (1989) performed some of the first research on seductive details. Adults and children were given text with and without seductive details inserted in the narrative. Based on the results of their study Garner et al. (1989) found that seductive details disrupted and interfered with the processing of the main idea of the text.

Argument for adding seductive details. The foremost theory for including seductive details in educational text is the arousal theory (Mayer, 2009). Arousal theory (Weiner, 1990, 1992) is the notion that students learn best by being emotionally interested in the learning material. This higher level of interest should translate into better attention and reward the learner with a better understanding of the material (McCrudden & Corkill, 2010). Arousal theory is based on the model of knowledge transition; information is transferred from the teacher to the student, whereas CTML is based on the belief of knowledge construction; the students actively build the knowledge base in their own minds (Mayer, 2009).

Argument for excluding seductive details. On the contrary, it is believed that seductive details harm learning in three ways. First, seductive details divert the learner's attention away from the learning goal and cause increased attention to be spent on the seductive details (Mayer, 2009). The learner focuses on the seductive details at the expense of the learning goal. Within a lesson, seductive details appear as interesting factoids designed to catch the attention of the student and possibly increase learning. A classic example of seductive details in multimedia learning involves the teaching of lightning formation (McCruden et al., 2010). To increase the significance of a lesson on lightning formation an instructor may decide to insert stimulating stories of people struck by lightning. These exciting stories of personal experience with lightning strikes, based on research, tend to draw the learner's attention away and leave less cognitive ability to focus on the true goal of learning lightning formation (Rowland-Bryant et al., 2008). There is some evidence that if these seductive details are to be placed in a lesson, they should be placed at the end of the material, after the learning has occurred (Verkoeijen & Tabbers, 2009). This sort of harm is described as the reduced attention hypothesis; the learners ignore the learning goal and use their available attention to process seductive details (Lehman et al., 2007).

Second, seductive details disrupt the creation of mental models based on the learning goal (Ozdemir, 2009). Seductive details may insert themselves incorrectly into cause-and-effect chains (Mayer, 2009). Lightning formation is based upon a prescribed number of steps. Using the lightning formation lesson spiced up with personal narratives, the reader incorrectly inserts the stories of personal experience of strikes in the steps of lighting formation, thereby disrupting the true learning goal; which is the cause-and-effect chain of lightning formation (Mayer, 2009). This disruption in formation of a correct mental model is known as the coherence break hypothesis; seductive details break comprehension and interfere with the learner's ability to construct accurate mental models of the learning goal (Lehman et al., 2007).

Third, the learner may incorrectly assume that the seductive details are the learning goals and construct their mental model around the seductive details, at the expense of the true learning goal (Mayer, 2009). Using the lightning example again, the reader constructs framework around personal stories of lightning strikes and not on lightning formation (Mayer, 2009). This is referred to as the inappropriate schema hypothesis; the mental model is created around the seductive details and not the learning goal (Lehman et al., 2007).

Basis of the seductive detail effect. Harp and Mayer (1998) performed one of the earliest studies to determine what is the cause of the seductive detail effect. The authors framed the study with three hypotheses; (a) distortion hypothesis – reader's attention is pulled to the seductive details rather than to the main ideas, (b) disruption hypothesis – readers are unable to create meaningful models based on the main idea, and (c) diversion hypothesis – inappropriate prior knowledge is integrated with new information to create flawed mental models. Harp and Mayer (1998) used four experiments testing undergraduate students; each experiment included a base passage, a base passage plus seductive detail, and base passage plus treatment to offset the seductive details. Recall was tested with free response answers explaining what was learned, and free response transfer questions designed to test if new knowledge could be applied to new scenarios (Harp & Mayer, 1998).

Harp and Mayer's (1998) first experiment (n = 81) used bold, italicized text to guide learning. Bold and italicized text did not help students retain or transfer information and it did not counter the seductive detail effect (Harp & Mayer, 1998). Experiment 2 (n = 83) informed students of the learning objective prior to reading the passages. Prior knowledge of the learning objective did assist students in recall and transfer of the knowledge, but the seductive detail still caused poorer recall and transfer results (Harp & Mayer, 1998). Experiment 3 (n = 96) used signaling (outlines) to produce better recall and transfer results. Outlines did provide higher recall and transfer results, but did not overcome the seductive detail effect (Harp & Mayer, 1998). Experiment 4 (*n* = 97) placed seductive details at the beginning, interspersed, or at the end of a passage. Placing the seductive details at the beginning caused the students to use the seductive detail as the organization structure of the material, interspersing the seductive details caused students to suffer on recall and transfer, and placing seductive details at the end of the passage caused similar scores as students who had no seductive details in their passage (Harp & Mayer, 1998).

Harp and Mayer (1998) reported that this study provided no support for the distraction and disruption hypothesis. However, the study did support the diversion hypothesis, by activating inappropriate prior knowledge and creating an incorrect model. According to Harp and Mayer (1998) seductive details should be placed at the end of a passage or not be included at all.

Discrepancies with the seductive detail effect. Studies confirming the coherence principle (seductive details harm learning) share two important facts; they were all implemented in a laboratory setting with tightly controlled variables (Bryant, 2010; Lehman et al., 2007; Lusk, 2008; Mayer et al., 2008; McCrudden & Corkill, 2010; Rowland et al., 2008; Rowland-Bryant et al., 2009; Verkoeijen & Tabbers, 2009) and they were performed on college-aged, adult learners (McTigue, 2009). There is debate that the seductive detail effect does not replicate into authentic K-12 learning environments (Harskamp et al., 2007; Issa et al, 2011; Muller et al., 2008).

An additional concern with the legitimacy of the seductive detail effect in an authentic learning environment is how recall is tested (Harskamp et al., 2007).

Laboratory testing of seductive details have relied on testing recall by prompting the participants to write as much as they can remember about the tested lesson on a blank sheet of paper (Bryant, 2010; Lehman et al., 2007; Lusk, 2008; Mayer et al., 2008; McCrudden & Corkill, 2010; Rowland et al., 2008; Rowland-Bryant et al., 2009; Verkoeijen & Tabbers, 2009). Perhaps it is too ambiguous to require students to recall a lesson without structure. Prompting, as used with multiple-choice questions, may be a better measure of recall (Towler, 2009).

Towler and Kraiger (2008) approached recall testing from a different perspective. They chose to replicate testing of an authentic classroom by using multiple-choice type questions. A study sponsored by the US Army to determine if seductive details had an effect on recognition and transfer skills performed three separate experiments. Towler and Kraiger (2008) proposed two opposing hypotheses to frame their research. The first hypothesis stated that removing seductive details would improve learning on declarative knowledge tests [recall test using multiple choice answers] (Towler & Kraiger, 2008). The second hypothesis stated that including seductive details would improve learning on transfer tests (Towler & Kraiger, 2008). In this case, Towler and Kraiger (2008) refer to transfer as skills rather than knowledge. Experiments were based on training participants in the use of Microsoft Excel (Experiment 1) and Microsoft Word Mail Merge (Experiment 2). Participants were randomly assigned to groups which included/excluded seductive details.

In Experiment 1 and 2, there was no reported negative effects of seductive details on recognition using multiple-choice questions. Particularly in experiment one, prior experience with Microsoft Excel proved a more significant positive indicator in regards to recognition. Participants who were exposed to seductive details had no significant effect on recognition. A positive effect was reported with transfer tasks involving skills. Transfer performance improved when a group was exposed to seductive details. In a third experiment, separate from the Microsoft studies, Tower and Kraiger (2008) replicated Harp and Mayer's (1998) lightning formation study and produced results in favor of excluding seductive details.

The contrary results of this study may have been caused by a difference in the type of material learned. Prior studies focused on learning new knowledge while this study used skills that participants intend to use. Additionally, previous studies used recall (open-ended timed tests) as the measure of learning as opposed to recognition tests (multiple choice). Recall tests and recognition tests may be processed differently. Towler and Kraiger (2008) proposed that seductive details do not harm learning when tested by recognition because cognitive processes may be fast enough to negate schema formation. Seductive details may also cause a negative effect on learning at the point of organizing and storing of information and not at the point of remembering it.

Towler (2009) revisited the seductive detail effect with a study using trainer expressiveness (animated and approachable) and trainee mastery orientation (motivation to learn the material and apply it to the job) with seductive details to determine the optimal conditions in order to recall and transfer information learned at training seminars. Towler (2009) hypothesized that highly motivated learners will increase their problem solving skills with material learned in a training seminar when they are exposed to expressive trainers and seductive details. Participants (n = 132) were assigned to one of four groups, either with an expressive or nonexpressive lecturer or with seductive or nonseductive details. Trainees who experienced lectures with seductive details and expressive trainers performed better on problem solving written tests (Towler, 2009). Motivated trainees who were exposed to expressive/nonseductive details recalled the most information (Towler, 2009). Towler (2009) found that the conditions that benefit transfer (problem solving) are not the same conditions that benefit recall. According to these results, critical thinking skills (problem solving) are supported by the inclusion of seductive details (contrary to CTML), while rote memorization (recall) is encouraged most by the omission of seductive details (in agreement with CTML).

Park et al. (2011) completed an investigation to determine the relationship between seductive details and cognitive load. Park et al. (2011) performed a 2x2 experiment (simultaneously tests two independent variables) with high school students (*n*=100) learning biology; in this case onscreen text/narration with and without seductive details, for a total of four experimental design groups. Most seductive detail experiments test text passages or seductive illustrations. This experiment tested high cognitive load processing (seductive details with onscreen text) and low cognitive load functioning (seductive details with narration). Park et al. (2011) hypothesized that seductive details will impair the learning with onscreen text, but not narration. Accordingly, learning increased with seductive details and narration, but not with onscreen text. Seductive details, along with narration and prior knowledge, increased the students' engagement with the material and produced a learning benefit.

Ozdemir (2009) initiated testing to determine if recall and transfer skills are affected by seductive details. In experiment 1, Ozdemir (2009) used lightning animation to identify context-dependent (details that are more interesting if the subject knows the topic) and context-independent (details that are equally interesting to a subject that does not know the material). With experiment 2 ($n = 184$), Ozdemir (2009) used context-dependent seductive details to test recall and transfer of undergraduate students. Group 1 watched animation without any seductive details, group 2 watched animation with context-dependent seductive details, group 3 watched animation with context-independent seductive details, and group 4 watched animation with both types of seductive details (Ozdemir, 2009). According to Ozdemir (2009), context-dependent seductive details (group 2) produce no significant effect on recall and transfer. Ozdemir's (2009) findings share a similarity with Park et al. (2011) in that prior knowledge had a slight effect on mitigating any seductive detail effect, however in this study seductive details did not assist learning, they merely caused no harm.

Lusk (2008) performed an investigation to see if seductive details and/or segmentation (breaking the material into smaller chunks and allowing the learner to progress at a self-controlled pace) had any effect on interest, recall, or transfer scores. The participants consisted of 167 undergraduate students randomly assigned to one of four groups (seductive detail/segmentation, no seductive detail/segmentation, seductive detail/no segmentation, and no seductive detail/no segmentation).

Interest, recall, and transfer tests were administered after the treatment. Lusk (2008) found no relationship between the groups regarding interest, recall, and transfer. The results did not provide support for existing literature on seductive details and segmentation. The seductive details did not provide any harm to the learner. It should be noted they did not provide any assistance either, calling into question again if seductive details should/should not be included.

Coherence principle summary. CTML forms the umbrella for twelve principles of designing instruction for multimedia education (Mayer, 2008). One of these principles is named coherence (Mayer, 2010); which states that people learn better when unnecessary information is omitted from instructional design (Austin, 2009). This needless material is referred to as seductive details (Lusk, 2008). Seductive details may take the form of graphic narratives of people struck by lightning, while teaching a lesson about lightning formation (Mayer, 2009), or anecdotal stories involving sexual harassment (Towler, 2009). According to CTML the brain will use its limited cognitive resources and focus on the more interesting seductive details at the expense of learning lightning formation, the true learning goal, commonly referred to as the seductive detail effect (Mayer et al., 2008).

The criticism for the seductive detail effect centers on how the majority of the seductive details experiments were performed. Most studies confirming the seductive detail effect were performed on undergraduate students, in a controlled lab (one-on-one testing), and tested recall and transfer using open-ended questions (Bryant, 2010; Lehman et al., 2007; Lusk, 2008; Mayer et al., 2008; McCrudden & Corkill, 2010; Rowland et al., 2008; Rowland-Bryant et al., 2009; Verkoeijen & Tabbers, 2009). Studies that showed seductive detail helped learning were either performed in authentic classrooms [one teacher/many students] (Park et al., 2011) or where the interest generated from the seductive details provided further benefits and outweighed any seductive detail effect (Lusk, 2008; Muller et al., 2008; Ozdemir, 2009). Additional studies found benefit in using multiple-choice style or fill-in-the-blank questions to test recall, as opposed to open-ended questions (Towler, 2009; Towler & Kraiger, 2008).

History of the Planetarium

Before any explanation of planetarium research can be given it is helpful to define what a planetarium actually is. A planetarium is a circular, domed theater using projection equipment to created simulated astronomical events (stars) on the ceiling of the dome (Perhoniemi, 2006). Croft (2008) defined a planetarium as a place where individuals would be inspired to learn more about the cosmos. Croft (2008) states that a planetarium must; (a) be an immersive dome, (b) incorporate music, (c) take the audience on a journey, (d) include live presentations, and (e) be a peaceful, relaxed environment. Peterson (2003) defines a planetarium as a theater that projects the relative motion and position of the objects in the sky.

Early astronomy instruction. Prior to the invention of the planetarium most astronomy instruction was performed with either a textbook or telescopes (Maraché, 1999). Astronomy was prized as a field of study because of the mental disciple that was required to visualize astronomical phenomenon and the time required studying with a telescope, often in the late, cold night (Marchè, 2002). During the late 1800s college entrance requirements depended on the specific institution. The National Education Association (NEA) set about standardizing the requirements across the country (Bishop, 2003).

It was decided that science requirements for colleges would consist of biology, chemistry, and physics. Astronomy was relegated to an elective course, causing many high schools to drop astronomy from its course offerings (Marchè, 2002). This led to an overall decline in astronomy interest and knowledge in the United States. Bishop (2003) called the first half of the twentieth century the ‘dark ages’ of astronomy education.

Interest resumed during the 1930s with a new invention, from Europe, which replicated the night sky in a domed theater - the planetarium (Maraché, 1999). National attention towards astronomy reached an all time high when the Soviet Union launched Sputnik in 1957 (Krumenaker, 2009b). President Eisenhower asked school boards across the county to look at the education requirements of Soviet era teens and determine if the United States was falling behind in this new ‘Space Race’. It was found that Russian graduates from high school spent almost 40% of their time on math and science, which included an entire year devoted to the study of astronomy (Bishop, 2003). Education reform in the United States poured millions of dollars into improving science curriculum. This caused a greater national interest in astronomy, as US citizens participated in the new ‘Space Race’ (Maraché, 1999).

The planetarium. Humans have been modeling the night sky long before recoded history began (Peterson, 2003). History is full of physical depictions of celestial motion – diagraming the three-dimensional sky onto a map or globe. Anaximander, of ancient Greece, is perhaps credited as being the first to portray the night sky with models (Couprie, 2011). Archimedes created a globe with a sky map overlay, in the third century BC, which had moving parts depicting planetary movements. Eratosthenes, famous for calculating the circumference of the Earth, built an armillary sphere - an inverted globe or bowl depicting the night sky. During the Middle Ages, in an effort to accurately map the night sky, inventors built astronomical clocks, known as astrariums, and models of planetary movement, known as orreries (Peterson, 2003).

The earliest known planetarium is considered the Gottorp globe, built in the 17th century (Peterson, 2003). This wooden dome had holes drilled in it to represent stars and used exterior light to produce the effect of twinkling stars. E. Hindermann of Switzerland in 1912, built the Orbitosope, which used movable orbs and a light bulb to represent the planets and our Sun (Peterson, 2003). In 1913 the Museum of Chicago Academy of Sciences commissioned the Atwood globe, which included moveable light bulbs along with the stars depicted (Peterson, 2003).

The first modern planetarium projector was designed and built at the Carl Zeiss optical company of Jena, Germany by Walter Bauersfeld in 1919 (Howe, 2011). Over the next several years this projector was refined to project 4,500 stars accurately onto a domed ceiling. In 1923 the Zeiss Mark 1 projector was unveiled using multiple projectors held on a central sphere (Lantz, 2011). Each individual projector used plates to accurately model the size and luminosity of individual stars. With each succeeding generation of projectors the Zeiss model continued to refine and improve the projected image (Peterson, 2003).

The following year saw the first permanent installation of the Zeiss projector in a newly built ten-meter dome in the Deutsches Museum of Munich, Germany (Deutsches Museum, 2012). News of this new invention spread throughout Europe and the United States and was seen a spectacular educational tool for astronomy instruction (Marchè, 1999). Officials from the American Museum of Natural History, New York traveled to the Deutsches Museum in 1925 to visit this new apparatus, known as the ‘Wonder of Jena’ (Marchè, 1999).

The large cost associated with Zeiss projectors meant that only a relative few institutions could afford to build and operate a planetarium (Howe, 2011). In the 1930s the first seven planetariums were built in the United States (Marchè, 1999). Planetariums in Chicago, Philadelphia, Los Angeles, New York, and Pittsburgh used the Zeiss Mark 2 as their planetarium projector. Two of these planetariums, New York and Philadelphia, came into being due to associations with existing institutions, New York City's American Museum of Natural History and Philadelphia's Franklin Institute respectively. Chicago's Adler Planetarium, Los Angeles' Griffith Observatory, and Pittsburgh's Buhl Planetarium became independent operations administered by city governments (Marchè, 1999).

Post World War II events caused the break-up of the Carl Zeiss firm into two separate companies. One located in West Germany, supplying optical components to the West, and the other located in East Germany, supplying optics to Soviet Bloc countries. The Zeiss firm was later reunited in 1990 (Carl Zeiss International, 2012). This disruption allowed competing firms, namely Spitz, Inc., to capitalize on consumer demand of planetarium projection equipment (Marchè, 1999).

During the 1940s and 50s two events occurred that drastically increased the number of planetariums in the United States. First, Armand Spitz developed a cheaper alternative to the expensive Zeiss projectors (Howe, 2011). Using a metal cylinder, proportionally sized holes, and a compact light source, Spitz was able to create a mass produced pin-hole projector at a drastically reduced price (Brazell, 2009). Secondly the launch of the Soviet Union's Sputnik caused concerns in the US government that we were not spending enough money on science and mathematical instruction. Funds were made available, at an unprecedented scale, to improve and advance education. The National Defense Education Act of 1958 (NDEA) allowed money to be spent on new equipment and/or retrofitting of facilities. School districts around the country responded with the creation of small planetariums at an explosive rate. This federal aid, combined with affordable projectors, led to a rebirth of astronomy education.

The space race of the 1960s spurred public interest in astronomy and provided an audience for these newly built planetariums (Howe, 2011; Lantz, 2011). As audiences became more familiar with planetarium productions, interest began to wane. In order to increase attendance and boost profits, planetarium directors developed more dazzling shows. Slide projectors were incorporated to display astronomical images, music was added and cues were timed to coincide with tempo changes (Brazell, 2009).

The next major advancement in planetarium development occurred in 1983 when the company of Evans & Sutherland introduced the first digital planetarium projector, named the Digistar 1 (Evans & Sutherland, 2012; Lantz, 2011). As the projectors continued to improve in quality and decrease in price, digital projectors became an increasingly relevant option for installation and/or retrofitting. Full-dome immersive projection allows for true 360-degree projection of images and video, greatly enhancing the ability to convey scientific concepts (Lantz, 2011). Optical projectors can only depict the night sky from an Earth-based perspective, while digital projectors use a computerized star catalog and are able to simulate the cosmos from any conceivable angle (Howe, 2011).

With a greatly reduced price of projection, introduced by Spitz, a new market was developed with portable planetariums. Star Lab introduced the first inflatable planetarium in 1977 (Star Lab, 2012). This inflatable planetarium used air blowers to inflate an igloo type dome, thus providing the curved sphere necessary for proper projection. As time and advancement continued, digital projection was also incorporated into portable planetariums and Digitalis become the first all digital portable planetarium manufacturer (Digitalis Education Solutions, 2012).

An increasingly complex system of presentation and improved efficiency of automation led to the decline of live interactive programing, in favor of push-button, scripted shows (Lantz, 2011). An increase in sophistication leads to an increase in production expenses; many planetariums would rather automate the process and hire technicians to run a produced show rather than employ an astronomer to use the planetarium and provide ‘star talks’ (Bishop, 2003; Lantz, 2011). There has been a push in recent years to return to the format of live interaction and distinguish the planetarium from a movie theater (Live Interactive Planetarium Symposium, 2012). Plummer (2011) points out the many benefits of live interaction with an audience include increased motivation to learn and improved understanding of celestial motion.

The future of planetariums involves an improvement of the visitor’s experience, when the lights dim the audience needs to forget they are in a theater (Lantz, 2011). To accomplish this planetariums need to include higher frame rates of projection, advanced spatialized audio, increased brightness of stars, improved black levels, and better star-point resolution (Howe, 2011; Lantz, 2011). An obvious compromise may lie in the combination of optical and digital projectors, a blending of the best star simulations [optical] and a hyper accurate database of the known universe [digital] (Howe, 2011).

The primary objective of this project is the blending of CTML, specifically the coherence principle with planetarium education. As the planetarium education community has developed, it is no longer necessary to evaluate the performance of classroom instruction compared to planetarium instruction; according to Brazell (2009) the planetarium is generally the better environment for teaching astronomy. With this as the theoretical foundation, the remainder of this literature review will focus on what teaching strategies have been tested and evaluated for use within a planetarium.

Teaching strategies within the planetarium. A dramatic rise of school-site planetariums prompted researchers to determine if the planetarium provided a better environment for teaching astronomy than a classroom. The research supplied multiple answers, with contradicting results as to which environment (classroom vs. planetarium) delivered a significant advantage (Brazell & Espinoza, 2009). Some studies showed that the planetarium provided a benefit (Dean & Lauch, 1972; Larsen & Bednarski, 2011; Palmer, 2007; Wright 1968; Yu & Sahami, 2007), while others contributed evidence that the classroom was a superior instructional environment (Reed 1970a; Smith 1966).

According to Brazell and Espinoza (2009), who performed a meta-analysis of 19 planetarium studies ranging from 1966 to 2007, planetariums have a positive effect on student learning, specifically from kindergarten to twelfth grade, and are generally the preferred environment. Their analysis determined that eleven studies favored the planetarium (Baxter & Preece, 2000; Dean & Lauck, 1972; Edoff, 1982; Hayward, 1975; Palmer, 2007; Ridky, 1975; Sonntag, 1981; Tuttle, 1966; Twiest, 1989; Wright 1968; Yee et al., 1971), six preferred the classroom (Pitluga, 1971; Reed, 1970a; Reed, 1970b; Reed 1973; Reed & Campbell, 1972; Smith, 1966), and two determined the planetarium and classroom as equal in effectiveness (Rosemergy, 1968; Sunal 1972).

As an interesting side note, Reed (1970b) expressed a possible unfair advantage of the classroom over the planetarium in the similarity of chalkboard diagrams to classroom assessments (Marchè, 1999). Brazell and Espinoza (2009) also concluded that the planetarium provided better observational astronomy instruction (what one sees in the night sky), but the classroom provided a more familiar environment to ask questions. Using this data to frame this particular study, the planetarium is therefore the favored environment in which to perform astronomical educational studies.

Before going into detail about what strategies work in a planetarium, it would be constructive to ask planetarians (individuals responsible for a planetarium experience) what is important to a successful planetarium visit. Small and Plummer (2010) reported that planetarians believe that most experiences in a planetarium are passive and that most planetarians attempt to engage and educate their audiences. Planetarians believe that well constructed, interactive experiences will be well received by the audience. Croft (2008) reported that planetarians feel that planetariums should be a place where big questions can be posed to cause the audience to think and ask about their place in the universe.

Since the mass introduction and development of planetariums in schools, especially in Pennsylvania which led the nation in NDEA assistance funding and became a federal model of educational reform (Marchè, 1999), it is beneficial to know the perspective of teachers in regards to astronomy education. Plummer and Zahm (2010) used an online survey to determine what educators felt about astronomy education and how it is covered in middle and high school. Their survey found that most astronomy instruction is fragmented across multiple grade levels, emphasized more in middle school, and unstructured in content delivery. Results such as these point to an undisciplined astronomy curriculum that needs support and guidance from a national level.

From Brazell and Esponoza's (2009) study came the recommendation that planetarium research should not focus on which environment is superior, but rather what instructional techniques provide the best learning outcome. A review of the recent literature reports that successful strategies in a planetarium include; (a) multimedia learning theories, (b) active audience participation, (c) use of multiple learning modalities, (d) misconception correction, (e) inquiry, (f) moving frames of reference, and (g) audience lead programs.

Multimedia learning theories. In an attempt to increase retention of material learned in the planetarium, Fisher (1997) inserted humor related to pop culture every ninety seconds during a fifteen-minute planetarium lesson. The prediction was that humor would relax the participants and provide greater recall of the material. Participants who did not experience the humor scored higher than those that did. In fact, the humor acted as a distraction and prevented the subjects from learning the material. The humor represented a seductive detail, interesting but irrelevant material that did indeed harm the learning goal (Bryant, 2010).

Muller et al. (2008) performed a study testing 104 students in late high school and early college with online learning of astronomy concepts. The authors wished to test an authentic learning environment with the coherence principle, removing the study from a tightly controlled lab. By doing so they were testing if the coherence principle (specifically seductive details) becomes a factor when student interests and attention are included in the study design. Students were assigned an online multimedia astronomy presentation with seductive details. The seductive details consisted of interviews with professional astronomers. Students were not monitored, as with most studies, and all learning took place at home with a computer. At the conclusion of the study students were tested according to what they learned and, based on the results, the group with the seductive details scored comparably to the group without the seductive details. In other words, the coherence principle did not generalize to authentic settings. Muller et al. (2008) theorized that the increased cognitive load experienced by the additional seductive details might have been offset by the increased attention of the interesting seductive detail. In addition, the material may have been below the cognitive capacity of the students.

Teaching astronomy with technology is now so common that a set of guidelines is necessary in order to maximize the amount of learning achieved (Mayer, 2009). Miller and James (2011) applied CTML to the use of PowerPoint slides in the teaching of Introductory Astronomy. The PowerPoint slides were well organized, concise, and designed as to not overload cognitive functioning (Miller & James, 2011) in accordance to CTML, which suggests that lessons need to be consistent with the dual-channel assumption, not stress a student's cognitive load, and allow for active processing (Mayer, 2008). Miller and James (2011) reported no significant increase in learning from slides designed to adhere to CTML, other than students favoring those slides. This is in stark contrast to the predictions that CTML makes about learning. Perhaps CTML theories apply better in laboratory setting and do not translate well to authentic classrooms. A better use of a student's time in a planetarium might be physical involvement in the lesson.

Active participation. Physically engaging the audience with the planetarium lesson was attempted by Platco (2005) and Plummer (2009). Both studies wanted to use participation in order to increase the amount of material learned in the lesson. Platco (2005) found that participatory oriented planetarium (POP) lessons provided more retention of the material compared to a recorded planetarium show. However, the recorded show proved the better use of time for learning new material in the planetarium.

Plummer (2009) actively moved the students with body gestures (kinesiology) to trace the movement of the Sun, Moon, and stars. These arm gestures, designed to teach celestial motion, worked best when teaching apparent motion of the Sun and Moon due to Earth’s rotation, but provide the least improvement in retention of seasons and motion of the stars. Active participation seems to offer some improvement to planetarium instruction, but only in specific circumstances. These findings offer additional strategies for use within the planetarium; perhaps involving the senses would provide additional benefits and assist learning.

Multiple modalities. Involving the use of more than one of the five senses was the recommendation of Sumner, Reiff, and Weber (2008). They found that learning increased in a planetarium when students were able to hear, see, discuss, and experience the lesson. Sumner et al., (2008) concluded with Platco (2005) and Plummer (2009) that interaction is key to a planetarium lesson. Pausing the planetarium show for discussion and/or distribute manipulatives provided a more meaningful experience (Sumner et al., 2008). These pauses may assist the students in creating correct mental models, but how can the planetarium correct flawed mental models?

Misconception correction. Conceptual change learning theories attempt to construct knowledge from students’ incorrect naive misconceptions (Vosniadou, 2007). Sarrazine (2005) tackled planetarium instruction by teaching misconceptions within the framework of multiple intelligences. By doing so Sarrazine (2005) hoped to correct middle school students' misconceptions of the Moon's composition, luminosity, and phases. A single visit to a planetarium proved successful in correcting these misconceptions; unfortunately the same misconceptions could be corrected with classroom activities (Sarrazine, 2005), adding to the debate that the planetarium offers no significant advantage to properly planned classroom instruction.

In order to create an environment of conceptual change, students need to be dissatisfied with their own model that they have incorrectly constructed and be actively seeking a replacement model (Zhou, 2010). Trundle and Bell (2010) used astronomical simulation software (Starry Night) to correct misconceptions pre-service teachers have about the Moon's phases. In contrast to Sarrazine's (2005) findings that classroom instruction was equivalent to planetarium instruction, Trundle and Bell (2005) found that computer simulations were more effective than direct observation, and/or classroom activities.

The computer simulations provided an opportunity for students to manipulate the phases in ways that direct observation and classroom activities could not (Trundle & Bell, 2010). The findings of Sarrazine (2005) and Trundle and Bell (2010) point to a possible successful learning environment where students are able to work independently in a planetarium and use real-time software to manipulate astronomical sittings. This provides a change in setting on how astronomy is typically taught with the teacher presenting information as the 'expert'. The planetarium, along with astronomy software, can be used as a lab where students are able to explore their misconception and facilitate changes. These findings support the use of the planetarium over the use of a classroom.

Building on the theme of knowledge construction, Palmer (2007) observed that since the invention of central air conditioning and heating, combined with the use of indoor lighting, students are less apt to know the night sky. Using the planetarium to create experiences that construct knowledge and ‘unlearn’ misconceptions, Palmer (2007) found that a visit to a planetarium, in conjunction with classroom instruction, proved to be a superior learning experience than classroom instruction alone. Due to an indoor lifestyle, students need planetarium instruction in order to understand the movements of celestial objects (Palmer, 2007). While this study demonstrates the importance of planetarium instruction it also agrees with prior studies (Brazell, 2009), which demonstrate the value of classroom instruction. Brazell (2009) concluded that the planetarium environment intimidates students and the classroom offers a better medium for asking questions. Perhaps the planetarium should be used to create an environment where these questions could be answered?

Inquiry. Hobson, Trundle, and Sackes (2010) also used Starry Night to simulate the phases of the Moon in order to allow students the opportunity to gather observational data and answer their own questions about the cosmos. The simulations proved as effective as observations in nature. A real value of simulations and planetariums is the ability to speed up time and make multiple observations in minutes that would normally take days (Trundle & Bell, 2010). Further explorations to create an appropriate view of the heavens includes using data from multiple sources to develop one cohesive understanding of celestial motion (Hobson et al., 2010).

Moving between frames of reference. A fundamental skill needed in order to understand and visualize astronomical concepts is the ability to comprehend one frame of reference and simultaneously apply that knowledge to an alternate frame of reference while still understanding what those frames of reference describe (Plummer et al., 2011). An example of this would be to observe the movements of the Sun and the movements of the stars (entirely difference sets of motion) and tying these two independent sets of motion into one complete picture. Plummer et al., (2011) reported that once students mastered that skill, astronomical understanding became obtainable. According to Plummer et al. (2011) most students who participated in their planetarium activities acquired the skills to move between multiple frames of reference to understand the larger picture of astronomical motion. The next juncture of increasing sophistication would be to let the audience dictate what the planetarium lesson should be about. Thankfully, with modern computers real-time simulations are now possible.

Audience lead programs. Modern digital fulldome planetariums have benefited from the use of computers to the point that real-time rendering software allows the audience to dictate what the program will be about. Yo et al. (2011) studied the use of immersive virtual reality software presenting global change lectures to the general public. While a departure from astronomical shows, the use of a planetarium for other topics highlights the flexibility that digital planetariums present. These lectures are planned in advance, but because of the use of real-time rendering software there is flexibility as to where the discussions may lead. Public education combined with a fulldome immersive planetarium added value to the intended lectures (Yo et al., 2011).

These strategies used within the planetarium highlight the maturity of planetarium education research and demonstrate how the research has progressed from classroom versus planetarium studies to studies identifying specific instructional techniques within the planetarium. This research project will add to this list of tested instructional techniques used for planetarium instruction by testing the use of seductive details, part of the coherence principle of CTML, in a planetarium lesson.

Teaching strategies within a planetarium started as studies testing what approaches worked in a planetarium and evolved into increasing level of sophistication. Testing the effectiveness of CTML led to studies corroborating the use of active participation. Further projects tested multiple modalities, misconception correction, inquiry, moving between multiple frames of reference, and culminating in audience directed programing.

Implications

In terms of astronomy education, the planetarium is the more effective environment for teaching observational astronomy (Brazell, 2009). The direction of current studies should focus on the best sort of instruction to use while in a planetarium. The relative maturity of planetarium instruction in the United States has left a gap in research about the most effective form of instruction within a planetarium. Early studies attempted to determine whether the planetarium was a superior learning environment to the classroom.

The findings of this study will either confirm the coherence principle of Multimedia Learning by showing that seductive details harm instruction, or the findings will suggest that seductive details in an authentic classroom assist with instruction. The infinite variables associated with instruction in an authentic classroom may be too numerous to detail. Additionally, the coherence principle may be an insignificant variable in an environment where interest, attention, classroom management, and discipline dominate the instructional environment. Perhaps the interest generated by seductive details in an authentic classroom override the seductive detail effect.

It is the goal of this research project to determine if seductive details placed in a planetarium lesson provide an increase or a decrease in learning. If seductive details assist learning within a planetarium, than planetarians can feel confident that the inclusion of irrelevant facts aid in the learning and comprehension of astronomical data presented in a planetarium. If seductive details harm learning then planetarium lessons will need to adhere to the topics presented in an interesting manor, while not including extraneous material. A third option exists where seductive details neither assist nor harm learning. If this is the case then seductive details are not a deciding factor of learning within a planetarium and an educational instructional variable has been eliminated.

Summary

CTML assumes that people learn better from words and pictures, than from words alone (Mayer, 2008). Learning is based on selecting words and pictures, followed by organizing words and pictures, and integrating with prior knowledge (Mayer, 2010). The human brain processes information with dual-channels of input, auditory and visual. Each channel has limited-capacity, a set amount that can pass through the channel. Any overloading of a channel results in decreased learning (Austin, 2009). Active processing is achieved by selecting, organizing, and integrating material (Mayer, 2008).

Effective instruction is achieved when extraneous processing is reduced, essential processing is managed successfully, and generative processing is encouraged (Mayer, 2009). Extraneous processing is reduced by coherence, signaling, redundancy, special contiguity, and temporal contiguity (Mayer, 2008). Essential processing is managed by segmenting, pretraining, and modality design principles (Mayer, 2009). Generative processing is fostered by the multimedia and personalization principle (Mayer, 2010).

The coherence principle states that all extra, irrelevant material should be removed in order to allow the learner the opportunity to focus on the learning goal (Lehman et al., 2007). This irrelevant material is referred to as seductive details (Lusk, 2008). In laboratory settings seductive details have shown to hinder learning, as determined by recall ability and transfer of knowledge (Bryant, 2010; Lehman et al., 2007; Lusk, 2008; Mayer et al., 2008; McCrudden & Corkill, 2010; Rowland et al., 2008; Rowland-Bryant et al., 2009; Verkoeijen & Tabbers, 2009). It is unclear if seductive details create harm in authentic classrooms (Park et al., 2011). In a limited number of studies performed outside of a laboratory, seductive details have shown either no negative effect on learning or a positive effect with both recall and transfer (Lusk, 2008; Muller et al., 2008; Ozdemir, 2009; Towler, 2009; Towler & Kraiger, 2008).

The Carl Zeiss Corporation of Jena, Germany, developed the first planetarium projects, but due to their extreme expense, they were only initially placed in five of the seven United States' planetariums (Marchè, 1999). The expenditure required procuring a projector and the disruptions of World War II set the stage for a new projector, developed and built by Spitz Inc., to dominate the market (Howe, 2011). The launch of the USSR satellite Sputnik fueled the nation's desire to invest in public education, specifically mathematics and science (Howe, 2011). Under proposed legislation, school districts could build and maintain educational planetariums (Lantz, 2011).

This dramatic increase in planetarium availability sparked researchers to determine which environment, the classroom or the planetarium, is better suited to teach astronomy. Multiple studies from the 1950s and onward have determined that each environment, classrooms and planetariums, offers distinct advantages (Baxter & Preece, 2000; Dean & Lauck, 1972; Edoff, 1982; Hayward, 1975; Palmer, 2007; Pitluga, 1971; Ridky, 1975; Reed 1970a; Reed, 1970b; Reed 1973; Reed & Campbell, 1972; Rosemergy, 1968; Smith 1966; Sonntag, 1981; Sunal 1972; Tuttle, 1966; Twiest, 1989; Wright 1968; Yee et al., 1971), with the planetarium showing a slight edge in retention (Brazell, 2009). New research is focusing on what sort of instruction best assists learning in the planetarium (Brazell & Esponoza, 2009).

Interesting distractions have shown to be a poor substitute for good instruction (Fisher 1997). While active participation involving manipulatives and physical movements offer the benefit of retention, but no direct increase in learning (Platco, 2005; Plummer, 2009). Multiple modalities (the use of the senses) provide the best use of instructional time in the planetarium (Sumner, et al., 2008).

The maturing planetarium educational research community no longer needs to test which instructional environment, classroom or planetarium, is better suited for teaching astronomy (Brazell, 2009); the planetarium is better apt to instruct students in astronomy (Brazell & Espinoza, 2009). Previous research in planetarium instructional techniques includes multimedia learning theories (Fisher, 1997; Miller and James, 2011; Muller et al., 2008), active audience participation (Platco, 2005; Plummer, 2009), use of multiple learning modalities (Sumner et al., 2008), misconception correction (Sarrazine, 2005; Trundle & Bell, 2010), inquiry (Hobson et al., 2010), moving frames of reference (Plummer et al., 2011), and audience-led programs (Yo et al., 2011).

It is the goal of this project to test if seductive details assist or harm instruction within a planetarium. To accomplish this an inflatable planetarium with digital projection will be used to instruct fifth grade students in basic astronomy concepts. One group of fifth graders will receive instruction embedded with seductive details and the other group will receive instruction without seductive details. CTML predicts that the group without seductive details will perform better on learning assessment tests (Mayer, 2009), while a criticism of CTML predicts that learning in authentic classrooms, filled with common distractions, is aided by the inclusion of seductive details to focusing the learner's attention on the material being taught (Muller et al., 2008).

By studying the effects of educational techniques in the planetarium, it is hoped that the inflatable planetarium will become an adopted piece of equipment that more local schools will have access to. An increased use of inflatable planetariums has the potential for increasing interest and awareness of astronomy that may drive the local high schools to offer comprehensive astronomy education. This increase in interest and awareness has the potential for rectifying the local problem of students not enrolling in astronomy courses.

Section 2: The Methodology

Introduction

To determine if seductive details affect planetarium instruction, this study will use a quantitative experimental design with purposeful group assignments and will employed the use of an inflatable planetarium to instruct students in basic astronomy concepts. Approximately 75 fifth graders participated with half receiving a lesson embedded with seductive details and the other half receiving a lesson without seductive details. Seductive details are described as details that offer no instructional information, but are included to pique the interest of the learner (Park et al, 2011). CTML predicts that students' cognitive processing will be diminished by the inclusion of seductive details (Mayer, 2009); however, there is evidence that the inclusion of seductive details added to lessons in authentic classrooms benefit the learner (Muller et al, 2008). The lesson for the planetarium consisted of objects in the sky; such as the Sun, Moon, and stars, see Appendix C. These students learned that celestial objects have predictable patterns of movements (Sadler et al, 2010).

This particular approach, which used effect size as the quantitative measure, has been chosen because it replicates the design structure of many recent CTML studies (Austin, 2009; Bryant, 2010; McCrudden & Corkill, 2010; McTigue, 2009; Park et al., 2011; Roland-Bryant et al., 2009; Towler, 2009; Verkoeijen & Tabbers, 2009) and previous quantitative planetarium studies (Baxter & Preece, 2000; Palmer, 2007; Twiest, 1989). According to Mayer (2009) and Brazell (2009) the chosen methodology allows for comparison between this study and either CTML or planetarium studies. This comparison provided validation of CTML design principles and/or planetarium-favored astronomy instruction.

Participants and Setting

Participants included fifth grade students from a K-8 school in the High Desert region of Southern California. All students had a choice to participant and may have left the study at any time without any repercussions. A student asset form explained any potential risks in a language easily understood by fifth graders, see Appendix B. Along with the student assent form, a parent permission form had been developed which explained the parents rights and ability to not participate in this study. This site was not the researcher’s home school.

A key demographic descriptor for any school in California is its Academic Performance Indicator (API), which for this school is 837 and it has a Similar School Rank of 7/100 (California Department of Education, 2011-2012a). The API is a summary of a school’s standardized test scores and ranges from 200-1000 with 800 being the goal (Great Schools, 2012a). The Similar School Rank compares this school to 100 other schools with similar demographics, such as mobility, ethnicity, socioeconomic status, teacher quality, pupil demographics, and class size; higher test scores at a school site produces a higher rank within this grouping (California Department of Education, 2011-2012b). This school has an ethnicity of 48% White, 30% Hispanic or Latino, and 8% African American compared to the state average of 28%, 49%, and 7% respectively (Great Schools, 2012b).

Based on this data, this school ranked more favorably than other similar schools. While this school may be a better achieving school compared to the state average, the assumption is that a higher performing school has the latitude to purchase an inflatable planetarium. Therefore, this school provided excellent generalization of the data to the rest of the state for schools in a position to purchase or use an inflatable planetarium.

This school used Pearson Education Inc. as its textbook publisher for fifth grade science (Foresman, 2008). The textbook covers life, earth, and physical science, with astronomy a part of the physical science unit and is specific to the Sun and eight planets (California Department of Education, 2009). The astronomy section is broken into four lessons including the Sun, planets revolving around the Sun, the inner planets, and the outer planets (Foresman, 2008). Supplemental activities provided by the district science coach include an interview with the Sun, Sun/Earth models, gravity demonstrations, hike through the solar system, planet models, a mock debate surrounding the number of planets in the solar system, and misconception probes about solar and lunar eclipses (Science Curriculum Guide, 2012). Using a planetarium to conduct a live interactive lesson of celestial objects was not a part of this school's curriculum.

Two classes of fifth grade students were involved, for a total of 56 students. Each student was scored by a pre-test to determine his or her level of prior knowledge about astronomy. Pre-test scores were used to purposely assign the students into the two groups (1 and 2), so as to have equal numbers of low, medium, and high scoring students. Random assignment and experimental control are part of effective experimental comparison (Mayer, 2009), but in this case it is more advantageous to purposefully assign the students to guarantee two groups of equal ability and thus provide equivalent testing parameters.

Each group (1 and 2) had 28 students, which was near the maximum occupancy (700 square feet) of the inflatable planetarium. Purposeful assignments produced groups with the same percentage of high, medium, and low levels of students based on pre-test scores. For this project, pre-test scores above 80% represented mastery and placed the student in the high achieving group (Sadler et al., 2010). Scores between 20% and 80% placed the student in the medium achievement group and scores below 20% placed the student in the low achieving group. See Table 1.

Table 1

Subgroup Breakdowns by Pre-Test Scores

Subgroup	Description	Pre-Test Score Percentage
a	High achieving group	81 - 100
b	Medium achieving group	20 - 80
c	Low achieving group	0 - 19

This break down ensured that a score of 49% as the median score of the medium achieving group. Forty-nine percent was the average correct response (prior to any instruction) based on testing, review, and validation performed by Project MOSART (Misconceptions-Oriented Standards-Based Assessment Resources for Teachers) of all thirteen questions to be used for assessment (MOSART; 2007, Sadler et al., 2010). Subgroups, within groups 1 and 2, were created with (a) representing the high achieving group, (b) representing the medium achieving group, and (c) representing the low achieving group. Regardless of the individual pre-test scores the groups had equal numbers of high, medium, and low achieving students, thereby causing each group to be equally balanced.

Group 1 received instruction on introductory astronomy concepts with seductive details (experimental group) and group 2 received instruction without seductive details (control group), satisfying the other condition (experimental control) of effective experimental comparisons (Mayer, 2009). The pre- and post-test consisted of recall type questions along with transfer type questions meant to test how students were able to recall information and to apply the material toward new situations (Mayer, 2010). Transfer questions included troubleshooting (why a system works and what-if (new situations) type questions. (Mayer, 2008). Table 2 provides sample questions (MOSART, 2007). Multimedia studies, such as this one, typically test effective learning conditions with recall and transfer questions (Mayer, 2009).

Table 2

Sample Questions (MOSART, 2007)

Question	Type
On a dark moonless night far from any bright lights, how do the stars appear to be spread across the sky?	Transfer (trouble-shooting)
Imagine Earth had no air, rain, or clouds. What would the temperatures be like during the night?	Transfer (what-if)
What is the largest source of heat for the surface of Earth?	Recall

Materials

Digitalis Education Solutions Inc. of Seattle, Washington provided the inflatable planetarium, digital fisheye projector, computer, and related hardware for a six-week period (Digitalis, 2011). A pre-test was used to set a baseline of prior knowledge and a post-test was administered to determine the amount of learning achieved by the students, see Appendix A. Groups (1 and 2) and subgroups (a, b, c) scores were collected and analyzed, using SPSS, to determine the instructional effect size, consistent with reporting for other multimedia studies (Mayer, 2009).

Lessons were created using Nightshade Astronomical Simulation, which is an open-source platform based on Stellarium Astronomical Simulation, but optimized for use in a planetarium (Nightshade, 2011). Custom controls and instructions in the planetarium can be recorded and replayed using Nightshade's scripting language, known as Stratoscripts (Nightshade User Guide, 2010). Stratoscripts are an open-source set of computer commands used by the Nightshade Astronomy Simulator software to automate multiple routine directions, allowing the planetarium operator to focus on the audience and not on the equipment (Nightshade, 2011).

Research Design and Approach

The lessons are based on the K-4 grade national astronomy standards of the National Science Education Standards published by the National Research Council [NRC] (National Academy of Sciences, 2012) and the American Association for the Advancement of Science (AAAS) Benchmarks (Project 2061, 2012). Table 3 describes each standard. To make this project more appealing to the participating fifth grade teachers and parents, an additional lesson was included based on California Fifth Grade Science Standards most related to astronomy, see Table 4 (California Department of Education, 2009). There is overlap between these two sets of education standards, with the California Standards including the eight planets of the solar system. The planetarium lessons were designed so as to cover each set of standards (see Appendix C).

Table 3

K-4 Planetarium Lesson Standards (MOSART, 2007)

Lesson Standard	Description
1	"The [S]un, [M]oon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described." (National Science Education Standards, 1996, p.134)
2	"The [S]un provides the light and heat necessary to maintain the temperature of the [E]arth." (National Science Education Standards, 1996, p.134)
3	"There are more stars in the sky than anyone can easily count, but they are not scattered evenly, and they are not all the same in brightness or color." (Project 2061, 2012, "The Physical Setting 4A", para. 5)
4	"Objects in the sky have a pattern of movement. The [S]un, for example, appears to move across the sky in the same way every day, but changes slowly over the seasons. The [M]oon moves across the sky on a daily basis much like the [S]un. The observable shapes of the [M]oon changes from day to day in a cycle that lasts about a month." (National Science Education Standards, 1996, p. 134)

Table 4

Fifth Grade California Science Standard #5 (CA Dept. of Education, 2009)

Standard	Description
5	The solar system consists of planets and other bodies that orbit the Sun in predictable paths.
a	Students know the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.
b	Students know the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.
c	Students know the path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.

According to Croft (2008), effective planetarium lessons are; (a) immersive, (b) include music, (c) provide a journey from start to finish, (d) use live narration, and (e) provide a peaceful environment. The lessons for this project adhered to these requirements in order to maximize the experience for the learners. Immersion is inherent in the physical layout of a planetarium, tricking the senses into believing the illusion of depth. Providing for a journey will be created by proper lesson design and pacing. Music was embedded in the lesson directly within the Stratoscripts and a peaceful environment was ensured by a proper orientation. In order to deliver live narration the researcher instructed all the lessons in the planetarium.

The pre-test and the post-test, titled The Astronomy and Space Science Concept Inventory (ASSCI), was designed by Project MOSART with funding from NASA's Science Mission Directorate (#NCC5-706) and are specifically targeted for fifth grade students (see Appendix A) (MOSART, 2007). Since this project took place at the beginning of the fifth grade year, it is appropriate to use this assessment, based on K-4 learning, to measure the students' performance as a result of the planetarium intervention (Sadler et al., 2010).

Each question provided "distractor-driven" multiple-choice answers (DDMC). DDMC tests include popular misconceptions as provided answers, forcing the test taker to chose between a single correct answer and one or more research-identified misconceptions. Examples of popular misconceptions, that cross international borders, are the beliefs among second graders that the Earth is spherically shaped and we live inside a flat area with air (Bryce & Blown, 2006; Klein, 1982; Mali & Howe, 1979; Nussbaum; Nussbaum & Novak, 1976; Sadler et al., 2010; Sneider & Ohadi, 1998; Sneider & Pulos; Vosniadou & Brewer, 1987). DDMC tests reproduce results obtained by interviews to ascertain student conceptual framework of content knowledge (Sadler et al., 2010). Sadler et al., (2010) performed eight steps to develop the catalog of DDMC astronomy questions: 1) review of relevant misconception literature; 2) examination of the relevant astronomy standards and drafting of initial test questions; 3) expert review; 4) pilot testing (1,000 students); 5) large scale validation (7,599 students); 6) item analysis; 7) final test construction; and 8) field testing (787 students).

Table 5 correlates pre-test questions with identical post-test questions, identifies the question type, planetarium lesson standard, and provides the correct response. The last column titled 'Percent Responding Correctly' represents the average correct response rate, based on field testing and mastery of a content standard is considered 80% (Sadler et al., 2010). The total mean average of all thirteen questions is 49%, which should represent the median score of the medium achieving subgroup (b) based on the pre-test.

Table 5

Item Correlation and Expected Response Rate (MOSART, 2007)

Item #					
Pre-test	Post-test	Question Type	Lesson Standard	Correct Response	Percent Responding Correctly
1	13	Transfer (what-if)	1	B	60%
2	11	Transfer (troubleshooting)	4	C	47%
3	5	Transfer (what-if)	2	C	35%
4	10	Transfer (what-if)	4	A	44%
5	9	Recall	4	C	42%
6	12	Transfer (troubleshooting)	4	E	49%
7	3	Recall	2	A	63%
8	6	Transfer (what-if)	1	C	32%
9	1	Recall	1	D	72%
10	2	Transfer (troubleshooting)	3	E	67%
11	7	Recall	1	D	42%
12	8	Transfer (troubleshooting)	3	B	54%
13	4	Recall	1	D	34%

Using this average as a scale, a question difficulty ranking can be produced. Questions with the highest average can be considered easy and questions with the lowest average can be considered difficult. These tests are available to the public for assessment, evaluation of programs, or as curriculum. See Appendix A for test questions.

It should be noted that the pre-test and the post-test use the same questions, but in a different order as determined by Sadler et al. (2010) (MOSART, 2007). This might have an effect on internal testing validity (Lodico, Spaulding, & Voegtle, 2010), as the same questions on the pre-test may influence the responses on the post-test. Millsap and Maydeu-Olivares (2009) reported that this influence may be in a positive direction, as familiarity with the topic is achieved; or it may be in a negative direction, by diminishing the student's sensitivity to the material. In an unrelated study, Buhay, Best, and McGuire (2010) reported no negative effect when they tested student learning using the same questions on the pre-test and the post-test. The students were not made aware of the pre- or post-test answers. The pre-test was scheduled approximately two weeks before the planetarium lesson/ post-test in order to minimize this influence.

From these pre- and post-tests scores several descriptive statistics will be generated, using SPSS, which will allow better understanding of the research data. The mean, standard deviation, range, and variance was produced for each group (1 and 2) and individual pre-/post-test questions (1-13) along with a mean for each lesson standard. To compare the groups and subgroups inferential statistics will be used. A t-test was used to compare the means of the groups and subgroups ($p < 0.05$) and an effect size was created to determine if the inclusion of seductive details proved significant. Effect size is the typical measure used in CTML studies to provide evidence of individual principles (i.e. coherence principle) (Austin, 2009; Bryant, 2010; Dunsworth & Atkinson, 2007; Harskamp et al., 2007; Lehman et al., 2007; Lusk, 2008; Mayer, 2003; Mayer et al., 2008; Mayer & Jackson, 2005; McCrudden & Corkill, 2010; McTigue, 2009; Ozdemir, 2009; Park et al., 2011; Rowland et al., 2008; Roland-Bryant et al., 2009; Towler & Kraiger, 2008; Towler, 2009; Verkoeijen & Tabbers, 2009).

According to Mayer (2009), one of the requirements to consider a research study as core evidence of multimedia learning is that; first, the dependent variable involve problem-solving transfer (see Table 5) and second, the mean scores and standard deviations are reported. This allows an effect size to be calculated that permits comparison of studies that used different designs and treatments. According to Cohen (1988) effect size (*d*) is calculated by subtracting the control group's mean score from the experimental group's mean score and dividing by the pooled standard deviation. The effect size determines how many standard deviations of improvement a particular treatment has caused (Mayer, 2009).

Swaminathan, Horner, Rogers, and Sugai (2012) define effect size as measuring the magnitude of the opposing results using standardized units. A small effect would be less than .3, a medium effect would be greater than .3 but less than .8, and a large effect would be greater than .8 (Cohen, 1988; Mayer, 2009). If the effect size is large or medium then there is a relationship between seductive details and learning; conversely if the effect size is small then the relationship between seductive details and learning is quite small (Mayer, 2009). Effect size (*d*) was computed by subtracting the mean score of the lesson without seductive details (control group 2) by the mean score of the lesson with seductive details (experimental group 1) and dividing by the pooled standard deviation (Cohen, 1988). See Equations 1 and 2.

$$d = \frac{\overline{X}_C - \overline{X}_E}{SD_{pooled}} \quad (1)$$

In Equation 2.1, d represents the effect size. The mean score of the lesson without seductive details (control group 2) is represented by $\overline{X}_C$ and $\overline{X}_E$ represents the mean score of the lesson with seductive details (experimental group 1). The pooled standard deviation, which serves as the denominator of the formula, will be determined by using Equation 2.2. In equation 2.2, N_E is the sample size and SD_E is the standard deviation for the experimental group 1 (lesson with seductive details). The control group 2 (lesson without seductive details) is represented by N_C as the sample size and SD_C as the standard deviation.

$$SD_{pooled} = \sqrt{\frac{(N_E - 1)SD_E^2 + (N_C - 1)SD_C^2}{N_E + N_C - 2}} \quad (2)$$

There were two types of lessons developed for the planetarium. See Appendix C. The difference between the lesson types was the addition of seductive details, which will take the form of interesting but irrelevant text, stories, pictures, and/or videos. Each lesson type included a view of the night sky, a tour of our solar system, the lunar cycle, eclipses, and understanding of the seasons. To automate these lesson types and allow the operator to focus on the audience, the lessons were written as Stratoscript instructions (Digitalis, 2012). Sctratoscrips are an ordered collection of planetarium control commands that are executed as one file, as opposed to performing individual commands, within Nightshade (Nightshade, 2011).

Procedures

The first step in this study was to meet with the prospective teachers to determine their interest in participating in the process. Preliminary agreements had already been reached with the teachers, the school site administration and the district science coach. Dates and times were then agreed upon. Once these details had been verified, an introductory meeting was held to explain the process to the teachers and students, provide an overview of the planetarium, and distribute the parental consent form and the student assent form (Appendix B). The parental consent form was used to allow the parents the opportunity to opt out of this project while the student assent form provides the same choice to the student, written in simplified language.

Upon completion of step 1, the next step involved an introduction to the planetarium, both on the inside and out, in order to assure a reduction in the Hawthorn effect (Brazell, 2009). The Hawthorn effect is the induced excitement and elevated levels of attention to new and exciting stimuli (Willoughby & Gustafson, 2009). The introduction explained the procedures for entering the dome, expected behavior inside the dome, exiting procedures, and a small sample of what celestial objects looks like in a planetarium. This familiarization hopefully translated to a better experience for the students.

The third step implemented the pre-test, score the pre-test, and assigned the students to either group 1 or group 2 and subgroups a, b, and c. The researcher administered both the pre- and the post-test in the student’s classrooms. The pre-test took place approximately two-weeks before implementation of the planetarium lessons and took about twenty minutes to complete. This two-week separation was designed to limit any influence the pre-test may produced towards the post-test.

Each group was created purposefully, based on pre-test scores. Purposeful assignment created two groups with equal numbers of (a) high achieving (b), medium achieving (c), and low achieving levels of prior astronomy knowledge. The specific size of the subgroups within the groups is not at issue as long as the two groups are balanced. Post-test improvement determined the effectiveness of seductive details and the make-up of the subgroups is immaterial to the coherence principle,

After group assignments, the succeeding step executed the study design. The planetarium lessons were created and piloted and the inflatable planetarium was ready for testing. The students were called during physical education (P.E.) instruction, by their assigned groups (1 and 2) and participated in live instruction running about forty-five minutes. The post-test took outside of this forty-five minute window and lasted approximately twenty minutes.

Physical education requirements in California mandate 200 minutes every ten days (California State Board of Education, 1999), so participation in a forty-five minute study plus twenty minutes of testing balances well with P.E. requirements. The lessons were specifically designed to augment classroom instruction and contained fifth grade science standards regarding astronomy instruction (California Department of Education, 2009). At the conclusion of the lesson the students exited the dome, returned to their classroom, where the post-test was administered before the next group was invited in.

The final step scored and analyzed the post-test, which was given immediately at the end of the planetarium lesson. Each student received a numbered test document ensuring his or her confidentiality. Once the tests were complete they were scored and inputted into SPSS to create descriptive and inferential statistics that was used to illustrate the data sets. An effect size was generated in order to compare this study to other seductive detail studies and determine if the instruction method of removing seductive details is effective. Effect size is the standardized unit of measurement for multimedia learning studies (Mayer, 2009).

Research Hypothesis

It is hypothesized that students who receive instruction in an inflatable planetarium with design principles consistent with CTML will demonstrate a higher level of astronomy comprehension than students who received instruction in an inflatable planetarium with design principles contrary to CTML. The CTML design principle being employed by this study is the coherence principle. The coherence principle states that any unnecessary information should be removed from instruction (Mueller, Lee, & Sharma, 2008). In this case unnecessary information is referred to as seductive details (Park et al., 2011). The null hypothesis states that there will be no significant difference ($p < 0.05$) in astronomy comprehension between the control group that receive instruction in an inflatable planetarium with CTML design principles and the experimental group that receive instruction in an inflatable planetarium without CTML design principles.

Assumptions, Limitations, Scope and Delimitations

This research attempted to develop techniques and strategies that assist both classroom educators and planetarium professionals on how to develop lessons that maximize the learning potential of students in a planetarium. It is assumed that planetariums are not an everyday teaching environment for students and the time spent under a planetarium dome is finite and precious. It is also assumed that educators will want to maximize the learning potential of students while they are in the planetarium. Furthermore, it is assumed that the planetarium instructor for this study, who is also the researcher, is new to teaching in a planetarium and does not have the experience of a professional planetarian.

The strength of this study lies in the adaptation of CTML in an authentic classroom setting. By applying CTML to a wider range of environments, CTML increases its validity as a learning theory. Additionally, by applying CTML to planetarium instruction another learning strategy becomes available to the planetarium community. There are potential limitations to this study's validity that may decrease this study's benefit. First, the planned seductive details have not been proven as interesting distractors to fifth grade students, as has been done in other studies (Lehman et al., 2006; Mayer et al., 2008; Ozdemir, 2009). Secondly, the excitement of being in the planetarium may override the distractions caused by the seductive details. This can be potentially controlled by introducing the students to the planetarium before the planned assessment, otherwise known as the Hawthorn effect (Willoughby & Gustafson, 2009). Thirdly, the researcher acting as the planetarium instructor may introduce bias towards one particular group due to the lack of experience the planetarium instructor has teaching in a planetarium. Finally, the apparent motion produced in the planetarium may cause a distraction to learning and become an unchecked seductive detail.

This project's scope of study only tested one principle of CTML, namely the coherence principle, which states that unnecessary information should be left out of any instructional lesson (Park et al., 2011). This unnecessary information is referred to as seductive details. Seductive details are interesting, but irrelevant information that are used to draw the learner attention, but may result in interfering with the creation of a mental model of the learned material. The boundaries of this project will only be to study the effects of seductive details in an inflatable planetarium. This project will not be studying any of the other principles of CTML nor shall it replicate previous seductive detail studies and test undergraduate students in a control setting using one-on-one instruction and assessment (Bryant, 2010; Lehman et al., 2007; Lusk, 2008; Mayer et al., 2008; McCrudden & Corkill, 2010; (McTigue, 2009; Rowland et al., 2008; Rowland-Bryant et al., 2009; Verkoeijen & Tabbers, 2009). This study will be testing the effects of seductive details in an inflatable planetarium and will not be using a permanent planetarium with fixed seating. Finally, this study will be using a digital project to display the planetarium lesson and will not be using an analog star ball to display the images of stars.

Ethical Protection of Human Subjects

All participants had parental permission to participate and all were notified of potential hazards. Students had a choice to participate and leave the study at any time without any negative repercussions. A student assent document explained the potential risks in a language easily understood by fifth grade students (see Appendix B). This study was reviewed for any negative effects by the site principal, the site dean of students and Walden’s Internal Review Board (IRB). One such health risk included disorientation brought on by the total immersion achieved in a planetarium. The disorientation is only an allusion and can be alleviated by closing the eyes or leaving the planetarium. All lessons were designed to minimize this problem by decreasing the potential feeling of flying brought on by rapid screen transfers.

Findings

Two groups participated in the planetarium lesson with one group experiencing the experimental lesson embedded with seductive detail design elements and the other group participating in the controlled lesson without seductive details. A total of fifty-six (*n* = 56) 5th grade students were selected based on: (a) attending the orientation, (b) taking the pre-test, (c) submitting a student accession form and returning a parent permission slip, (d) participating in either the experimental or controlled lesson, and finally (e) completing the post-test. One hundred and fifteen students, from four classrooms, experienced some part of the project, however only fifty-six completed every phase. Students were grouped by their pre-test scores and by their classroom. To alleviate scheduling problems and reduce teacher confusion, students from two classrooms made up the experimental group and students from the other two classrooms made up the control group.

The experimental group comprised twenty-eight (*n* = 28) students with one student scoring in the high achievement subgroup (a), twenty-six students scoring in the medium achievement subgroup (b), and one student scoring in the low achievement subgroup (c) based on pre-test scores ($\overline{X}_E$ = 42%, sd = 17, r*ange* = 77, *var* = 300). The control group was of equal size with twenty-eight students (*n*=28) and having all twenty-eight students in the medium achievement subgroup (b) ($\overline{X}_C$ = 43%, sd = 8, *range* = 38, *var* = 72). It should be noted that the control group had a slightly higher pre-test average of one percent as compared to the pre-test average of the experimental group. An independent t-test was performed on the experimental and the control groups pre-tests results. The difference between the two pre-test means was not significant $t(54) = 0.2816$, $p<0.05$.

The lesson given to students in the control group was approximately thirty-four minutes in length and contained five topics. The topics included an overview of the night sky, an explanation of the seasons, examples and diagrams of solar and lunar eclipses, a grand tour of the solar system, concluding with a depiction of the lunar cycle. This lesson was designed without any distracting seductive details. The lesson presented to the experimental group contained the exact same design elements with the inclusion of seductive details. These seductive details were represented by fifty-three images and approximately twenty-seven deviations from the control lesson script. These extra seductive details translated to an additional three minutes of instruction, for a total run time of approximately thirty-seven minutes, see Appendix C. On average a seductive detail image interrupted the lesson every 40 seconds and script deviations were experienced every 78 seconds. These interruptions were at a faster pace than Fisher's (1997) insertion of humor every 90 seconds, with similar end results of interesting material harming learning.

An initial glance at the results shows that the post-test score did increase compared to the pre-test scores, providing ancillary evidence that learning does occur in the planetarium, see Table 6. The control group ($\overline{X}_C$ = 55%, *sd* = 14, *range* = 54, *var* = 218) had a larger gain in learning by twelve percentage points than the experimental group ($\overline{X}_E$ = 47%, *sd* = 22, *range* = 85, *var* = 490) gain of five percentage points, indicating that a larger amount of learning was achieved by excluding seductive details with the control group than by including seductive details with the experimental group. This provides initial evidence that seductive details have a harmful effect on learning. Pre-test/post-test questions 4/10, 6/12, 7/3, 9/1, 10/2, and 12/8 showed an actual decrease in learning from the pre-test to the post-test in the experimental group, while only questions 6/12, 7/3, and 10/2 showed a decrease for the control group. This possibly points out that seductive details included in the experimental group's lesson had a larger harmful effect.

Table 6

Comparison of Individual Test Question Percentages

Item #		Percent Responding Correctly			
		Experimental Group (1)		Control Group (2)	
Pre-test	Post-test	Pre-test Average	Post-test Average	Pre-test Average	Post-test Average
1	13	75%	86%	71%	82%
2	11	18%	39%	21%	43%
3	5	39%	79%	39%	89%
4	10	39%	36%	25%	50%
5	9	21%	32%	14%	29%
6	12	57%	25%	82%	39%
7	3	75%	29%	93%	46%
8	6	18%	57%	11%	68%
9	1	54%	25%	64%	32%
10	2	46%	32%	39%	36%
11	7	29%	46%	18%	46%
12	8	50%	46%	46%	68%
13	4	29%	71%	32%	82%
Final Results		42%	47%	43%	55%

By comparing the results by Lesson Standards (Table 3) the overall trend of the control group outperforming the experimental group continues. The experimental group post-test average lesson standards 1-4 compared lower to the control group post-test average lesson standards 1-4, see Table 7. Lesson Standard 2 (Sun's influence), Lesson

Standard 3 (stellar distribution), and Lesson Standard 4 (patterns of movement) actually showed a decrease in learning from the pre-test to the post-test in the experimental group.

Table 7

Comparison of Lesson Standard Percentages

Item #		Percent Responding Correctly			
		Experimental Group (1)		Control Group (2)	
Pre-test	Post-test	Pre-test Average	Post-test Average	Pre-test Average	Post-test Average
Lesson Standard 1					
1	13	75%	86%	71%	82%
8	6	18%	57%	11%	68%
9	1	54%	25%	64%	32%
11	7	29%	46%	18%	46%
13	4	29%	71%	32%	82%
Total		41%	57%	39%	62%
Lesson Standard 2					
3	5	39%	79%	39%	89%
7	3	75%	29%	93%	46%
Total		57%	54%	66%	68%
Lesson Standard 3					
10	2	46%	32%	39%	36%
12	8	50%	46%	46%	68%
Total		48%	39%	43%	52%
Lesson Standard 4					
2	11	18%	39%	21%	43%
4	10	39%	36%	25%	50%
5	9	21%	32%	14%	29%
6	12	57%	25%	82%	39%
Total		34%	33%	36%	40%

All three of these concepts where included in the lesson, but it is possible that the included seductive details masked that concept and prevented the students from learning, or worse contributed to learning the concept incorrectly. The only Lesson Standard to show growth for the experimental group was Lesson Standard 1 (predicted motions). The control group showed a gain in all Lesson Standards, with Lesson Standard 1 displaying the largest growth.

The first step in computing an effect size is to calculate the Pooled Standard Deviation (SD_{pooled}), see Equation 2. The sample size (N_E) and standard deviation (SD_E) for the experimental group was 28 and .22 respectively. The control group produced a sample size (N_C) of 28 along with a standard deviation (SD_C) of .14. Inserting these values into the Pooled Standard Deviation (SD_{pooled}) formula produced a value .18, see Equation 3.

$$SD_{pooled} = \sqrt{\frac{(28 - 1).22^2 + (28 - 1).14^2}{28 + 28 - 2}} \quad (3)$$

After the Pooled Standard Deviation (SD_{pooled}) is known an Effect Size (*d*) was determined, see Equation 4. The mean score of the control group ($\overline{X}_C$) was 55% and the mean score of the experimental group ($\overline{X}_E$) was 47%. By subtracting the experimental group ($\overline{X}_E$) mean from the control group ($\overline{X}_C$) mean and dividing by the Pooled Standard Deviation (SD_{pooled}) yields an Effect Size (*d*) of .4, see Equation 4. Effect Size is published as a value between 0 and 1, so the decimal equivalents were used in calculating Effect Size.

$$d = \frac{.55 - .47}{.18} \quad (4)$$

When comparing the two post-test means an effect size of .4 (d = 0.4) denotes that a medium effect was observed between the two post-test means. This suggests that the exclusion of seductive details had a medium sized effect on learning. Student learning was harmed by the inclusion of seductive details. Placing this into prospective in regards to the post-test means, twenty students (71%) in the control group (*n* = 28) outscored the mean score for the experimental group. While only 10 students (36%) in the experimental group (*n* = 28) outscored the mean score for the control group. Indicating that the control group performed significantly better with the exclusion of seductive details.

Mayer (2009) reports that medium and large effects are considered significant, while small effects are evidence of chance. It is interesting to note that Brazell (2009) and Brazell and Espinoza (2009) reported that planetariums have a small positive effect on learning, indicating that a small effect size can still be considered significant in the context of their meta-analysis. A number of studies have indicated that small effect size provides little relationship between the group means (Lusk, 2008; Ozedemir, 2009; Verkoeijen & Tabbers, 2009). While a medium and large effect is considered significant (Austin, 2009; Dunsworth & Atkinson, 2005; Harskamp, Mayer, Suhre, 2007; Lehman, Schraw, McCrudden, & Hartley, 2007; Mayer, 2003; Mayer & Jackson, 2005; Rowland-Bryant, Skinner, C. H., Skinner, A., Saudargas, Robinson, & Kirk, 2009).

According to these findings it is worth concluding that the research hypothesis was correct, students who received instruction in an inflatable planetarium with design principles consistent to CTML (no seductive details) demonstrated a higher level of astronomy understanding than those students who experienced a lesson with design principles contrary to CTML (seductive details were included). The evidence for this conclusion is the increase in the post-test mean scores between the experimental group ($\overline{X}_E =$ 47%, sd = .22) and the control group ($\overline{X}_C$ = 55%, sd = .14). This increase can be summarized by the size of the effect (d = 0.4) between the two groups. With these results in mind it is possible to answer the first research question that planetarium instruction consistent with the design principles of CTML does cause an increase in learning. This study is also able to answer the second research question that seductive details do have a negative effect on learning.

Limitations of Study Design

The interaction of seductive details and student learning may be more complex in an authentic classroom than previously documented (Muller, Lee, & Sharma, 2008). Perhaps seductive details create a positive student/teacher relationship that leads to an increase in student performance. It may be fair to speculate that the introduction of seductive details in an authentic classroom may create a more favorable relationship with the teacher, thus providing the students an increased motivation to perform for their teacher; further studies are recommended for this area of CTML research.

This research did not conclusively determine that seductive details are bad for lesson design. Perhaps seductive details have a positive effect on student behavior. Seductive details may act as a catalyst to good classroom behavior and the removal of such seductive details will have a negative effect on classroom management. Seductive details may provide adequate stimulation and interest to keep students engaged in the lesson. It is foreseeable for lessons excluding seductive details to become boring and uninspiring, causing students to seek stimulation with negative behavior. At the other end of the lesson, the teacher may become bored repeating the same lesson multiple times a day. Perhaps, seductive details allow the teacher to invigorate the lesson and stimulate some excitement not being realized. More testing needs to be completed applying CTML design principles to authentic classrooms.

There was one minor technical problem observed during both lessons. During both the control and experimental lesson the North Star, known as Polaris, was lower in the horizon than planned. It is assumed that this was caused by the default location not set to the actual location. The lessons were designed ahead of time on a computer running Digitalis Nightshade (Digitalis Education Solutions, 2012). This computer had the default location set to the latitude and longitude of Southern California. It is assumed the computer that was used for the lessons had the default location set to Seattle, Washington (headquarters of Digitalis Education Solutions). This difference meant that at one point during the lesson the North Star and the constellation Ursa Major, commonly known as the Big Dipper, were lower in the horizon than planned. This was not an issue in any other part of either lesson (control/experimental) after this point because the Nightshade Script had the location hard coded and/or a view of the night sky was not needed. The error associated with the placement of the North Star and Uras Major was left alone for the experimental lesson, meaning that the experimental lesson saw the same placement of the North Star and Ursa Major as seen in the control lesson. This specific part of the lesson taught the students how to find the North Star using the two pointer stars within Ursa Major, named Dubhe and Merak. It is unknown why this occurred, as this was not observed during any of the tests performed by either computer, perhaps a practice lesson loaded prior to the control lesson set the unintended default location. This error could not be traced, as the computer and all support material were shipped back to Digitals soon after the lessons were presented. It is doubtful this technical gaff had any influence on the outcomes, since both lessons (control and experimental) saw the same night sky with identical locations. Perhaps students sitting up front obscured the view of the North Star and Ursa Major.

The seductive detail experimental lesson may have introduced a second CTML principle by mistake. The immersive environment with three hundred and sixty degrees of dome allowed placement of seductive detail images over a wide area of projection. This caused the students heads to move around to follow the narrative. This may have introduced the spatial contiguity variable; in that the images were not in the same physically location and this may have accidently interfered with student learning. Seductive details may not have been the only distraction at play.

It is also possible that bias was introduced to the experimental lesson containing seductive details since the lead researcher was also the individual conducting the planetarium lessons. There was an attempt to mitigate this issue by using identical scripts that the presenter used while teaching in the planetarium. The possibility still exists that some bias may have crept into the lesson.

Another point to consider is that this project may not have replicated a truly authentic classroom. In a genuine authentic classroom students have a feeling of comfort from being present in the room for a longer period of time than which these students experienced in the inflatable planetarium (Brazell & Espinoza, 2009; Marchè, 1999; Reed, 1970b). Perhaps the inflatable planetarium was still too new in the minds of the students and the Hawthorn effect (Willoughby & Gustafson, 2009) was not eliminated. This may have caused the students to experience a heightened level of attention not present in a truly authentic classroom. This state of hyper attention may have had an effect on student learning.

According to the evidence presented in this project, seductive details had a harmful effect on student learning. These findings may have been limited by a) the complexity of the seductive detail effect, b) technical projection discrepancies, c) an unintended introduction of another CTML principle, d) an inadvertent bias in instruction, e) or the influence of an authentic classroom environment. However positive seductive details may appear to be, their influence is unmistakably negative even in an authentic classroom. A number of studies in which seductive details where tested in a more controlled environment showed a large effect between learning and seductive details (Austin, 2009; Dunsworth & Atkinson, 2005; Harskamp et al, 2007; Lehman et al, 2007; Mayer & Jackson, 2005; Verkoeijen & Tabbers, 2009). The introduction of an authentic classroom did show a lessening of the seductive detail effect (medium effect); nevertheless the effect was still harmful to learning. It is doubtful that the technical problems influenced any lesson, since both the experimental and the control group experienced identical lessons.

The unintentional introduction of the spatial contiguity principle may have influenced the testing of the coherence principle, however this issue seems to strengthen CTML policy; indicating that the principles of CTML do indeed have a place in instructional design. Instructional bias was controlled, as best as possible, with the use of a script and a planned program, see Appendix C. The influence of an authentic classroom was controlled, to a certain degree, with an introductory lesson designed to familiarize the students with the planetarium. It is doubtful, based on economics, that planetariums will ever be as familiar to fifth grade students as their assigned classroom. It is reliable to anticipate that planetariums will always be a source of excitement and wonder to this population of students. Based on the evidence presented in this study, this project recommends eliminating seductive details in a planetarium.

Conclusion

This study used an inflatable planetarium dome with digital projection to teach fifth grade elementary students astronomy concepts with and without seductive details. Lessons were constructed around National Science Education K-4 astronomy standards and California Fifth Grade Standards relating to astronomy (California Department of Education, 2009; National Academy of Sciences, 2012; Project 2061, 2012). The assessment is based on the ASSCI developed by project MOSART (MOSART, 2007). In order for this project to be comparable to other CTML studies, reporting of problem-solving means and standard deviations are included along with an effect size (Mayer, 2009).

The initial step of this project was to contact the teachers, confirm their involvement, and complete the necessary student forms. An inflatable planetarium orientation and pre-test preceded the actual lesson. The final step involved assessment and analysis of the pre- and post-tests to determine the effects of seductive details.

All participants (site administrators, teachers, parents, and students) were notified about their rights regarding this research study, including the right to not participate. The parents and students were informed of any potential risk and that participation is optional. The students, either due to parental concern or their own feelings, had the option of withdrawing from this study without any negative repercussions, see Appendix B.

According to the findings, the control group (lesson excluding seductive details) scored better than the experimental group (lesson included seductive details). Therefore, these results validate the research hypothesis. The data also provided an answer to the research questions by demonstrating that CTML, when applied to planetarium instruction, does cause an increase in learning and that seductive details do have a negative effect on learning. The evidence suggests that seductive details do in fact have a detrimental effect on student learning. These results are in line with the predictions of CTML (Mayer, 2009) that the control group (no seductive details) will outperform the experimental group (seductive details included) on assessment performance tests, the inclusion of seductive details may have increased student attention, but this increase in attention did not translate into higher test scores.

Section 3: The Project

Introduction

Since this project provided evidence in favor of the coherence principle applied to fifth grade students in a whole group setting, it is favorable to promote the catalog of design principles outlined in CTML. A working knowledge of these principles would allow science/astronomy teachers the ability to implement complex multimedia planetarium shows with the expectation of maximizing the audience/student's experience. This proposed professional development project provides the 'how' of lesson development as compared to the 'what' of content specialization. Since earlier chapters determined that astronomy is a neglected subject (Bishop, 2003) the remainder of this project will focus on the creation of professional development modules using specific CTML principles for science/astronomy teachers focusing on astronomy instruction who own or plan to purchase an inflatable planetarium.

Description and Goals

This project will create a 3 day professional development unit, based on an adult training model, to present to science/astronomy teachers who own, recently purchased, or plan on purchasing an inflatable planetarium about the benefits of CTML based multimedia instruction, with the intent of allowing them to create effective science/astronomy lessons grounded in proven CTML principles. With ever decreasing prices in technology, along with improvements in hardware (Campos, Campos, & Jorge, 2011) the inflatable planetarium becomes a viable option for science/astronomy teachers wishing to instruct astronomy in an immersive environment. The outcome and adoption of Common Core Standards (Porter, McMaken, Hwang, & Yang, 2011) and the Next

Generation Science Standards [NGSS] (Wysession, 2012) will determine the importance of astronomy instruction in the classroom. The professional development module will reference a training guide, see Appendix D, and will include descriptions of CTML, poor lesson development according to CTML, specific examples of select CTML principles most applicable to inflatable planetariums, and allow the participants to create a set of guiding rules for effective planetarium lesson development.

The goals of this project include: (a) train the science/astronomy teaching community about the research-based CTML design principles, (b) provide examples of what design elements to include and exclude based on selected CTML design principles, and (c) provide additional training for teachers using an inflatable planetarium in effective content creation. Specifically this project will educate science/astronomy teachers, focusing on astronomy, on the effectiveness of the CTML design principles of redundancy, special contiguity, temporal contiguity, pre-training, and personalization.

In addition to the project goals, the training session will have the following four goals; (a) describe CTML theory with enough understanding to be able to use these principles in future planetarium lessons, (b) recognize examples of poor planetarium lesson design to reinforce CTML theory in future planetarium lesson designs, (c) explain the five chosen principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) with accuracy in order to use these principles to create an abbreviated planetarium lesson, and (d) construct a list of do’s and don’ts, based on the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) that will guide the participants while generating planetarium lessons.

Rationale

The original problem set forth in this project was that students are not enrolled in astronomy courses (California Department of Education, 2011a) due to difficulties associated with teaching astronomy (Guimarães, 2009; Krumenaker, 2009b; Plummer & Zahm, 2010; Trundle & Bell, 2010). A possible solution presents itself to encourage CTML design principles in the creation and development of astronomy lessons. This project will introduce CTML to the science/astronomy teaching community, focusing on astronomy, in a professional development setting with the intent of creating lessons in an inflatable planetarium. Educating science/astronomy teachers who own, recently purchased, or plan on purchasing an inflatable planetarium about CTML may be the catalyst needed to increase interest in astronomy and increase student learning in multimedia-based astronomy lessons.

Additionally, it has been found that owners of inflatable planetariums receive training on how to set up and run the equipment, but not on how to effectively use the hardware and software to its full potential (Digitalis Educational Solutions, 2012; e-Planetarium, 2013; Star Lab, 2013). Very little, if any, time is spent on how to create meaningful, research-based instructional lessons. According to the adult training model, this sort of deficiency in practice is referred to as a gap and finding a need to fill this gap is known as gap analysis (Goad, 2010). This project seeks to fill this need/gap and train teachers how to create astronomy instruction that maximizes the learning potential of their students, thereby justifying the enormous purchase price of an inflatable planetarium.

With the previous chapters provided additional evidence encouraging CTML, further studies are recommended tying planetarium-based instruction to CTML. Perhaps additional research would provide an improved understanding of learning and instruction in immersive digital environments, such as with inflatable planetariums. A professional development seminar might just be the avenue needed to start this trend in research.

Review of the Literature

This literature review will be divided into two main sections. The first half of the review will concentrate on CTML and the five potential principles of redundancy, spatial contiguity, temporal contiguity, pre-training, and personalization. The second half will focus on the adult training model, which uses the theory of andragogy (adult learning) as its basis.

Design Principles of the Cognitive Theory of Multimedia Learning

CTML is an overarching learning theory that explains how people learn best in a multimedia (words, pictures, text, narration, animation, video, etc) environment (Mayer, 2009). According to this theory the human brain has two input channels: visual and auditory [dual-channel] (Mayer, 2008). Information can be received in either channel. However, if additional material is presented to the same channel, an overload can occur (Clark & Mayer, 2011). The human brain only has so much capacity for understanding; information overload causes extra information to be ignored [limited-capacity] (Mayer, 2009). Correctly designed lessons foster deeper understanding of the material [active processing] (Mayer, 2008). The design principles of CTML provide a framework for instructors to create effective lessons that promote active processing, regulate dual-channel input, and control limited-capacity (Mayer, 2010).

While students learn, they are experiencing a cognitive process that places a stress or load on their mental faculties (Clark & Mayer, 2011). CTML has identified three types of cognitive loads that need to be addressed if effective learning is to be achieved: a) extraneous processing, b) essential processing, and c) generative processing (Mayer, 2010).

Extraneous processing is the learning of material that is not important to the instructional goal and can be exacerbated by poorly designed instruction (Clark & Mayer, 2011). Essential processing is the learning of the most critical information; the learner is able to construct an effective mental model of the material (Mayer, 2009). Generative processing is the organization and integration of the new material with prior knowledge (Mayer, 2008). For effective learning to be achieved the instructional lesson must reduce extraneous processing, encourage essential processing, and foster generative processing (Clark & Mayer, 2011).

One of the earliest multimedia studies sought to determine if soldiers could learn more effectively by watching films. Hall and Crushing (1947) wanted to verify whether classroom, film, or self-study was the most effective form of instruction for US Army soldiers; attempting to justify the millions being spent on film production. According to their research, all three methods were equally as effective (Hall & Crushing, 1947), leading to the eventual conclusion that instructional design is much more important than instructional medium, something than CTML provides.

CTML promises a set of instructional design principles that create meaningful learning, as depicted by good retention of the material and good transfer of information to new experiences (Mayer, 2009). These principles are referred to as; (a) coherence, (b) signaling, (c) redundancy, (d) spatial contiguity, (e) temporal contiguity, (f) segmenting, (g) pre-training, (h) modality, (i) multimedia, (j) personalization, (k) voice, and (l) image (Mayer, 2008). Table 8 provides an explanation of each principle.

Table 8

CTML Design Principles (Mayer, 2009)

CTML Design Principle	Explanation	Cognitive Processing
Coherence	Extra information is excluded from the presented lesson	Extraneous
Signaling	Important and relative information is emphasized	Extraneous
Redundancy*	Material is presented as graphics and narration versus graphics, narration, and printed text	Extraneous
Spatial Contiguity*	Related words and pictures are presented closer together	Extraneous
Temporal Contiguity*	Narration and pictures presented simultaneously	Extraneous
Segmenting	Learner is able to control the pace of the lesson	Essential
Pre-training*	Outline the relative learning goals prior to the actual lesson	Essential
Modality	Pictures presented with spoken words as opposed to written text	Essential
Multimedia	Words and pictures are better than words alone	Generative
Personalization*	Informal rather than a formal language style	Generative
Voice	Human voice is better than a computer synthesized voice	Generative
Image	Image of the narrator is superimposed over the lesson	Generative

* Included with this literature review

Based on experience gained performing from this study, it is this project’s recommendation to include redundancy, special contiguity, temporal contiguity, pre-training, and the personalization principle in the professional development module for science/astronomy teachers instructing astronomy education using a multimedia environment, like an inflatable planetarium. Taken as a whole, the five principles emphasize a distinct type of cognitive load and provide a well-rounded philosophy of curriculum design that reduces extraneous processing (redundancy, special contiguity, temporal contiguity), encourages essential processing (pre-training), and improves generative processing (personalization). These principles were selected because of their unique contribution to an inflatable planetarium. What follows is a description of these five principles, why they were selected, and examples of use.

Redundancy. People learn best when material is presented as graphics and narration versus when material is presented as graphics, narration, and printed text (Clark & Mayer, 2011). The redundancy principle helps in the reduction of extraneous processing (Mayer, 2009). This principle applies a ‘less is more’ philosophy, meaning that less instruction (omission of printed text) is more beneficial to learning (Van Gerven, Pass, & Tabbers, 2006).

Pastore (2012) was concerned that instruction with printed text took less time than instruction with audio narration since then human brain can read faster than an instructor can speak, thus making an audio lesson longer to implement. (McKerrow, Gronbeck, Ehninger, & Monroe, 2000). Pastore (2012) used audio time-compression to speed up recorded narration and tested if multiple representations (graphics, narration, and text) of the same material at the same time harmed learning. Students were exposed to science lessons regarding the anatomy of the human heart. Compression as much as twenty-five percent had no negative effect on learning (Pastore, 2012) In addition, students who only experienced graphics and narration performed better than similar groups who were subjected to graphics, narration and redundant written text (Pastore, 2012).

Redundancy, in an astronomy classroom, would take the shape of omitting any text associated with projected images of galaxies. A teacher might be instructing a lesson on the various types of galaxies in the universe and how to identify each type (Galaxy Zoo, 2012). The teacher would leave any explanatory text off from the projected image and limit the explanation to the accompanying narration.

Spatial contiguity. Meaningful learning can be achieved if related words and pictures are presented closer together as opposed to being farther away from one another in a multimedia presentation (Johnson & Mayer, 2012). The spatial contiguity principle assists in the reduction of extraneous processing (Mayer, 2009). This design principle applies more to new learners as opposed to high-knowledge learners and is a factor of diagram complexity (Mayer, 2009). In other words, if the learner has a great deal of knowledge about the subject matter the spatial, contiguity principle plays less of a factor in learning and the complexity of the corresponding diagram necessitated a stronger reliance of the spatial contiguity principle.

Ayres and Sweller (2005) found that the spatial contiguity principle is dependent on the learner a) not being familiar with the subject matter, b) the diagram is only comprehensible with words, and c) the material is complicated in nature. According to Johnson and Mayer (2012) good special contiguity design encourages the learner to integrate related words and pictures in working memory, while poor spatial contiguity disrupts this cognitive process. A poorly designed spatial contiguity diagram, in an astronomy classroom, would have a technical drawing of a star (StarTeach Astronomy Education, 2012) with a description placed at the bottom or off to the side of the drawing, while a diagram consistent with CTML design philosophy would have the same description imbedded within the diagram next to the relative parts (Johnson & Mayer, 2012).

Spatial contiguity becomes a larger factor for lesson development when the available viewing area increases to three hundred and sixty degrees of view, as in an inflatable planetarium. The ease of lesson development using modern planetarium scripting software (Digitalis, 2011) and a larger canvas can lead to a poorly designed lesson, without proper planning (Clark & Mayer, 2011). Imagine having a diagram of a star on one side of the planetarium and accompanying explanation placed one hundred and eighty degrees of view away. This dramatic headshake can have potential disastrous consequences for instruction in an inflatable planetarium (Mayer, 2009).

Temporal contiguity. Narration and pictures presented simultaneously are more advantageous than presenting narration and pictures successively (Clark & Mayer, 2011). The temporal contiguity principle helps in the reduction of extraneous processing (Mayer, 2009). Research for this principle was established by Mayer, Moreno, Boire, & Vagge (1999) when undergraduate students were subjected to computer-based learning of lightning and automobile braking systems. In both experiments students who saw simultaneous animation scored better in both retention and transfer than those students who saw large chunks of animation followed by narration or vice-versa (Mayer et al., 1999).

Schüler, Scheiter, Rummer, and Gerjets, (2012) confirmed this principle that learners will perform better with simultaneous presentation of spoken text and pictures rather that sequential presentation of spoken text and pictures despite the fact that learners have more time with sequential presentations. This additional time provides no benefit to learning and in fact puts learner at a disadvantage through an increase in their cognitive load (Schüler et al., 2012).

Astronomy is a visual science (Cudnik, 2012), so it is entirely appropriate to use imagery to convey the concepts intended for instruction. This principle forms a basic tenant of lesson organization; include narration with the presented images. This is true for classroom and planetarium based instruction. Perhaps a teacher wishes to create online-based videos to supplement their instruction, such as those describing the life cycle of stars (Kahn Academy, 2012). Students will learn more and be better prepared for classroom instruction if supplemental online videos present narration and pictures simultaneously (Mayer, 2009).

Pre-training. When a student is provided an outline of the relative learning goals prior to the actual lesson, pre-training has occurred (Mayer, 2009). The pre-training principle assists in essential processing (Mayer, 2009). By presenting the information in two stages rather than all at once, cognitive load is decreased (Haslam, 2011). The pre-training introduction reduces complexity with the material and causes the pre-training to become prior knowledge when the full lesson is taught (Mayer & Moreno, 2003).

This principle has also been studied under the term isolated-interacting elements instructional method (Pollock, Chandler, & Sweller, 2002). Ayres (2012) found that when 13-14 year old students were introduced to algebraic problems using isolated-interacting methods (pre-training), math performance increased. Effective isolated-interacting method lessons increased in complexity until the students were able to complete the assigned tasks.

Pre-training can be accomplished, with astronomy, by giving a class of students an outline of the material to be covered in the planetarium, before they enter the planetarium. With pre-training the brain has already begun the process of essential learning necessary to understand new material (Mayer, 2009). Cognitive load is decreased because the brain can use its limited capacity towards the material instead of needing to mentally organize the lesson. An example of this might be to provide an outline of the planetary bodies within our Solar System, including the organization of the Inner Solar System, the Outer Solar System, and the dwarf planets (NASA, 2012), before the students experienced a grand tour of the Solar System.

Personalization. People learn best when information is written in an informal, rather than a formal language style (Kartal, 2010). The personalization principle fosters generative processing (Mayer, 2009). Clark and Mayer (2011) define the personalization principle as learning being improved when using a conversational style as opposed to a formal style in both narration and reading. Moreno and Mayer (2007) found that a conversational style of language provided better transfer and recall results and they recommend an informal approach in all multimedia learning environments.

This finding appears to be valid with other languages with structures different than English. Kartal (2010) tested text explaining stellar formation/death using the Turkish language, where pronunciation dictates levels of formality. Three grammatical structures were used: a) personalized formal, b) personalized informal, and c) nonpersonalized (neutral) formal. Kartal's (2010) findings were consistent with the published literature that increased learning favors a personalized style of language.

The personalization principle becomes important when an instructor has created a lesson to be presented in a planetarium. Planetarium lessons require many hours of labor to create meaningful experiences (Bishop, 1992). This level of effort oftentimes has a scripted narration to accompany the lesson, with set timing and performance cues (Youth

Astronomy Apprenticeship, 2009). It is in the instructor's best interest to thoroughly practice the narration to the point that the narration sounds casual to the listener than reading from a script with a formal inflection. Better yet, it may be better for a planetarium instructor to create an outline, as opposed to a script, and allow the lecture to unfold in a natural manner, with random pauses creating a unique and relaxed experience.

Summary. CTML is a learning theory that attempts to explain how people best learn in environments of video, animation, narration, and text (Mayer, 2009). CTML supposes that the human brain has one input channel for auditory and a second input channel for visual [dual-channel] (Clark & Mayer, 2011). If too much material is presented to the same input channel an overload can occur (Mayer, 2008) and the human brain cannot process this additional material [limited-capacity] (Mayer, 2010). Properly designed lessons create ideal learning conditions [active processing] (Mayer, 2009). The act of learning stresses the brain and places a cognitive load (extraneous, essential, and generative processing) on the learner and can be controlled by the twelve design principles of CTML (Clark & Mayer, 2011). Extraneous processing can be decreased by the coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principle (Mayer, 2009). Essential processing can be managed by the segmenting, pre-training, and modality principle (Mayer, 2008). Generative processing can be increased by the multimedia, personalization, voice, and image principle (Clark & Mayer, 2011).

Adult Training

Training is a process that causes a learner to acquire new skills, knowledge, or attitudes that improve or enhance their performance and allow an organization to perform better, faster, easier, with higher quality, and with a better return on investment, known as ROI (Biech, 2007). Training differs from education, in that training focuses on adult learning (andragogy) and education focuses on teaching children [pedagogy] (O'Carroll, 2012). According to O'Carroll (2012) effective adult training needs to include active participation, hands-on activities, and be directed to specific goals or objectives. Goad (2010) points out that during tough economic times training budgets and the accompanying facilitators are one of the first to be reduced in any organization Careful planning and adhering to the needs of the learner has the potential of staving off these types of cost reductions.

Theoretical basis for adult learning and training. Adult training has been heavily influenced by the principles established by Malcolm Knowles in his book The Adult Learner (Knowles, Holton, & Swanson, 2011). During the 1960s the term andragogy was developed to describe adult learners and differentiate from how children learn, known as pedagogy (Stolovitch & Keeps, 2011). Knowles, Holton, and Swanson (2011) describe six adult learning assumptions: a) need to know b) readiness, c) experience, d) self-concept, e) orientation and f) motivation. As a point of clarification, the readiness, experience, self-concept, and orientation assumptions were developed in the late 1970s (Knowles, 1975, 1978, 1980) the last assumption, motivation, was added in 1984 (Knowles, 1984), and the first assumption, need to know, was added in the late 1980s (Knowles, 1989, 1990).

Need to Know. Before any adult training can occur it is essential that the adult learner is understood. Adults need to know why they should learn something (Knowles, Holton, & Swanson, 2011). Children are the opposite. They are content learning new concepts for the sheer joy of learning. One of the opening tasks of any training session is for the trainer to convince the participants the value of the training and make a rational case for their being involved (Knowles, Holton, & Swanson, 2011).

Readiness. Adult learners come to any learning environment with their own attitudes and priorities, they must be convinced that this learning situation solves a problem, provides an opportunity, or includes growth (Stolovitch & Keeps, 2011). Adults become ready to learn when the learning helps them cope with real-world situations, the key is to time learning experience with their developmental understanding of their perceived need (Knowles, Holton, & Swanson, 2011). Trainers must convince the participants that a learning situation will help them to be more successful (Lawson, 2009).

Experience. Once the learner has been convinced that a particular training is beneficial, the next step is to recognize the experience of the learner. The trainer needs to understand that adult learners arrive with their own unique knowledge and possess more experience than young children do (Stolovitch & Keeps, 2011). Any new information, received through training, would need to be assimilated with past knowledge and experience. It is suggested that trainers send out pre-training questionnaires to determine this level of experience and conclude if training could be detrimental to the learning process (Lawson, 2009).

Self-Concept. Adults are autonomous beings who want to take responsibility for their own lives, including their learning experiences (Stolovitch & Keeps, 2011). Adult learners are self-directed and want to take an active role in their learning, including the planning, implementation, and evaluation of the activities; this does not mean that the trainer releases responsibility of the training to the adult learners, rather, the learning must be created as a collaborative effort (Lawson, 2009). Adult learners want to be treated with respect, even when they make mistakes. Respect is critical for allowing adult learners to make errors in a safe environment. The adult learner is often more fragile than a child, since failure can have a devastating effect on an adults career (Stolovitch & Keeps, 2011). This creates a delicate balance between the trainers giving responsibility to the adult learner while maintaining an environment free from negative judgment.

Stolovitch and Keeps (2011) suggest a) creating opportunities for the adult learner to participate with hands-on activities, simulations, and games, b) allow adult learners to contribute their own ideas and solutions, and c) reinforce and reward independent and innovative ideas. Adult learning autonomy is a continuum, from a complete controlled environment to a loosening of all constraints; the competency of the adult learner dictates the positioning of the course on this continuum (Stolovitch & Keeps, 2011). It is highly recommended that trainers conduct a pre-training survey to understand where their participants are on this continuum (Biech, 2007; Goad, 2010; Lawson, 2009; Matthews, 2012; O'Carroll, 2012; Stolovitch & Keeps, 2011).

Orientation. Adult learners want immediate, real world learning that helps them solve problems or tasks back at their work site (Lawson, 2009). Learning will be considered most effective when it has applications to adult situations (Knowles, Holton, & Swanson, 2011). Adults attend training to learn how to improve or alter their job performance. To ensure a successful program the trainer must focus the adult learner's attention on how they can immediately apply what they have learned to a specific problem back at work (Stolovitch & Keeps, 2011).

Motivation. Internal factors, such as self-esteem, recognition, curiosity, quality of life, self-confidence, self-actualization, and the desire to learn, motivate adults to learn (Lawson, 2009). The best learning situations tap into this internal motivation and remove negative barriers to complete the training (Knowles, Holton, & Swanson, 2011). If an adult is able to see an internal reward they have a higher likelihood of learning and completing the training (Stolovitch & Keeps, 2011).

Training Model. Prior to any training actually happening a specific, formal process known as the training cycle or training model must be followed (O'Carroll, 2012). Many authors subscribe to a specific model of development that follows a basic pattern (Goad, 2010; Lawson, 2009; Matthews, 2012; O'Carroll, 2012). A typical training cycle consists of five stages: a) analysis, b) design, c) development, d) delivery, and e) evaluation (Lawson, 2009). Each stage is designed to move the process forward and deliver a successful training session, emphasizing adult learning, active participation, and fits the needs of the clients (Goad, 2012). The training model can be considered cyclical, in that the last stage of evaluation can have input into the first step of analysis when the training is to be performed multiple times and improvements are sought (Biech, 2007).

Analysis. The first stage of any proposed training course or seminar is to conduct an analysis and determine who the learners are, what knowledge or skills they already have, and what they need to acquire (O'Carroll, 2012). If a gap exists between what the learners need to know and what they currently know, known as gap analysis, then some sort of intervention (training) may be necessary (Matthews, 2012). Lawson (2009) refers to this as a Needs Assessment. The first step in a Needs Assessment is to identify the problem or need, with the purpose being to solve this particular problem or a perceived problem within an organization (Lawson, 2009). In a practical sense, the desired result minus the current situation is identified as the need. Part of this process is a determination if training will be the answer; often a different solution other than training may correct the problem (Goad, 2010).

After the needs have been identified, learning objectives would need to be written that potentially define what the training should accomplish (Lawson, 2009). Goad (2010) states that learning objectives need three parts to be effective; (a) performance (what should be accomplished), (b) condition (to what degree should the learning improve), and (c) standard (when the learning should occur). As part of the analysis Lawson (2009) believes that it is important to determine if the problem is caused by a lack of skills or knowledge or is the problem inherent in the structure of the organization, or perhaps it is policy elated, in which case training would not be considered a solution. Once the learning objectives have been written, data such as observations, interviews, questionnaire/surveys, document examination, etc. should be collected to root out the true cause of the problem followed by further analysis and a report of the findings (Lawson, 2009).

Design. At this stage the philosophy of course design is implemented, relying heavily on the theoretical foundation of andragogy (adult learning). Stolovitch and Keeps (2011) point out that during the design phase the trainer must focus on being learner centered and performance based. In other words the training program must focus on the needs of the learner and provide achievable, meaningful, and verifiable results (Stolovitch & Keeps, 2011). A key element in adult training is to vary the instructional techniques in order to accommodate a variety of learning styles (Biech, 2007; Goad, 2010; Lawson, 2009; Matthews, 2012; O'Carroll, 2012; Stolovitch & Keeps, 2011).

As part of the design process it must be determined who is going to be trained, when will it take place, where will it be held, why is this training necessary, what should the participants do, and how will the instruction communicate the necessary skills (Lawson, 2009; Matthews 2012). According to Stolovitch and Keeps (2011) all of these plans will help to create a design that is learner centered (attending to adult's learning styles) and performance based (choosing the correct activities to facilitate success). Goad (2010) suggests that as part of the design process trainers should provide a good first example, show enthusiasm with the subject, conduct the training in an informal environment using realistic examples, provide hands-on activities that relate to what they already know, use variety, repetition and feedback, remove any fear of learning, serve as facilitator by guiding and prompting (not just telling), inform the learners of the objectives and relate the activities to these objectives, and finally allow this particular material to transfer to other skills.

Development. Once the trainer understands the needs of the learners and what should be presented, it is time to actually develop the learning material. Goad (2010) recommends following a seven step process to design a training program; (a) identification and selection of the necessary training materials (training guides, handouts, activities, etc.), (b) selection of the delivery process (classroom, self-paced, online, etc.), (c) selection of the participants, (d) selection of the facilitator, (e) selection of evaluation strategy, (f) determine physical logistics (location, time, refreshments, etc.), and finally (g) pilot training.

During the development process a training manual is created that contains the course description, objectives, syllabus, presenter's notes, copies of all handouts, a detailed explanation of all included activities, a trainee's handbook, and all necessary assessment criteria, see appendix D. This manual should be comprehensive enough to cover the essential material to the point that another trainer, unfamiliar with the program, could deliver the training successfully (O'Carroll, 2012). It is recommended that the course syllabus not contain any reference to time, as this allows the trainer the flexibility to add or subtract minutes to an activity without causing the participants any anxiety (Matthews, 2012).

Delivery. With all the planning and preparation complete it is now time to implement the training and deliver the information to the participants. Lawson (2009) has one word of advice to determine success while delivering training: preparation. Proper preparation includes having all the materials created, practice the training prior to actual implementation, arriving at the training venue early, have the ability to adjust the activities where needed, and being able to place the participants in a receptive state of learning once they do arrive (Lawson, 2009). To be an effective learner, the participants need to be motivated to learn, alert, curious about the material, relaxed, focused, energized, and finally interested (Matthews, 2012).

Matthews (2012) suggests that success can be achieved if the trainer knows the group (pre-training questionnaires), can build positive expectations about the training, create an attractive environment, stress the benefits of the training, deal with resistant learners, build rapport with the group, navigate the logistics of work related training, keep the energy in the room flowing, put participants at ease, and be aware of the trainer's own personal state of focus/energy. Passion for the material can go along way with motivating the participants to learn (Lawson, 2009). A training program should not be considered a failure if the program deviates from the planned schedule; the needs of the learner must come first and if the program is not working then the trainer may need to make last-minute adjustments (O'Carroll, 2012). Finally, a trainer should never apologize if something isn't working; it undermines the trainer credibility and can easily be eliminated by careful planning and preparation (O'Carroll, 2012).

Evaluation. Training programs need to be evaluated to show their success to upper level management, who may see training as an unnecessary expense during tough economic times (Lawson, 2009). Kirkpatrick and Kirkpatrick (2006) wrote the definitive guide to training in 1959 that describe four levels of evaluation: (a) reaction, (b) learning, (c) behavior, and (d) results. A fifth level was recently added describing return on investment, or ROI (Biech, 2007, Phillips, 2012). As a trainer progresses further into each level, greater effectiveness of the program can be determined.

The first level, reaction, asks how the participants felt while they were in the training program and includes end-of-training evaluation forms that are filled out asking how the training was perceived (Goad, 2010). Often referred to as 'smile sheets', it is of upmost importance that the participants enjoyed their time in the training session or future participation may be affected (Matthews, 2012). Negative reactions can reduce the motivation to learn (Kirkpatrick & Kirkpatrick, 2006). The second level, learning, seeks to determine what the participants have learned (Lawson, 2009). Learning can be defined as any change in attitudes, knowledge, or skills (Smidt, Balandin, Sigafoos, & Reed, 2009). The third level, behavior, seeks out what behavioral changes the participants have because they attended the training (O'Carroll, 2012). Behavioral changes require the training participants to; (a) have a desire to change (b) know what to do and how to do it, (c) work in an encouraging environment, and (d) be rewarded for change (Kirkpatrick & Kirkpatrick 2006). Knowing the environment a participant is returning to can determine the success of the training; the returning environment influences change by being preventing, discouraging, neutral, encouraging, or requiring (Kirkpatrick & Kirkpatrick, 2006).

The fourth level, results, are the final outcomes that occurred because the participants have attended the training (Goad, 2012). Results are concerned with the larger picture of costs, improved efficiency, overall quality, and in corporations - profits (O'Carroll, 2012). Results point to the initial need to have the training in the first place and should be closely tied to the training objectives (Kirkpatrick & Kirkpatrick, 2006). The newest level, ROI compares the cost of the training to the potential monetary benefit that may be achieved due to the training (O'Carroll, 2012). Data, such as material expenses, venue costs, utilities, training salaries, travel expenses, administrative costs, overhead, and refreshments are converted to monetary values and used to determine the effectiveness of the program (O'Carroll, 2012). Trainer often fears ROI because it may expose their program as being a bad investment (Biech, 2007). However, due to the complex nature and multiple variables involved in the evaluation of adult training the reality is that these effects can only truly be estimated (Lawson, 2009).

Implementation

This project will follow guidelines set forth by multiple authors of adult training development and their suggestions for successful implementation of a training seminar (Goad, 2010; Lawson, 2009; Matthews, 2012; O'Carroll, 2012; Stolovitch & Keeps, 2011). First and foremost, this training seminar needs to focus on the learning of adults (Goad, 2010), involve active participation of the learners (Matthews, 2012), and vary the instructional style to fit a variety of learners (Lawson, 2009).

It has been determined by Brazell (2009) that the vast majority of planetarium research has focused on comparing the classroom to the planetarium Since the planetarium has been determined to be the better environment for teaching observational astronomy (Brazell & Espinoza, 2009) and very little focus has been placed on effective lesson development (Plummer, 2011) there is a need for training planetarium educators on the benefits of lesson design utilizing CTML theory. The desired result of more students enrolled in astronomy minus the current lack of scientific lesson design equals the need for CTML based training of planetarium educators (Goad, 2010). Following Lawson's (2009) training model, four learning objectives have been established for the participants to be completed by the end of the training session and follow Goad's (2010) standard of including performance (what will be learned), condition (how it will be applied), and standard (level of performance) descriptions; (a) describe CTML theory with enough understanding to be able to use these principles in future planetarium lessons, (b) recognize examples of poor planetarium lesson design to reinforce CTML theory in future planetarium lesson designs, (c) explain the five chosen principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) with accuracy in order to use these principles to create an abbreviated planetarium lesson, and (d) construct a list of do’s and don’ts, based on the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) that will guide the participants while generating planetarium lessons.

Potential Resources and Existing Supports

Other planetarium professionals can serve as a potential resource for this training program. Known as subject matter experts (SME), these individuals may have the necessary skills and knowledge to assist in the delivery of the training part of this project (Lawson, 2009). Stolovitch and Keeps (2011) caution about the use of SMEs, as they see a problem different than that of a novice learner. SMEs may have experience and knowledge that is so ingrained in their vernacular that they might be unable to see the how a topic can be difficult for a beginner (Lawson, 2009).

Manufacturers and distributors of inflatable planetariums may serve as an existing base of support for this project and its related training program. Adding a training program that teaches possible buyers about the benefits of research-proven instructional practices has the potential of increasing sales of inflatable planetariums (Digitalis Educational Solutions, 2012; e-Planetarium, 2013; Star Lab, 2013). This program has the most direct benefit for school districts or individuals (science/astronomy teachers) wishing to purchase an inflatable planetarium and provide custom instruction to classrooms.

Potential Barriers

Two of the greatest obstacles to successful training programs are difficult participants and group conflict (Goad, 2010; O’Carroll, 2012; Lawson, 2009; Matthews, 2012). These problems are inevitable, particularly if the training session is made of people with different experiences, backgrounds, opinions, perspectives, and interests (O'Carroll, 2012). Problem behaviors can be caused by participants who don't want to be in attendance, don't understand the material, are anxious about the training, have a learning style that doesn't match the training, covered the material previously, thinking of more important things, bored, or have simply nothing to say (Matthews, 2012). Proper preparation and a professional attitude can reduce or eliminate the majority of these problems (Lawson, 2009).

Goad (2010) has identified five types of difficult participants; (a) monopolize – a person who feels their opinions and comments need to be inserted into every discussion, (b) quiet-ones – someone who is present in body only and provides little verbal participation, (c) digressers – a learner who always steers the conversation to another topic, (d) chatterboxes – a person who enjoys hearing their own voice and participating in private conversations during the training, and (e) disruptors – a participant who feels their concerns and objections need to be heard by everyone in attendance. All of these types of difficult participants should be handled with professionalism, dignity and respect for the learner (Goad, 2010; Lawson, 2009). Lawson (2009) suggests creating a professional atmosphere by lowering the pitch of your voice, breathe slowly, control the speed of your voice, control your volume, and reduce nervous gestures. Small nonverbal queues may be enough to alleviate the problem behavior such as thanking the individual for the contribution, seeking responses from specific individuals, reminding participants of the main topic, polite pauses during presentations, acknowledgement of legitimate concerns, and quite possibly direct confrontation (Goad, 2010). Matthews (2012) points out that trainers need to be aware of a 'tipping point', a balance between keeping order and maintaining rapport with the group. If a problem is handled with too much force the group may rebel and side with the difficult participant.

If these difficult participants problems engulf into a larger group conflict more drastic measures may need to be instituted (Goad, 2010). Lawson (2009) notes that during these episodes a trainer should stop the dysfunctional behavior, keep individuals engaged, keep the group involved, and above all respect the individual while attempting to prevent the person from withdrawing from the session. Goad (2010) suggests a) manage the activity while not drawing attention to the problem, b) use proximity and body language, c) speaking to the person during a break, d) speaking to the person in front of the groups, e) reevaluate the training approach, and finally as a last resort f) sending the problem individual home. At a certain point a trainer needs to realize that despite all their efforts some situations are not in their control. A trainer should solve the problem to the best of their ability, with professionalism, dignity, and respect; realizing that if the situation could have been handled better, a new approach should be performed for the next session (Lawson, 2009).

Proposal for Implementation and Timetable

The specific training session will be scheduled to take place over three days and fill approximately twenty-three hours of training time, see Table 9, Table 10, Table 11 and Appendix D. Care has been taken to vary the instructional strategies to accommodate a variety of adult learning styles (Biech, 2007; Goad, 2010; Lawson, 2009; Matthews, 2012; O’Carroll, 2012; Stolovitch & Keeps, 2011). If an activity doesn’t seem to be working at the moment it was scheduled, it becomes the trainer’s responsibility to adjust the training (Lawson, 2009).

Pre-Training. Prior to any activities taking place a pre-training packet containing a questionnaire/survey will be sent out in order to get a better understanding of who is attending the session, what prior knowledge they may possess, and what is their degree of expertise in regards to planetarium lesson design (Stolovitch & Keeps, 2011). This pre-training packet will serve as a welcoming to the course, provide an outline of the sessions, and explain what needs to be completed prior to the training event (Lawson, 2009). As part of the pre-training packet, a letter will be sent to the participant's supervisors explaining how the training will benefit the learner. Hopefully this will create a welcoming environment once the learners have returned back to their work site (Kirkpatrick, L. & Kirkpatrick, D., 2006).

Day 1 - Training Activities. The training event will begin at approximately 8:00 am each day and allow participants thirty minutes to arrive before any activities take place. Each participant will be greeted as they enter with the hope of creating a warm, friendly, safe environment (Matthews, 2012). The room will be neatly arranged with astronomy related posters and decorations hung around the room (O'Carroll, 2012). The seating arrangement will be largely determined by the needs of the room, however adjustments will be made to create the appropriate environment (Lawson, 2009). First impression will dictate the success of the program (O'Carroll, 2012).

The first activity will be an icebreaker activity designed to form a bond within the group (Goad, 2010). Movie posters related to astronomy (Movie Posters, 2013) will be placed around the room, see Appendix D. Instruction sheets and a verbal explanation will be included with the activity (Matthews, 2012). This activity will have three rounds; during each round the participants will select their three favorite posters, casing each round to have a different mix of individuals (Lawson, 2009). During the first round the participants will move to the movie poster that they most identify with (favorite), introduce themselves to the new group, by stating their name, where they live, and what their job is. Round two, they will move to their second favorite poster and find something they each have in common with this new group. During round three they are to move to their third favorite poster and create a list of concerns they may have with attending this training session. At the end of each round the groups will be given a flip chart to create a poster summarizing what they learned. The poster for the first round will include a list of names, with a circle round the person who traveled the farthest to attend this training. The second round poster will include a list of items the participants have in common. The third round poster should have a list of concerns and/or expectations they have about the training and perhaps items they are most interested in learning. The posters will be presented after each round and hung around the room following the activity.

Once the participants have sufficiently bonded, a personal story relating to the power of the planetarium to inspire young minds will be told (Meader, 2006). Lawson (2009) points out that often during training, personal stories are what participants enjoy most and set the stage for an individual learning experience. After the readiness story (story preparing the learners) the objective of the course will be presented and participants, including the trainer, will introduce themselves (O’Carroll, 2012). The group will establish ground rules in regards to cell phones, emergencies, breaks, private discussions, etc. (Lawson, 2009). Matthews (2012) suggests allowing the group to create their own ground rules; as they are more apt to follow rules they created themselves.

Table 9

Proposed Training Outline - Day 1

Time/Duration	Activity	Explanation
8:00 am (30 minutes)	Arrive	The trainer will greet each participant at the door prior to arrival.
8:30 am (30 minutes)	Movie Posters Icebreaker	Play an astronomy-based game to familiarize themselves with the trainer and other participants.
9:00 am (30 minutes)	Introductions / Objectives / Ground Rules	Readiness story will be told. Participants will introduce themselves, ground rules will be established, and the training objectives will be discussed.
9:30 am (30 minutes)	Examples of Poor Planetarium Lessons Poster	Working in small groups, create a poster listing examples of poor planetarium lessons that have been observed and present it to the class.
10:00 am (20 minutes)	BREAK	
10:20 am (20 minutes)	CTML Lecturette	CTML Theory will be explained in an abbreviated lecture.
10:40 am (40 minutes)	CTML Crypto Cluster Game	A secret code (CTML Theory) has been encoded in a message and needs to be deciphered.
11:20 am (45 minutes)	Literature Review Jigsaw	Facilitate a review of the relevant CTML literature using a jigsaw approach
12:05 pm (60 minutes)	LUNCH	
1:05 pm (75 minutes)	Question Discussion	Facilitate a question/answer session outlining what makes a successful planetarium lesson.
2:20 pm (20 minutes)	BREAK	3:00 pm – 20 minutes
2:40 pm (90 minutes)	Planetarium Instruction	View CTML based lessons in an inflatable planetarium
4:10 pm (20 minutes)	Summary	Create a mnemonic sentence to remember CTML principles.

The first true activity relating to CTML and planetarium instruction will be for the participants to form into small groups and create a poster, using a flipchart and markers, highlighting observed examples of poor planetarium instruction. If the group does not have sufficient experience with planetarium lessons they may choose any examples of poor instruction, hopefully the examples will either be related to science or astronomy. The groups will be formed by using a technique described by Lawson (2009) entitled “Finding Famous Fictional Friends and Family” (Lawson, 2009, p. 238) and adapted to meet the needs of astronomy instruction. Index card will be created with names from specific astronomy related categories. The categories may include groups such as planets, stars, constellations, famous astronomers, etc. The cards will only include the names within each category and will not list the names of the categories themselves. For example, the names for the planet category will include the names: Mercury, Venus, Earth, Mars, etc. It will be the participant’s responsibility to figure out the grouping, place themselves in the appropriate group, and select which person should assume the role of the group leader. The group will determine the group leader by deciding which card is the most scientifically significant. The number of grouping and the names within the group will need to be adjusted to accommodate the size of the training group. After the posters have been created the group leader within each group will present the posters to the whole. A twenty-minute break will separate this activity from the next.

After the break the group will observe a lecture regarding CTML instructional theory. Biech, (2007) suggests referring to lectures as lecurettes, since the term lecture has many negative feelings associated with it and term lecturette makes the activity sound much less intensive. The lecturette will guide the group through the major points regarding multimedia learning, how the brain processes information, the different types of cognitive processing, and the twelve principles of CTML.

To break-up two intensive activities regarding CTML a game will be played called “Crypto Cluster” adopted from Stolovitch & Keeps (2011, p. 132). This game will use a phrase borrowed from CTML theory “people learn better from words and pictures than from words alone” (Mayer, 2009, p. 1) or perhaps a listing of the twelve principles of CTML. Whatever phrase is eventually chosen, each letter in the phrase will be encrypted with a simple letter substitution. For this activity participants will be paired with their neighbor. Pairing is the surest method of making every learner participate (Matthews, 2012). To reinforce the competitive nature of this game the event will be timed, with a clear starting and stopping point. Winners will be awarded candy. Matthews (2012) suggests treating small groups like children to get the best results.

Before the scheduled lunch the participants will be divided into random groups by reshuffling and redistributing the index cards from the “Finding Famous Fictional Friends and Family” (Lawson, 2009, p. 238) activity. Each group will be given part of an article to read (Mayer, 2010) and summarize, referred to as jigsawing, that outlines CTML principles and associated research. Each group will then teach their part to the whole class. The groups will be scheduled in order of the article so the entire article has been summarized.

After lunch an active symposium will allow the learners to participate in a discussion and answers session. These questions will be open-ended and require the participants to provide thought and reasoning with their answers. Open-ended questions are questions requiring the participant to think and provide more than a simple yes or no as an answer and can be used to great effectiveness to stimulate learning (Lawson, 2009). The first question will be ‘how do you think most planetarium lessons are designed in terms of student learning?'. Depending on how long this discussion lasts a second question can ask 'what could you do differently in a planetarium lesson to increase interest in astronomy?' and finally with 'what sort of structure should a planetarium lesson have?'. Questions should be phrased as to avoid a yes/no type of answer (Goad, 2010).

The last activity of the day will be for all participants to enter an inflatable planetarium and see firsthand what a lesson without CTML principles feels and sounds like. This will be contrast with the same activity to end of day two; however the second day's inflatable planetarium session will adhere to CTML principles. An activity of this caliber is planned as an exciting cap to end the first day of training and generate excitement about the following day of learning (Matthews, 2012).

Each day of training will end with a summary allowing member to focus on what had been learned. Matthews (2012) notes that training is only as good as the debriefing that follows. The summary on the first day of training will require each participant to create a mnemonic sentence for each of the twelve principles of CTML (Matthews, 2012). This will be prepared by each individual and quickly shared with the group.

Day 2 – Training Activities. The second day of training will begin, as did the first, allowing time for the participants to arrive and settle in for more learning. A quick review of the proposed objective will refocus the learning goals (Lawson, 2009). An icebreaker activity is not planned, as the group should already be in a receptive state of learning.

While the day is new and the participants are fresh, a lecturette will delve into greater depth of the five chosen CTML principles that have the most potential for influence in a planetarium (redundancy, special contiguity, temporal contiguity, pre-training, and personalization). Examples will be provided on how these principles could be inserted into a planetarium successfully.

Table 10

Proposed Training Outline - Day 2

Time/Duration	Activity	Explanation
8:00 am (30 minutes)	Arrive	
8:30 am (15 minutes)	Review Objectives	
8:45 am (60 minutes)	Five CTML principles Lecturette	The five chosen CTML principles will be explained in an abbreviated lecture and playing the game 'Press Conference'.
9:45 am (60 minutes)	Jeopardy Review Game	Play a Jeopardy style game of CTML review.
10:45 am (20 minutes)	BREAK	
11:05 am (60 minutes)	Hit or Myth Game	Play a game of choosing true or false statements
12:05 pm (60 minutes)	LUNCH	
1:05 pm (90 minutes)	Do's and Don'ts poster	Working in small groups, create a poster of do's and don'ts (based on the five principles) for creating a planetarium lesson and present it to the entire class.
2:35 pm (20 minutes)	BREAK	
2:55 pm (90 minutes)	Planetarium Instruction	View CTML based lessons in an inflatable planetarium
4:25 pm (5 minutes)	Summary	Review of the day's events using a mock paper snowball fight.

To alleviate any boredom that may have set in due to the lecturette and to energize the training, a game of jeopardy will be played summarizing what the participants have learned thus far (Stolovitch & Keeps, 2011). Jeopardy is a television game where the game board has multiple columns representing different topics and under each topic is a set of questions assigned dollar values with increasing difficulty. The topics will be CTML Principles, How the Brain Works, Types of Cognitive Processing, Learning Theory, and to inject humor, Things you Find Under a Rock (random questions associated with trivial CTML facts). The class will be divided into two teams by dividing the room in half. The winning team will receive a candy treat.

The next activity is a game called “Hit or Myth” (Stolovitch & Keeps, 2011, p. 136) where the participants must choose between true or false statements. A list will be distributed to the same teams that were formed during the jeopardy game and the group must decide which statements are true and which are false. Each group will then develop five statements of their own. The list will be read aloud and points will be awarded to the groups that are able to determine which statements are true or false. The groups will then read their own list of five statements and they will earn points if they can convince the class that their statements are correct or incorrect.

After lunch the class will again be divided into random groups by reshuffling and redistributing the “Finding Famous Fictional Friends and Family” (Lawson, 2009, p. 238) index cards. Each group will be given one poster board and supplies to create a poster outlining what should and should not be included in a planetarium lesson according to the five CTML principles. This poster will serve as the basis for the participants bringing CTML based experience back to their work site. The posters will be presented to the class and a discussion will follow each presentation allowing additional learning to take place.

As on the first day, the class will participate in a CTML lesson presented in an inflatable planetarium. This lesson will contrast with the first day by adhering to CTML principles. It is the intent of this activity to provide examples of how to integrate CTML principles within a planetarium.

After the inflatable planetarium the participants will convene with a brief summarizing activity titled “Snowball Fight” (Matthews, 2012, p. 153). Each participant will be given several half-sheets of paper. Each person will be allowed to write questions about what they have learned on the half-sheets of paper, preferably one question per paper. Each half-sheet is crumbled into a ball and gently thrown around the room in a mock snowball fight. At the completion of the snowball fight participants pick up the nearest snowball, open the crumbled paper, and answer the question.

Day 3 – Training Activities. The third day will begin just as the first two days did, with a morning arrival period and a review of the training objectives. By now a routine will have been created and group norms will have been established (O'Carroll, 2012). Because of these established norms more active hands-on activities and group discussions have been planned as an alternative to lecurettes.

The first activity will be a group discussion asking what can be done to maximize the learning in a planetarium. The discussion will be open to any strategy that increases learning and does not have to include CTML principles. The point of this discussion is to draw out the existing expertise in the room and not rely on the knowledge of the trainer.

Following this activity a game called "Critical List" (Stolovitch & Keeps, 2011, p. 131) will be played. The participants will pair with their neighbors and create a list of why planetariums are important. This activity allows the participants to be subject matter experts (SME) and regain a sense of control over material they may already know (Lawson, 2009). Each pair's list will be presented and the trainer will create a common list of between 10-15 items on a flip chart. Playing in rounds, a pair team will select the most important item on the master list and receive a point from other groups that have selected the same item. During succeeding rounds a different pair group will have an opportunity to play. The winning pair group will receive a candy prize.

Table 11

Proposed Training Outline - Day 3

Time/Duration	Activity	Explanation
8:00 am (30 minutes)	Arrive	
8:30 am (15 minutes)	Review Objectives	
8:45 am (45 minutes)	Presentation Discussion	Facilitate a discussion asking what can be done to maximize what a person learns in a planetarium.
9:15 am (45 minutes)	Critical List Pair Work	Working with a partner, develop a list of reasons why planetariums are important.
10:00 am (20 minutes)	BREAK	
10:20 am (45 minutes)	Past-Practices Discussion	Facilitate a discussion asking if CTML has been observed prior to training.
11:10 am (50 minutes)	Lecture Team Quiz	A brief review lecture will be followed by group created questions and answers.
12:00 pm (60 minutes)	Lunch	
1:00 pm (90 minutes)	Planetarium Lesson	Working in small groups, storyboard an abbreviated planetarium lesson consistent with the five CTML principles and present it to the entire class.
2:30 (20 minutes)	Break	
2:50 pm (30 minutes)	Evaluations	Evaluation forms will be completed.
3:30 pm (50 minutes)	Closing	Discussion reviewing what has been learned over the last three days.

Following the break the trainer will facilitate a discussion asking if any of the participants have observed CTML principles in the past and were not aware of the significance. This discussion will tie into past observations and hopefully trigger insight into CTML based lesson development. Adult training has a better chance of becoming an everyday behavior when the new material can be tied into everyday work related experiences (Goad, 2010).

After the discussion the group will play “Lecture Team Quiz” (Stolovitch & Keeps, 2011, p. 138). A review lecturette will be presented that covers what the participants have learned over the last few days. The class will again be divided into groups based on “Finding Famous Fictional Friends and Family” (Lawson, 2009, p. 238) index cards. Once the lecturette is complete each team will create questions based on the lecturette and must prepare to answer questions themselves. Each group poses the question to the whole class. If the other group correctly answers the question than that group receives five points. If no group is able to answer the question, then the asking group receives two points. At the end of several rounds, the scores are totaled and the winning group earns a candy prize.

The last learning activity will be a group task of creating an abbreviated planetarium lesson using the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization). The group will need to decide on a topic to base the lesson on and what elements to include. The lesson will be created on paper as a storyboard, with each individual storyboard representing an individual event within the planetarium lesson. The lesson itself should be planned to occupy about ten minutes of time. When the groups have had adequate time to complete their storyboards they will present their lesson to the whole class.

The final task of this training program will be having the participants fill out an evaluation form, often referred to as ‘smile sheets’ (Matthews, 2012). A sample evaluation form is included in appendix D (Goad, 2010). This sort of evaluation is part of the reaction phase of program training evaluation (Stolovitch & Keeps, 2011) and measures the participant’s satisfaction with the course (Lawson, 2009). Kirkpatrick and

Kirkpatrick (2006) note the importance of this phase and believe that if the participants are not happy with the course they will not be motivated to learn and bring their new skills to the work place.

Many training programs end their session with a test (Lawson, 2009). However, since CTML knowledge is not a requirement within the planetarium education field no final assessment will be administered (Stolovitch & Keeps, 2011). This training session will close with a discussion of what CTML means to planetarium educators. This closing activity will measure what the participants have learned while attending the course and is referred to as the learning phase of evaluation (Matthews, 2012). Specifically, the trainer will ask the question ‘do you feel that CTML principles are worth integrating into planetarium lessons and how would you go about doing this?’. If there is remaining time an additional question could be asked ‘how could you go about integrating CTML principles into existing planetarium lessons?’. It is the goal of these summarizing questions to insert the knowledge gained into their memory one last time before they walk out the door (Matthews, 2012).

Post-Training. Training is by no means the end of learning (Stolovitch & Keeps, 2011). The true effort of this training is to change the behaviors of planetarium educators, have them adopt CTML principles in their working environment and measure the results of CTML introduction (Kirkpatrick. & Kirkpatrick 2006). Encouraging a change in behavior is something that post-training follow-up can foster and is part of the behavior phase of training program evaluation (Lawson, 2009; Matthews, 2012). Several weeks after the training has concluded a follow-up notice will be sent which summarizes CTML principles (serving as a reminder) and asks for feedback of how CTML integration is happening and is part of the behavior phase. Measuring results of CTML integration and any associated monetary benefits, as part of the results and ROI phase, may be difficult to determine unless observations of planetarium lessons can be arranged and an increase in planetarium revenues can be determined after the training has taken place (Goad, 2010; O'Carroll, 2012).

Roles and Responsibilities of Student and Others

The training sessions have been planned as if the training were to be facilitated by the lead researcher of this project (Matthews, 2012). The trainer will act as a facilitator of knowledge, allowing adults to learn and acquire the skills and knowledge rather than merely presenting and lecturing about the material (Goad, 2010). This project training will create a change in the learner; instruction will help participants generalize beyond the extent of the course what they have learned, and education will allow the students in the class to build mental models of what they have been taught (Stolovitch & Keeps, 2011).

It is the responsibility of the trainer to have the necessary skill to deliver the appropriate training (Lawson, 2009). There are many skills an adult trainer needs in order to be successful. First and foremost, a trainer for this project would need specialized skills in planetarium education and CTML principles (O'Carroll, 2012). Along with specific specialized skills, a trainer will need a strong ability to manage (planning, budgets, time, resources, funds, etc.), excellent communication skills (personal, group, electronic), experience with solving and analyzing problems (program development, training site, personnel), information literacy (search/find needed information), and computer/media experience (presentation, online, digital technology) (Goad, 2010).

Project Evaluation

Evaluation of this project will be based on the successful implementation of a three day professional development seminar highlighting five chosen CTML principles and their successful use in an inflatable planetarium. In the context of this project, the evaluation will be goal-based, with the following three goals; (a) train the science/astronomy teaching community about the research-based CTML design principles, (b) provide examples of what design elements to include and exclude based on selected CTML design principles, and (c) Provide addition training for science/astronomy teachers using an inflatable planetarium in effective content creation.

This project provided evidence for CTML design principles in an authentic classroom setting and the adult training project has similar potential. With the ever-increasing use and decreasing cost of multimedia, schools have another tool at their disposal for classroom instruction. This new tool of multimedia needs boundaries, or there is the potential for instructional harm (Mayer, 2009). CTML provides these boundaries and allows instructors the flexibility of using multimedia with the knowledge that this new media will help, not harm, learning. It has been the goal of this project to introduce CTML and provide positive social change to the local and planetarium educational community.

Implications Including Social Change

This project creates positive social change by providing science/astronomy teachers with technical training on how to create immersive multimedia presentations that have been proven to increase student learning. The outcome of this training should produce science/astronomy lessons that are of higher quality and provide better learning, thus intensifying awareness in astronomy. An increase in astronomy interest would relate to the problems established earlier regarding the lack of appeal of astronomy.

Local Community

Professional development modules were created to teach science/astronomy teachers the benefits of applying CTML principles to the design and development of planetarium instruction. The local community has the potential of realizing the benefit of scientifically crafted lessons designed to limit extraneous processing of needless information, promote essential processing of critical material, and encourage generative processing of accurate mental models (Clark & Mayer, 2011). The local community may directly benefit from this research by applying CTML theory in their own classroom and experiencing immediate tangible results regardless of the subject taught. CTML principles are designed to maximize the learning in a multimedia environment regardless of the specific subject (Mayer, 2009).

The local community of science/astronomy educators may also experience content-based training to current and potential owners of inflatable planetariums with the hope of increasing student learning and interest in astronomy. It has been an overarching goal of this project to increase awareness and interest in astronomy education. CTML based teacher training has the potential of increasing student learning while simultaneously increasing interest.

Far-Reaching

Any far-reaching implications of this project would most likely involve an impact on how lessons are presented in the classroom. The use of digital projection is increasing, due to improved performance and decreasing costs (Campos et al, 2011). This project could bridge the increasing use of media and digital projection with CTML design principles. Classrooms of the future may employ a higher standard of digital projection, manipulation, and integration than ever thought possible (Lakhani & Marquard, 2013). CTML has the ability to ground this future classroom in proven design principles that improve student performs regardless of the media chosen for presentation (Mayer, 2009).

Conclusion

The goal of this part of the project is to develop a three day professional development training session that; (a) trains the science/astronomy teaching community about research-based CTML design principles, (b) provides examples of which design elements to include and exclude, and (c) provide science/astronomy teachers additional training in designing effective content for inflatable planetariums. This training program will fill a gap between the knowledge and training provided to run of digital equipment in an inflatable planetarium and the lack of experience creating effecting multimedia lessons (Digitalis Educational Solutions, 2012; e-Planetarium, 2013; Matthews, 2012; Plummer, 2009; Star Lab, 2013,) The literature revealed that CTML is based on the idea that humans can receive two channels of input, one visual and the other auditory [dual-channel], have only a finite capacity to comprehend material [limited-capacity], and the human brain understands best when it is able to comprehend the material during correctly designed lessons [active-processing] (Clark & Mayer, 2011). Three types of cognitive loads influence learning, extraneous processing must be reduced, essential processing must be encouraged, and generative processing must be encouraged (Mayer, 2008).

This training will focus on five of the twelve principle of CTML [redundancy, spatial contiguity, temporal contiguity, pre-training, and personalization] (Mayer, 2009) and will follow the six assumptions of andragogy [need to know, readiness, experience, self-concept, orientation, and motivation] (Knowles, Holton, & Swanson, 2011). The program is designed around a five step training model of analysis, design, development, delivery, and evaluation (Lawson, 2009). Specifically the training will alternate activities to attempt to accommodate all types of learners (Goad, 2010). Three days of training will teach uses of inflatable planetarium how to correctly design lessons that maximize student learning (Mayer, 2009).

Section 4: Reflections and Conclusions

Introduction

My initial intention with Walden was to try out this degree and see what happens. I never had the intention of completing the program; in fact my initial experience with online learning was quite horrible. As I continued in the program my stubbornness and determination set in and I learned the value of scholarship. My largest boost in confidence set in when I found the project I wanted to pursue: astronomy education. To some extent the project found me.

Along with the value of scholarship, I have discovered the importance of professional teaching organizations and vendors. While attending the 2010 National Science Teachers annual conference (NSTA, 2010) I stumbled upon an inflatable planetarium vendor (Digitalis Education Solutions, 2012) and struck up a conversation. This conversation led to the idea of borrowing a very expensive piece of equipment (inflatable planetarium) to use as the basis of my project. This networking has introduced me to professional organizations (IPS, 2013) and other experts in the field of astronomy education research (Plummer, 2011) along with invitations to the Live Interactive Planetarium Symposium (2012) conference

Project Strengths

While conducting the initial literature review regarding CTML I stumbled upon an insight. CTML supposed that people learn best with word and pictures instead of words alone, which has major applications in public education, but has rarely been tested in authentic classrooms. The majority of the research has been tested on undergraduate students, using short lessons (15 minutes), and used a one teacher to one student ratio (Issa et al, 2011).

One of the primary strengths of this project was the application of CTML to young children in an authentic classroom where distractions are common and part of the everyday experience. The very uncontrolled environment, as opposed to the sanitary environment of university research (Clark & Mayer, 2011), in an authentic classroom is the very testing ground needed to legitimize CTML as a true educational theory worthy of inclusion in the classroom.

A second strength was the highlighting of astronomy education in an environment that is negating its importance. The pending adoption of Common Core Standards (Porter et al, 2011) has potentially limited the amount of astronomy education that will be stressed in K-12 schooling. The partially adopted standards (Wysession, 2012) see little benefit for college bound students to study astronomy. However, the Common Core Standards are a departure from California State Standards, since Common Core Standards dictate what a child should know (known as performance standards), not how to teach it, as the current standards now dictate (Porter et al, 2011). It is perfectly foreseeable that a teacher could use astronomy as the means to teach any of the required ends. Providing evidence for the support of astronomy education may have a positive impact on future education performance standards.

A third strength was the usage of CTML as a learning theory to assist in the design of planetarium lessons promoting learning, something not always found in planetarium lessons (Small & Plummer, 2010). CTML has the potential of becoming a de-facto framework for planning and designing digital multimedia planetarium experiences. In order for this to be realized, additional testing must be done using CTML design principles in planetariums.

Finally, this project provided missing training for individuals or schools that own or have recently purchased an inflatable planetarium. Inflatable planetarium manufacturers/distributors provide training in how to setup their equipment, but are unable to provide astronomy lesson development training (Digitalis Educational Solutions, 2012; e-Planetarium, 2013; Star Lab, 2013). This project provided professional development for these astronomy educators, using select CTML principles, on how to create lessons and maximize student learning.

Project Limitations

Looking at this project it becomes apparent that this project's findings are based upon two classes experiencing the inflatable planetarium. A more robust study would have replicated this study to multiple classes and perhaps multiple grade levels. Any number of instances may have attributed to the control group scoring higher than the experimental group that could have been eliminated or controlled statistically had more students participated. A second limitation may have been any unintentional bias introduced by the lead researcher performing the planetarium lesson. A more robust study would have employed a trained planetarium professional, who has experience narrating lessons and working with students. This experience may have created a study that has more generalizable results to the planetarium community. In the case of this project the lead researcher had to learn how to instruct in a planetarium while this study was being implemented. A trained planetarian may have negated this hurried training.

The planetarium may not be the best environment to test CTML theory. So many variables are present in an inflatable planetarium that these results generated by CTML are based on other conditions, not necessarily those controlled for in this study. A classroom might be a better environment for testing CTML due to a more controllable set of conditions. However, the elimination of an inflatable planetarium as the testing medium would decrease this study's value to the planetarium community.

Recommendations for Remediation of Limitations

The process of remediating the project's limitation would involve three suggestions or recommendations. Initially, the first recommendation for improving this project would be to perform this study on a larger population of students encompassing multiple grade levels. This would establish the findings with a stronger statistical base than with just two classrooms. A more exacting study using several hundred students would be a natural extension of this research and provide a more robust analysis.

Secondly, eliminating testing within an inflatable planetarium and using an established classroom setting would allow generalization of these findings to a wider audience, namely teachers working in classrooms using digitally projected media. Using a common classroom would eliminate any unnecessary excitement (Willoughby & Gustafson, 2009) and added attention that may result from instruction within an inflatable planetarium. While this would drastically alter the framework of this project, the elimination of the inflatable planetarium could remove an additional instructional variable.

Finally, any future studies should distance the lead researcher from the planetarium instructor by employing a planetarian to design and facilitate any and all planetarium instruction. This would free the lead researcher to concentrate on the merits of CTML and leave the lesson design to an expert with experience teaching in a planetarium. A trained planetarium instructor would have the experience and foresight to create a lesson that maximizes the student's instructional time under the dome. This segregation of duties would eliminate any possible bias interjected by the lead researcher into the planetarium lesson.

Scholarship

Prior to starting this program my view of scholarship was not very positive. I have worked in the classroom and believed this to be the pinnacle of teaching experience. I felt that scholarship was performed by people who need to find employment in the teaching profession, but couldn't teach themselves. I incorrectly found little value in scholarship inside my everyday teaching environment. My opinion was that you could eliminate all scholarship and administration in order to improve any local school site. The problem I had was that I did not have a clear understanding of how scholarship impacted my everyday teaching life.

I now understand that scholarship is about discovering and documenting new and successful strategies and sharing this new material with others. Scholarship is about conveying clear and accurate messages without emotion or bias. I believe that this newfound appreciation for scholarship stems from the fact that I now have something to say and wish to tell others about my discoveries.

Scholarship is about being honest, truthful, sincere, accurate, and unambiguous. Scholarship is a style of writing, as is poetry, biography, and fiction, which is necessary in our culture to develop, record, and disseminate new ideas. It is a noble pursuit that places myself in the company of Galileo, Newton, Einstein, and Hawking and one that I am proud to associate with.

Project Development and Evaluation

Over the course of the last eighteen months I have learned that project development success can be found in the details of the project. I found it quiet easy to develop and create the larger scope of the project, often referred to as ‘the big picture’. What I found tedious and difficult was implementing the finer details, or the minutia. I can recall many hours spent crafting specifics within the larger scope of an idea.

Since this is an area that I need to work on, it becomes critical to spend extra time crafting the overall project, insuring that the scope and function of the project are in place before I spend time working out the small details. A correct global vision for the project will ease frustration later on.

Through this program, and my project specifically, I have found that evaluation is the driving force for improvement. It is through critical reflection and evaluation that I have found my weaknesses that I need to improve upon. In the future I will endeavor to make sure that evaluation is part of any project.

Leadership and Change

I was of the belief that school leadership rested exclusively in the hands of the site vice-principal and principal. Since beginning this project I have found that leadership belongs to those that lead (regardless of their position). There is a tremendous amount of work to be undertaken by those who embrace the responsibility and perform the monotonous chores of everyday leadership. Real leadership is not about recognition or success, it is not found in grand speeches or as the host of award ceremony, but in the everyday toil of vision, preparation, and hard work. Since becoming a teacher leader I have observed the importance that a good site leader (principal) has in choosing a focus and identity of a school.

On a personal level I have a new desire to lead, but not a desire to leave the classroom and become an administrator, something that I once believed was mutually exclusive. Leading a training program studying CTML instruction and planetarium lesson development feels like a natural extension of my wish to lead. A training program provides an experience in leadership with the ability to provide a working theory, stripped of its controlled variables, applicable to the emerging technology of media.

Introducing CTML provides me with an opportunity to implement a new method of professional development, promising science/astronomy teachers the ability to learn new material in a safe and supportive environment. Acting as a program trainer cements my role in my school district as a researcher and as a trainer (something that does not exist at this moment) further distinguishing myself as a teacher leader and providing positive social change that I have contributed to.

Analysis of Self as Scholar

When I first began this journey to earn a doctoral degree my initial impression about scholarly writing was that these journal authors must be frustrated writers, without the ability to publish in real magazines, like Newsweek or Time Magazine. I also felt that APA style of writing was cruel with the sole intent of a sleeping aid. I have since performed a complete reversal in my opinion. It is now my feeling that scholarly journals are at the forefront of research and having the ability to read these articles places me in direct communication with the latest advancements in science and education. I am no longer tied to the interpretations of an author from a popular source, I am free to read and analyze the article directly.

I have also learned the importance of producing high quality work. If I am going to perform a task that has my name attached to it I need to insure that this product is of the highest quality possible, good enough is not good enough. I have learned not to count the hours that went into the product as an indication of quality, but rather the value the product contains. I believe that this doctoral journey caused me to mature to the level of adulthood and see what I am able to contribute to this world.

Post-degree I am planning on continuing my research. I feel a deep commitment to continue the path I have set upon. I look into the future and see myself publishing articles in professional journals and becoming a leading authority in astronomy education with respect to CTML and inflatable planetariums. My immediate plans are to publish this dissertation in a scholarly journal, focusing on astronomy education and to write a children’s book detailing an imaginary trip to a planetarium.

Analysis of Self as Practitioner

To my genuine surprise, I have discovered that research is a fun and rewarding option that can be performed outside of my teaching responsibility and provide recognition in worthwhile endeavors. I can see myself, a little bit each year, becoming more of a researcher and less of a teacher: slowly transferring my responsibilities and duties until I no longer recognize my current self. I plan on taking on smaller research projects, at first, and see where this new direction takes me.

While working and developing this project, a new goal has emerged for myself. I wish to become an astronomy education researcher for my local school district. This would involve finding additional projects to work on as I become proficient in this practice. One of the potential projects I would like to pursue is a research grant that enables me to purchase an inflatable planetarium and test the remaining design principles of CTML. I believe that a tested catalog of design principles vetted in an inflatable planetarium would be of immense value to the astronomy education community, specifically in regards to planetariums.

One of the most surprising things I have discovered is just how accessible experts are. I found that nearly all journal authors include their professional email address as their official point of contact, with the expectation of receiving questions and comments. I was initially intimidated by the prospect of contacting these authors. I realized that these experts are more than happy to talk about their research and assist anyone who asks. I was able to speak to an expert in planetarium education research, which lead to using CTML as my theoretical foundation.

After CTML had been selected I was able to receive input directly from CTML experts on how best to frame my research. In talking with these experts I learned that most of their research receives little acknowledgment outside of their small circle of influence and having someone ask fort their opinions was a huge treat. Professional collaboration turned out to be one of the best lessons that I have taken away from this project.

Analysis of Self as Project Developer

One of the most crucial elements that I have learned about project development and management is paying attention to the details. Grand ideas and lofty aspirations are worthy endeavors, but I found that projects could come to halt without careful consideration of the finer details. Care must also be taken to implement these details in a fashion consistent with the project's goals. I found that examining the specifics of a project had a tendency to alter the project into a different research study. Reexamining the purpose of the research and careful contemplation of the outcomes provided me with the wisdom to continue the pursuit.

The CTML Training Manual was an interesting piece to create. On one hand I was able to draw upon my recent expert knowledge on multimedia learning, while using my experience as a classroom teacher to create meaningful, engaging, fun lessons for adults. The best piece of advice I read was to treat adult like children while developing training scenarios (Matthews, 2012). Children need constant reassurances and support in order to perform adequately. Matthews (2012) notes that adults in unfamiliar setting, such as trainings, have many of the characteristics of an unsecure child. This advice reassured me that I now have the appropriate expertise to train adult learners.

The Project's Potential Impact on Social Change

This project's potential impact on positive social change involves the application of CTML as a viable learning theory in the development and design of lessons using multiple forms of media for the intent of grade level instruction and design guidelines for the planetarium community. With this research the intent was to introduce CTML theory to the actual population (grade school learners) the theory was intended to benefit. A bridge was hopefully created linking current research and its use of short lessons, one-on-one instruction, and undergraduate testing and authentic classrooms using distraction common to this format (Lusk, 2008; Muller, Lee, & Sharma, 2008; Ozdemir, 2009; Towler, 2009; Towler & Kraiger, 2008). It is possible, due to the increases use of media and digital projection, that CTML may gain in popularity, as did the Theory of Multiple Intelligences (Gardner, 1999) did almost fifteen years ago. Hopefully the conditions are right for CTML to become a commonly sought after set of development standards whenever a teacher wishes to use multimedia in the classroom.

Additionally, this project has brought design elements and guidelines to the planetarium community, providing form and structure to a learning format converting from analog to digital (Plummer & Small, 2011). It was a goal of this research to introduce CTML into an inflatable planetarium as a model for future lesson design using a digital model, capable of unlimited projection formats. Finally, the project used the findings of this research to introduce CTML as a design option, providing realistic examples about the benefits of CTML to science/astronomy instructors focusing on astronomy education.

Implications, Applications, and Directions for Future Research

If CTML does prove to be a viable theory for lesson design and development then it becomes imperative to provide teachers across America with the knowledge and tools to implement this theory in their classrooms whenever they are applying multimedia to instruction. It may be possible for CTML to become a mainstream learning theory in modern classrooms, thanks to its focus on the new trend of using multiple forms of media in the classroom. Additionally, this project promotes CTML design principles to science/astronomy educators through professional development.

A natural application of this project would be to pursue research grants that allow for the purchase of an inflatable planetarium and continue researching the other principles of CTML. It is possible, with an inflatable planetarium, to continue testing the additional

CTML design principles using local students to determine the relevance of this theory. Further testing of CTML would make this learning theory more attractive to the planetarium community and astronomy education researchers as an avenue worth continuing.

Future research should be focused on applying CTML design principles to authentic classrooms without tightly controlled variables. Issa, Schuller, Santacaterina, Shapiro, Wang, Mayer, and DaRosa, (2011) criticized CTML research as focusing on testing undergraduate students, in tightly controlled environments, using one-on-one teaching methods, with short (15 minutes) lessons. This sort of validation of theory is not consistent with K-12 classroom learning. If CTML is to have any chance to succeed, the theory must be applied to young children, using longer lessons (45-55 minutes), and be set in a classroom where distractions are common and the room is crowded with students.

Conclusion

This project applies an authentic application to CTML instructional strategies; while at the same time applies these theories to a science/astronomy curriculum that benefits from multimedia instruction (inflatable planetariums). The specific finding of this project could be improved if the instructional lessons were based on a larger student population. I have learned that scholarship is the backbone of research and research is the driving force of acquisition of new knowledge. Teacher leadership takes place informally with teachers wishing to improve their own practices and curriculum.

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Appendix A: Assessments

Planetarium Assessment: Pre-test

For some questions, there may be more than one correct answer. However, each question has only one best answer. Choose the single best answer from the five choices for each question.

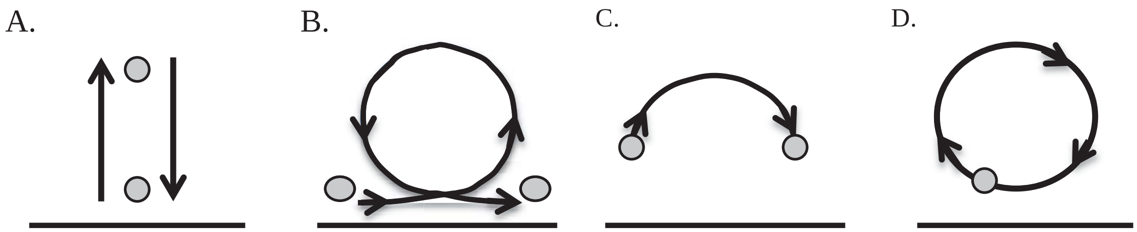
1. About what time of year would you have the most daylight?
    a. The first day of Spring
    b. The first day of Summer
    c. The first day of Fall
    d. The first day of Winter
    e. The length of daylight is the same all year.

2. Isabella looks outside and sees a full Moon. When should she look if she wants to see that it is full again?
    a. Three days
    b. About two weeks
    c. About one month
    d. One year
    e. Nobody knows because it changes often.

3. Imagine Earth had no air, rain, or clouds. What would the temperatures be like during the night?
    a. Temperatures at night would be the same.
    b. The night would get much hotter.
    c. The night would get much colder.
    d. The night would only warm up at the North and South Poles.
    e. There would not be any night.

4. Steve's bedroom window faces east. He woke up because the rising Sun was shining on him in bed. If Steve was in bed at sunset, would the setting Sun shine on him through the same window?
    a. No. The setting Sun could not shine through the same window.
    b. No. But the rising Sun will shine on him every clear morning.
    c. Yes. The setting Sun will shine through the window exactly as it did when it rose.
    d. Yes. But the Sun will be near the left edge of the window.
    e. Yes. But the Sun will be near the right edge of the window.

5. Which of the following best shows how the Sun moves over the course of a day?



a. A
b. B
c. C
d. D
e. The path of the Sun cannot be predicted.

6. Julia is sitting outside on a clear, dark night a few hours after sunset. Which direction in the sky must she look to be able to see stars?
   a. She will only see stars directly overhead.
   b. She must look in the direction the Sun rises.
   c. She must look where the Sun set.
   d. She must look along the horizon.
   e. She can look anywhere in the sky to see stars.

7. Earth would be covered with ice if we did not have:
   a. sunlight.
   b. the tilt of Earth's axis.
   c. volcanoes.
   d. human technology.
   e. the ozone layer.

8. You are outside on a clear night. You look overhead and see a bright star. If you looked overhead three hours later, you would expect to see:
   a. the star in the same place.
   b. the star farther east.
   c. the star farther west.
   d. the star would be no longer visible.
   e. It is impossible to know.

9. What is the largest source of heat for the surface of Earth?
   a. Volcanoes
   b. The ozone layer
   c. Cars, factories, and power stations
   d. The Sun
   e. Warm-blooded animals

10. On a dark moonless night far from any bright lights, how do the stars appear to be spread across the sky?
    a. In circular patterns.
    b. In square patterns.
    c. In triangular patterns.
    d. In other patterns (rectangles, spirals).
    e. Scattered unevenly.

11. One evening Nicholas looked up at the sky and noticed the positions of the Moon, some stars, and a cloud. Think about the distance to the Moon, stars, and clouds. Which picture best shows the order of these objects?

A: The stars are in front of the clouds and the cloud is blocking the Moon.

B: The Moon is in front of the cloud and the cloud is blocking the stars.

C: The cloud is in front of the Moon; the stars are in front of the Moon.

D: The cloud is in front of the Moon; the Moon is blocking the stars.

E: The Moon is in front of the stars; the stars are in front of the cloud.

12. As your eyes adjust to the darkness outside, you are able to see many stars overhead in the night sky. Which one of the following do you think you would see?
    a. The stars are all the same brightness.
    b. Stars can be found which are very bright, very dim, and everything in between.
    c. There is only one very bright star; all the rest are equally dim.
    d. Stars fall into only two classes, very bright or very dim.
    e. It is impossible to compare the brightness of stars.

13. At what time of night should you try to see the North Star?
    a. Early in the evening
    b. At midnight
    c. A few hours before sunrise
    d. Any time of night
    e. Never

Planetarium Assessment: Post-test

For some questions, there may be more than one correct answer. However, each question has only one best answer. Choose the single best answer from the five choices for each question.

1. What is the largest source of heat for the surface of Earth?
    a. Volcanoes
    b. The ozone layer
    c. Cars, factories, and power stations
    d. The Sun
    e. Warm-blooded animals

2. On a dark moonless night far from any bright lights, how do the stars appear to be spread across the sky?
    a. In circular patterns.
    b. In square patterns.
    c. In triangular patterns.
    d. In other patterns (rectangles, spirals).
    e. Scattered unevenly.

3. Earth would be covered with ice if we did not have:
    a. sunlight.
    b. the tilt of Earth's axis.
    c. volcanoes.
    d. human technology.
    e. the ozone layer.

4. At what time of night should you try to see the North Star?
    a. early in the evening
    b. at midnight
    c. a few hours before sunrise
    d. any time of night
    e. never

5. Imagine Earth had no air, rain, or clouds. What would the temperatures be like during the night?
    a. Temperatures at night would be the same.
    b. The night would get much hotter.
    c. The night would get much colder.
    d. The night would only warm up at the North and South Poles.
    e. There would not be any night.

6. You are outside on a clear night. You look overhead and see a bright star. If you looked overhead three hours later, you would expect to see:
    a. the star in the same place.
    b. the star farther east.
    c. the star farther west.
    d. the star would be no longer visible.
    e. It is impossible to know.

7. One evening Nicholas looked up at the sky and noticed the positions of the Moon, some stars, and a cloud. Think about the distance to the Moon, stars, and clouds. Which picture best shows the order of these objects?

A

The stars are in front of the clouds and the cloud is blocking the Moon.

B

The Moon is in front of the cloud and the cloud is blocking the stars.

C

The cloud is in front of the Moon; the stars are in front of the Moon.

D

The cloud is in front of the Moon; the Moon is blocking the stars.

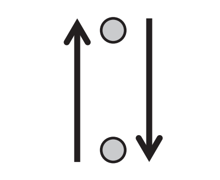
E

The Moon is in front of the stars; the stars are in front of the cloud.

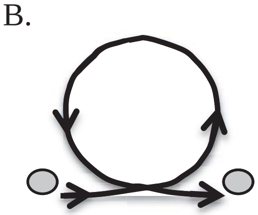
8. As your eyes adjust to the darkness outside, you are able to see many stars overhead in the night sky. Which one of the following do you think you would see?
    a. The stars are all the same brightness.
    b. Stars can be found which are very bright, very dim, and everything in between.
    c. There is only one very bright star; all the rest are equally dim.
    d. Stars fall into only two classes, very bright or very dim.
    e. It is impossible to compare the brightness of stars.

9. Which of the following best shows how the Sun moves over the course of a day?

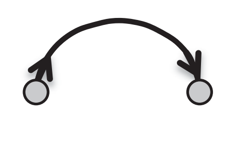
A.



B.



C.



D.

    a. A
    b. B
    c. C
    d. D
    e. The path of the Sun cannot be predicted.

10. Steve's bedroom window faces east. He woke up because the rising Sun was shining on him in bed. If Steve was in bed at sunset, would the setting Sun shine on him through the same window?
    a. No. The setting Sun could not shine through the same window.
    b. No. But the rising Sun will shine on him every clear morning.
    c. Yes. The setting Sun will shine through the window exactly as it did when it rose.
    d. Yes. But the Sun will be near the left edge of the window.
    e. Yes. But the Sun will be near the right edge of the window.

11. Isabella looks outside and sees a full Moon. When should she look if she wants to see that it is full again?
    a. Three days
    b. About two weeks
    c. About one month
    d. One year
    e. Nobody knows because it changes often.

12. Julia is sitting outside on a clear, dark night a few hours after sunset. Which direction in the sky must she look to be able to see stars?
    a. She will only see stars directly overhead.
    b. She must look in the direction the Sun rises.
    c. She must look where the Sun set.
    d. She must look along the horizon.
    e. She can look anywhere in the sky to see stars.

13. About what time of year would you have the most daylight?
    a. The first day of Spring
    b. The first day of Summer
    c. The first day of Fall
    d. The first day of Winter
    e. The length of daylight is the same all year.

Appendix B: Permission Form

Parent Permission Form

My name is Sean Gillette and I am a teacher at Vanguard Preparatory School in Apple Valley and a doctoral student from the Education Department at Walden University. Your child is invited to be in a research study about how children best learn in a planetarium. I am asking that your child take part because your child is of the age group (fifth grade) I want to study. I ask that you read this form and ask any questions you may have before agreeing to allow your child to take part in this study. This form is part of a process called "informed consent" to allow you to understand this study before deciding whether to allow your child to take part.

Background Information The purpose of this study is to find out how children best learn in an inflatable planetarium. An inflatable planetarium is similar in structure to a bounce house and shaped like an igloo. The inflatable planetarium has an opening that allows you to enter the interior of the dome. The ceiling becomes the projection screen and a digital projector will simulate the stars in the night sky. If you allow your child to take part, you child will view a 45 minute planned lesson in the planetarium and answer a short astronomy questionnaire about what they learned. The lesson will include instruction about the stars, moons, planets, and stellar motion and includes relevant fifth grade science standards covering astronomy (CA Fifth Grade Science Standards 5a, b, & c). The astronomy questionnaires will take about 20 minutes each.

Procedures: If you allow your child to be in this study, your child will be asked to:

- Answer a short astronomy questionnaire (20 minutes). This pre-test has been designed to gauge their astronomical understanding.
- Participate in a planetarium lesson (45 minutes). You child will be placed in one of two groups. One group will receive a standard planetarium lesson and the other will receive an enhanced planetarium lesson. The enhanced planetarium lesson will include additional interesting facts. The purpose of this study is to determine if these interesting facts distract from learning or increase attention.
- Answer a second astronomy questionnaire (20 minutes). This post-test has been designed to measure the amount of learning achieved in the planetarium.

Here is a sample question:

1. At what time of night should you try to see the North Star?
   a. early in the evening
   b. at midnight
   c. a few hours before sunrise
   d. any time of night
   e. never

Voluntary Nature of the Study: Your child's participation in this study is completely voluntary. Everyone will respect your decision of whether or not you want your child to be in this study. Of course, your child's decision is also an important factor. After obtaining parent consent, the researcher will explain the study and let each child decide if they wish to volunteer. No one at Sitting Bull Academy, Vanguard Preparatory School, Apple Valley Unified School District, or Walden University will treat your child differently if you or your child decides to not be in the study. If you decide to consent now, you or your child can still change your mind later. Any children who feel stressed during the study may stop at any time.

Risks and Benefits of Being in the Study: Being in this type of study involves some risk of the minor discomforts that your child might encounter in daily life such as nausea and disorientation. Since the projection screen encompasses 360 degrees of view some students may feel discomfort by the immersive sensation of the planetarium. The feeling of discomfort is only a visual sensation. The lessons have been specifically designed to minimize rapid screen movement that may cause this discomfort. Your student will be instructed on how to alleviate this sensation by closing their eyes and they will understand that at any time they may exit the dome. This study is scheduled to take place during non-academic school time, so your child will not be missing any pertinent classroom instruction. The benefits of this study include science instruction that may help on standardized testing.

Compensation: You or your child will not receive any financial compensation for participating in this project. Your child will receive a ‘thank you’ card at the completion of this study.

Privacy: Any information your child provides will be kept confidential. The researcher will not use your child’s information for any purpose outside of this research project. Also, the researcher will not include your child’s name or anything else that could identify your child in any reports of the study. The only time the researcher would need to share your child’s name or information would be if the researcher learns about possible harm to your child or someone else. Data will be kept secure and for a period of 5 years, as required by Walden University.

Contact and Questions: The researcher for this study is Sean Gillette. You may reach him at sean_gillette@avusd.org or 760-961-1066 extension 2819 (Vanguard Prep). The final project will be available for you should you wish to receive the findings. Please feel free to ask any questions you have now, or at any point in the future. If you want to talk privately about your child’s rights as a participant, you can call Dr. Leilani Endicott. She is the Walden University staff member who can discuss this with you. Her number is 1-800-925-3368 extension 1210. Walden University’s approval number for this study is 11-14-12-0186658 and it expires on 11/13/2013.

The researcher will provide an extra copy of this form for you to keep.

Statement of Consent: I have read the above information and feel I understand the study well enough to make a decision about my child’s involvement in this optional research project. By signing below I understand that I am agreeing to the terms described above.

Printed Name of Child	Printed Name of Parent	Parent’s Signature
Date of Consent	Printed Name of Researcher	Researcher’s Signature

Student Assent Form

Hello, my name is Sean Gillette and I am doing a research project to find out how children best learn in a planetarium. I am inviting you to join my project. I am inviting all fifth grade students to be in this study. I am going to read this form with you. I want you to learn about the project before you decide if you want to be in it.

WHO I AM:
I am a science teacher at Vanguard Preparatory School, just a few miles from here, and I am a student at Walden University. I am working on my doctoral degree.

ABOUT THE PROJECT:
If you agree to be in this project, you will be asked to:

- Complete a small test to find out what you know about astronomy.
- Learn about astronomy in an inflatable planetarium.
- Complete another small test to find out what you have learned in the planetarium.

Here is a sample question:

1. At what time of night should you try to see the North Star?
    a. early in the evening
    b. at midnight
    c. a few hours before sunrise
    d. any time of night
    e. never

IT'S YOUR CHOICE:
You don't have to be in this project if you don't want to. If you decide now that you want to join the project, you can still change your mind later. If you want to stop, you can.

Some kids get dizzy watching the stars move inside the planetarium. If you feel uncomfortable you can always close your eyes – you are not really moving. If you feel sick to your stomach you can leave the planetarium at any time. We are hoping this project might help others students in the planetarium. Remember, you are volunteering to help - you will not be paid for this project.

PRIVACY:
Everything you tell me during this project will be kept private. That means that no one else will know your name or what answers you gave. The only time I have to tell someone is if I learn about something that could hurt you or someone else.

ASKING QUESTIONS:
You can ask any question you want. If you think of a question later, you or your parents can reach me at sean_gillette@avusd.org or (760) 961-1066 then dial 2819. If you or your parents would like to ask my university a question, you can call Dr. Leilani Endicott. Her number is 1-(800) 925-3368 then dial 1210.

I will give you a copy of this form.

Please sign your name below if you want to join this project.

Name of Child	Child's Signature
Date	Researcher's Signature

Appendix C: Planetarium Lesson Excerpt

Speaking Script

Experimental Lesson - with seductive details (total runtime 37:00)
Brackets indicate additional photos assumed to be seductive details.

View of the Night Sky
File: sky_view(SD).sts

This is a view of the night sky from Earth. The air in our atmosphere causes the twinkling of the stars. Stars do not twinkle by themselves. This is what our stars would look like if we didn't have an atmosphere. See no twinkle. Let's return our atmosphere and the twinkling before we continue our journey. [1 – twinkle star]

<pause for twinkle to return>

If we travel back in time, long before the Internet, before television, before radio, before electricity, artificial lightning, and before books we reach a time when entertainment consisted of stories, when the night sky was available to everyone and stories where told about the stars. To make the stories about the stars interesting we needed characters. So the characters were drawn amongst the stars. [2 – clock, 3 – computer, 4 – television, 5 – radio, 6 – electricity, 7 – light bulb, 8 – book]

<pause for constellations lines to appear>

It might be easier to see these characters if we draw lines between the stars like dot-to-dot pictures. These pictures are called constellations and serve the function of guides to finding the stars. [9 - dot-to-dot picture]

<pause for boundaries>

Today modern astronomers don't use the constellation pictures as a guide, but rather the boundaries of each constellation. You see each constellation has a border, much the same way as countries have borders or fences. If any sort of event or discovery is found it is said to exist within that constellation's boundaries. [10 – fence]

<pause for planets>

Within our night sky we also can see the planets that orbit our Sun. [11 – saturn pic]

<pause until Ursa Major appears>

One of the better constellations to know is known as Ursa Major, the Great Bear. You may be more familiar with an asterism with the Great Bear known as the Big Dipper. The two stars at the edge of the cup of the dipper, known as Debhe and Merak are known as pointer stars and can be used to point to the North Star known as Polaris. [12 – bear, 13 – big dipper]

<pause until Polaris appears>

Polaris is key to knowing the night sky. Polaris sits right above the North Pole, sometimes known as where Santa lives and appears to never move in our night sky. [14 – north pole] It is always visible in our night sky.

<pause until Ursa Minor appears>

Polaris sits at the tail of Ursa Minor, or the Little Bear. You might know this constellation as the Little Dipper. The cup of the Little Dipper pours it's water into the cup of the Big Dipper and the water in the Big Dipper pours it's water back into the Little Dipper. [15 – bear_cub]

<pause until Draco appears>

Now each star in our night sky has a different brightness and we have a scale to numerically measure that brightness. Now this scale works in reverse - the brighter the star the smaller the number. This scale is called apparent magnitude. Let's look in the constellation Draco the Dragon. Here is the star Rastaban. Rastaban has an apparent magnitude of 2.78. A dimmer star, also in Draco, named 17 Draconis is dimmer, but with a large apparent magnitude of 5.06. The brighter stars have smaller numbers. This is Vega found in the constellation Lyra. Vega is one of the brightest stars in our night sky and it has an apparent magnitude of 0.0. Weird isn't it! [16 – dragon, 17 - harp]

<pause until the clouds appear>

Think of the night sky as layers, like the layers of an onion. The closest layer to us on the surface of the Earth is the cloud layer. These clouds help to keep our temperatures constant during the night. Beyond that layer is the Moon. Beyond the Moon are the planets. Beyond the planets are the stars and beyond the stars are other galaxies, like our galaxy the Milky Way. These galaxies have stars of their own. All these layers are visible in our night sky. Some are closer like the clouds and some are farther away like the galaxies. [18 – onion]

<pause until the stars move>

These layers appear to move in our night sky in different patterns. The stars all appear to move very slowly in the course of one night around the star

Polaris. Polaris seems to stand still. Ancient civilizations thought that the stars were moving. Today we know that the stars are fixed and the Earth is the one doing the rotating. This is known as apparent motion. Notice how the stars are spread evenly throughout the sky. If you were to look at one specific star you would see it moves to the west over several hours.

<pause until noon>

Now lets take a moment to understand why summer is so hot and winter is so cold.

<advance when the Sun stops moving>

Nightshade StratoScript Excerpt

Seductive Detail Lessons

```
#
# Sky View(SD)
# Sean Gillette
# July 13, 2012
#
# Files used: black.png, Direct2Brain.ogg, clouds.png, Moon.png
# SD Files used: twinkle_star.png, clock.png, computer.png, televison.png, radio.png,
electricity.png
# light_bulb.png, book.png, dot-to-dot.png, fence.png, saturn_pic.png, bear.png,
big_dipper.png
# north_pole.png, bear_cub.png, dragon.png, onion.png
#
clear state natural
flag script_gui_debug 1
#
# set date to July 1, 2012
date utc 2012:07:01T17:00:00
#
# Fade in
image action load name black filename black.png coordinate_system viewport alpha
1 scale 180
image name black alpha 0 duration 1
wait duration 3
#
# Play music file Direct2Brain2.ogg
audio action play filename Direct2Brain2.ogg output_rate 44000 volume 1 loop on
#
# Turn on atmosphere, landscape, candinal points, and star twinkle
timerate rate 0
```

```
flag atmosphere on
flag landscape on
flag cardinal_points on
flag star_twinkle on
#
wait duration 15
#
# Remove star twinkle
flag star_twinkle off
image action load name twinkle_star filename twinkle_star.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 15
#
# Return star twinkle
flag star_twinkle on
wait duration 4
#
# Turn on constellation art
image action drop name twinkle_star
image action load name clock filename clock.png coordinate_system horizontal
alpha 1 scale 50 altitude 35 azimuth 180
wait duration 4
image action drop name clock
image action load name computer filename computer.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 2
image action drop name computer
image action load name televison filename television.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 2
image action drop name televison
image action load name radio filename radio.png coordinate_system horizontal
alpha 1 scale 50 altitude 35 azimuth 180
wait duration 2
image action drop name radio
image action load name eletricity filename electricity.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 2
image action drop name eletricity
image action load name light_bulb filename light_bulb.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 2
image action drop name light_bulb
image action load name book filename book.png coordinate_system horizontal alpha
1 scale 50 altitude 35 azimuth 180
wait duration 2
```

```
image action drop name book
wait duration 10
flag constellation_art on
flag constellation_names on
wait duration 24
#
# Turn on constellation line drawing
flag constellation_art off
flag constellation_drawing on
wait duration 10
image action load name dot-to-dot filename dot-to-dot.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 3
image action drop name dot-to-dot
wait duration 5
#
# Turn on Constellation boundaries
flag constellation_drawing off
flag constellation_boundaries on
wait duration 15
image action load name fence filename fence.png coordinate_system horizontal
alpha 1 scale 50 altitude 35 azimuth 180
wait duration 8
image action drop name fence
#
# Identify planets in tonight's sky
flag constellation_names off
flag constellation_boundaries off
flag planets on
flag planet_names on
wait duration 12
image action load name saturn_pic filename saturn_pic.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 3
image action drop name saturn_pic
flag planet_names off
#
# Identify Ursa Major
flag cardinal_points off
select constellation uma
flag constellation_drawing on
wait duration 5
image action load name bear filename bear.png coordinate_system horizontal alpha
1 scale 50 altitude 35 azimuth 180
wait duration 7
image action drop name bear
```

```
image action load name big_dipper filename big_dipper.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 4
image action drop name big_dipper
flag constellation_art on
wait duration 15
flag constellation_art off
wait duration 1
flag constellation_names off
wait duration 1
flag constellation_drawing off
deselect constellation uma
wait duration 1
#
# Identify Polaris
select hp 11767 pointer on
wait duration 8
image action load name north_pole filename north_pole.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 5
image action drop name north_pole
#
# Select Ursa Minor
select constellation umi
flag constellation_drawing on
wait duration 10
flag constellation_art on
wait duration 5
image action load name bear_cub filename bear_cub.png coordinate_system
horizontal alpha 1 scale 50 altitude 35 azimuth 180
wait duration 5
image action drop name bear_cub
flag constellation_art off
wait duration 5
flag constellation_names off
wait duration 5
flag constellation_drawing off
deselect constellation umi
#
# Explain apparent magnitude
select constellation dra
flag constellation_drawing on
wait duration 22
image action load name dragon filename dragon.png coordinate_system horizontal
alpha 1 scale 50 altitude 35 azimuth 180
wait duration 4
```

```
image action drop name dragon
# Show Rastaban HP 85670 Apparent Magnitude 2.78
select hp 85670 pointer on
wait duration 18
flag constellation_drawing off
# Show 17 Draconis HP 81292 Apparent Magnitude 5.06
select hp 81292 pointer on
wait duration 18
# Show Vega HP 91262 Apparent Magnitude 0.00
select constellation lyr
wait duration 1
select hp 91262 pointer on
flag constellation_drawing on
wait duration 18
deselect constellation lyr
deselect hp 91262 pointer off
flag constellation_drawing off
#
# Layers of the night sky
image action load name onion filename onion.png coordinate_system horizontal
alpha 1 scale 50 altitude 35 azimuth 180
wait duration 10
image action drop name onion
# Show picture of clouds (closest layer)
image action load name clouds filename clouds.png coordinate_system viewport
alpha 1 scale 1
image name clouds alpha 1 duration 1
wait duration 10
# Show picture of full moon (middle layer)
image action drop name clouds
image action load name Moon filename Moon.png coordinate_system horizontal
alpha 1 scale 50 altitude 35 azimuth 180
image name Moon alpha 1 duration 1
wait duration 10
# Show planets
image action drop name Moon
flag planets on
flag planet_names on
wait duration 10
flag planet_names off
flag planets off
# Show stars
wait duration 10
# Show picture of other galaxies (farthest layer)
select nebula M31
wait duration 2
```

```
flag landscape off
zoom auto in duration 5
wait duration 10
zoom auto out duration 5
flag landscape on
wait duration 3
#
# Show the stars moving around Polaris
select hp 11767 pointer on
wait duration 5
timerate rate 500
wait duration 15
# Show planets and ecliptic
flag planet_names on
wait duration 10
flag ecliptic_line on
wait duration 150
timerate rate 0
#
# Call seasons1(SD)
script action pause
script action play filename seasons1(SD).sts
```

Appendix D: CTML Training Manual

The Cognitive Theory of Multimedia Learning and Planetarium Instructional Training Manual

by

Sean Gillette

Table of Contents

Course Description

This three day training course will focus on teaching current or potential planetarium educators about the benefits of instructional design for planetarium instruction. The course will cover how the brain works in multimedia environments, how to maximize the instructions and what design principles to incorporate to provide meaningful learning opportunities. Specifically the course aims to: 1) train the science/astronomy teaching community about the research-based CTML design principles, 2) provide examples of what design elements to include and exclude based on selected CTML design principles, and 3) provide addition training for science/astronomy teachers using an inflatable planetarium in effective content creation.

Course Objectives

Specifically this course will strive to accomplish the following goals during the three days of training.

1) Describe CTML theory with enough understanding to be able to use these principles in future planetarium lessons.
2) Recognize examples of poor planetarium lesson design to reinforce CTML theory in future planetarium lesson designs.
3) Construct a list of do's and don'ts, based on the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) that will guide the participants while generating planetarium lessons.
4) Explain the five chosen principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) with accuracy in order to use these principles to create an abbreviated planetarium lesson.

Course Syllabus

<u>Day 1</u>
Arrive
Movie Posters Icebreaker
Introductions / Objectives / Ground Rules
Examples of Poor Planetarium Lessons
BREAK
CTML Lecturette
CTML Crypto Cluster Game
Literature Review Jigsaw
LUNCH
Question Discussion
BREAK
Planetarium Instruction
Summary

<u>Day 2</u>
Arrive
Review Objectives
Five CTML principles Lecturette
Jeopardy Review Game
BREAK
Hit or Myth Game
LUNCH
Do's and Don'ts poster
BREAK
Planetarium Instruction
Summary

<u>Day 3</u>
Arrive
Review Objectives
Presentation Discussion
Critical List Pair Work
BREAK
Past-Practices Discussion
Lecture Team Quiz
Lunch
Planetarium Lesson
Break
Evaluations
Closing

Presenter's Notes

Pre-Training Activities (2 weeks prior to training)

Needed Supplies

welcome letter, questionnaire/survey, course outline, letter to supervisor

Directions

Assemble a package consisting of the welcome letter, questionnaire, and the course outline and send it out to the participants, four weeks prior to the training program. At that same time send the supervisor letter to the participants direct supervisor to educate them about the benefits of the training and what to expect when the participants have returned.

Steve Trainer
456 North Central Avenue
Los Angeles, CA 90015

<Today’s Date>

Joe Astronomer
123 South Planetarium Drive
New York, NY 10014

Dear Mr. Astronomer,

Subject: The Cognitive Theory of Multimedia Learning and Planetarium Instructional Training.

Thank you very much for your interest and scheduled participation in the Cognitive Theory of Multimedia Learning and Planetarium Instructional Training. We will be covering material related to the scientific understanding of learning in multimedia environments, which includes planetarium instruction. After completion of the training you should feel confident designing lessons that maximize the learning potential of students in a planetarium.

We will begin training on Month, Day 2013 at 8:00 am. The training site will be located at 8765 Main St. in Apple Valley, CA 92308, room 432. Continental breakfast, refreshments, snacks, and lunch will be provide each day of training. Please contact me directly if you have any special dietary needs. The training should conclude around 4:30 each day. Wi-Fi and internet access will be provide free of charge.

Attached you will find a brief questionnaire that will allow me to get to know your level of comfort and tailor a training program to your specific needs. Please fill out the questionnaire and return it. Also, you will find a course outline detailing the activities we will be doing over the scheduled three days. If you have any questions, please feel free to contact me at joe.trainer@train.com or 981-555-1234.

Sincerely,

Steve Trainer
Senior Training Consultant

The Cognitive Theory of Multimedia Learning and Planetarium Instructional Training Questionnaire

Please fill out and return prior to attending the training. All early submissions will be entered into a prize drawing. Thank you.

1) How long have you been involved with planetariums?

2) What role do you serve designing instruction for planetariums?

3) What do you hope to get out of this training?

4) Do you have any design philosophies for the creation of planetarium lessons? If so what are they?

5) Do you have any experience with the Cognitive Theory of Multimedia Learning (CTML)? Explain.

6) Do you have any future lessons planned which may need CTML design input?

7) What are you feelings toward training?

8) Is there anything you would like me to know about you?

The Cognitive Theory of Multimedia Learning and Planetarium Instructional Training Course Outline

The Cognitive Theory of Multimedia Learning (CTML) is a scientifically based learning theory that describes how people learn in a multimedia environment. This course will cover the basics of CTML theory, design principles, and integration into planetarium instruction. The training will focus on a varied approach to adult learning, attempting to cover a variety of learning styles. Specifically the course aims to: 1) train the science/astronomy teaching community about the research-based CTML design principles, 2) provide examples of what design elements to include and exclude based on selected CTML design principles, and 3) provide addition training for science/astronomy teachers using an inflatable planetarium in effective content creation.

The training will attempt to implement the following objectives:

1) Describe CTML theory with enough understanding to be able to use these principles in future planetarium lessons.
2) Recognize examples of poor planetarium lesson design to reinforce CTML theory in future planetarium lesson designs.
3) Construct a list of do’s and don’ts, based on the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) that will guide the participants while generating planetarium lessons.
4) Explain the five chosen principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) with accuracy in order to use these principles to create an abbreviated planetarium lesson.

The course schedule will be as follows:

<u>Day 1</u>

Arrive
Movie Posters
Introductions
Examples of Poor
  Planetarium Lessons
BREAK
CTML Lecturette
CTML Crypto Cluster
Game
Literature Review
Jigsaw
LUNCH
Question Discussion
BREAK
Planetarium Instruction
Summary

<u>Day 2</u>

Arrive
Review Objectives
Five CTML principles
  Lecturette
Jeopardy review game
BREAK
Hit or Myth Game
LUNCH
Do’s and Don’ts poster
BREAK
Planetarium Instruction
Summary

<u>Day 3</u>

Arrive
Review Objectives
Presentation Discussion
Critical List Pair Work
BREAK
Past-Practices
Discussion
Lecture Team Quiz
Lunch
Planetarium Lesson
Break
Evaluations
Closing

Steve Trainer
456 North Central Avenue
Los Angeles, CA 90015

<Today's Date>

Alex Supervisor
123 South Planetarium Drive
New York, NY 10014

Dear Mr. Supervisor,

Subject: Joe Astronomy attending Training Program

Thank you for supporting the Cognitive Theory of Multimedia Learning (CTML) and Planetarium Instructional Training. Joe Astronomy, under your direct supervision, will be attending this training program, which will cover material related to the scientific understanding of learning in multimedia environments, specifically planetarium instruction. After completion of this training Mr. Astronomer should feel confident designing planetarium lessons that maximize the learning potential of the participants.

This training will have the most benefit to your corporation if, upon return, you encourage Mr. Astronomer to put to use his new skill set in designing and implementing planetarium lessons. It may be beneficial to ask questions about what Mr. Astronomer learned during training. CTML contains specific design principles that aid in the creation of multimedia instruction; we will be applying these principles towards planetarium lessons. If you have any questions, please feel free to contact me at joe.trainer@train.com or 981-555-1234.

Sincerely,

Steve Trainer
Senior Training Consultant

Day 1 Activities - Movie Poster Icebreaker (30 minutes)
(Lawson, 2009; Movie Posters, 2013)

Needed Supplies

Movie Posters (movieposters.com), Flip Chart Paper, Markers

Directions

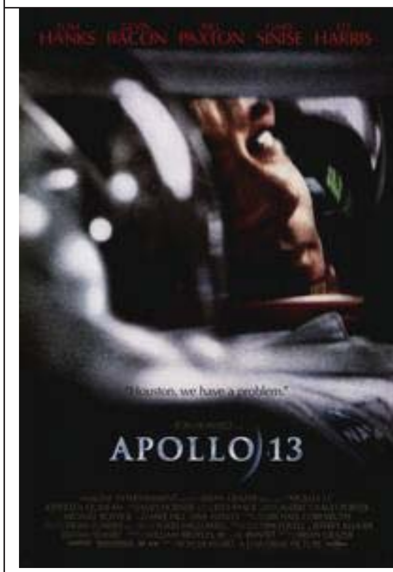
This activity will have three rounds; during each round the participants will select their three favorite posters, casing each round to have a different mix of individuals. At the end of each round the groups will be given a flip chart to create a poster summarizing what they learned. The posters will be presented after each round and hung around the room following the activity.

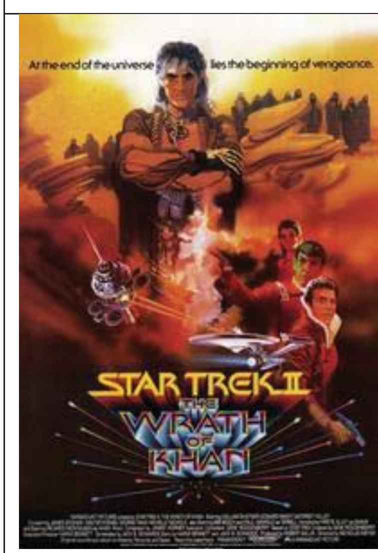
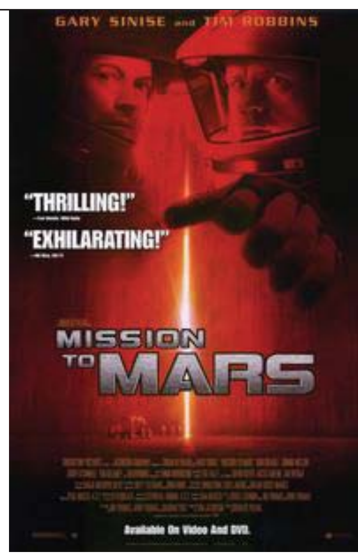
Round 1 - the participants will move to the movie poster that they most identify with (favorite), introduce themselves to the new group, by stating their name, where they live, and what their job is. The poster for the first round will include a list of names, with a circle round the person who traveled the farthest to attend this training.

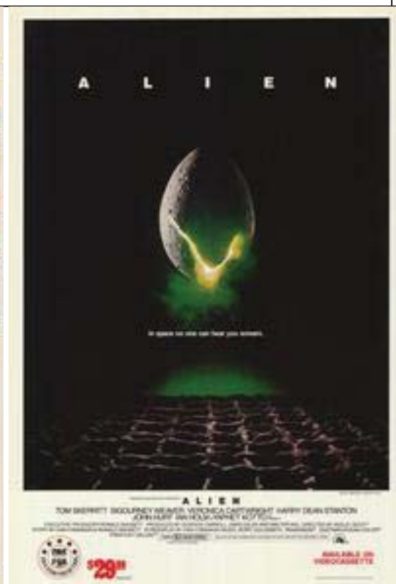
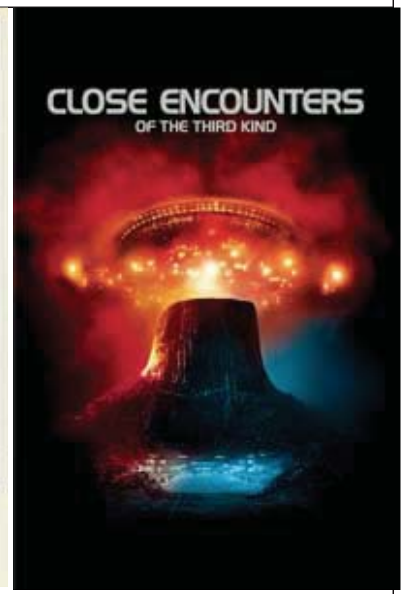
Round 2 - the participants will move to their second favorite poster and find something they each have in common with this new group. The second round poster will include a list of items the participants have in common.

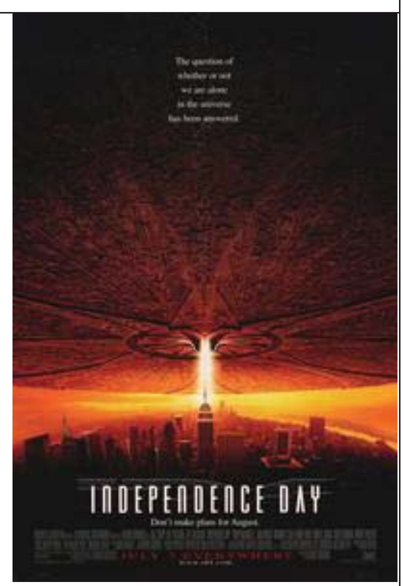
Round 3 - the participants are to move to their third favorite poster and create a list of concerns they may have with attending this training session. The third round poster should have a list of concerns and/or expectations they have about the training and perhaps items they are most interested in learning.

Suggested Movie Posters – order at moviepostershop.com

Apollo 13	Contact	Forbidden Planet
		

Star Trek	Mission to Mars	Star Wars
		

2001	Alien	Close Encounters
		

Silent Running	WALL-E	Independence Day
		

Movie Poster Icebreaker Handout

Look around the room and find your three favorite movie posters. This activity will have three rounds. Each round will require you to move to a different poster. At the end of each round you and members of your new group will create a poster that will be hung around the room.

Round 1 – Move to your favorite poster. Introduce yourself to the group by stating your name, where you live, and what your job is. The poster you create will have a list of names with a circle around who traveled the farthest.

Round 2 – Move to your second favorite poster. Create a list of activities or hobbies you have in common with the participants.

Round 3 – Move to your third favorite poster. Create a list of concerns or expectations you have regarding this training session. Congratulations – you many now hang your posters around the room.

Day 1 Activities – Introductions/Objectives/Ground Rules (30 minutes)

Needed Supplies

Flip Chart Paper, Markers

Directions

Read the Personal Story out loud to the group. Ask the participants if this was similar to their first visit to the planetarium.

Read the course objective to the class.

Using the flip chart brainstorm a session where the participants develop a set of ground rules to guide this course (i.e. - cell phones, emergencies, breaks, private discussions, etc.)

Personal Story - John T. Meader. The Planetarian, June 2006, Vol. 35, No. 2., page 31.

My First Planetarium Visit

My first visit to a planetarium was in April 1971 on a sixth grade field trip to Boston. It was a very exciting day. Growing up in central Maine, I, and most of my classmates, had never been to a city as big as Boston. The city itself was almost overwhelming. I have this vivid memory of riding through the streets of Boston in a school bus, windows down, with my twenty-five classmates singing Born Free at the top of our lungs. On that bright sunny April morning we felt as free and open to the world as we had ever been. We went to the New England Aquarium first, then on to the Museum of Science. We had no preparation for anything we saw that day. We were wide-eyed and sucking in everything: sea turtles at the aquarium, skyscrapers, and a melting pot of people of different races and cultural backgrounds that none of us had ever experienced in rural Maine.

The Museum of Science trumped our experiences that day with wonders none of us expected. The numerous interactive displays, the large T-Rex, and the giant Van de Graaff generators sent us through the roof. I'm surprised our teacher could even control us. Then at the very peak of our sensory overload they took us into this extremely bizarre room, the strangest place yet encountered.

The word planetarium meant absolutely nothing to any of us. After seeing the huge Van de Graaff generators and the lightning they produced, we knew that the machine centered in this large domed room was going to be magical. We didn't have a clue how. That moment of anticipation of the unknown has stuck with me to this day. None of us could have dreamed what was going to happen next. At that moment we'd already seen it all, everything the world had to offer, but we were unaware of the limit of our vision. Our day of discovery suddenly expanded beyond our immediate comprehension. When the lights dimmed and the stars came out we left the wonders of Boston behind and become lost in a galaxy of stars and planets. My small world suddenly grew beyond measure. I don't remember much about the star show itself, only the incredible wonder of it all.

We were riding a huge adrenaline rush all day, as excited as any group of school kids that I've ever experienced in my 28 years of teaching under a dome. The only thing I can remember the lecturer saying to us that day was to quiet down or he'd bring the lights back up. Can you imagine a planetarian ever threatening that!

Today whenever I have a group that can't get past the wonder of the stars enough to focus on the show's theme, I sometimes get frustrated, but I also understand what a profound moment those kids are having without me saying a word.

Course Objectives

1) Describe CTML theory with enough understanding to be able to use these principles in future planetarium lessons.
2) Recognize examples of poor planetarium lesson design to reinforce CTML theory in future planetarium lesson designs.
3) Construct a list of do's and don'ts, based on the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) that will guide the participants while generating planetarium lessons.
4) Explain the five chosen principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) with accuracy in order to use these principles to create an abbreviated planetarium lesson.

Day 1 Activities – Examples of Poor Planetarium Lesson Poster (30 minutes)

Needed Supplies

Flip Chart Paper, Markers

Directions

Working in small groups, create a poster listing examples of poor planetarium lessons that have been observed and present it to the class.

Divide the class into groups using the Finding Famous Fictional Friends and Family Cards. Cards have been created representing seven categories. The categories determine the groups (one category = one group). You can have a maximum of seven groups (create more categories if you wish to have more groups). The categories will not be on the cards, only the items included in the group. The number of cards in each category determines the size of each group. Cut out and attach each item and paste to a 3"X5" index card.

Pass out the cards and tell the participants that it is their responsibility to determine the groups based on the perceived categories. The leader of the group will be selected by determining which card is the most scientifically significant.

Planets

Mercury	Venus	Earth	Mars
Jupiter	Saturn	Uranus	Neptune

Stars

Polaris	Rigel	Mizar	Sun
Betelgeuse	Dubhe	Sirius	Vega

Constellations

Lyra	Ursa Major	Leo	Cancer
Pegasus	Bootes	Draco	Orion

Famous Astronomers

Newton	Galileo	Kepler	Copernicus
Brahe	Sagan	Hubble	Hawking

Moons

Moon	Titan	Phobos	Deimos
Io	Europa	Ganymede	Callisto

Moon Phases

Waxing Cresent	First Quarter	Waxing Gibbous	Full
Waning Gibbous	Third Quarter	Waning Crescent	New

Star Classifications

O Blue	B Blue	A Blue	F Blue to White
G White to Yellow	K Orange to Red	M Red	O Blue

Day 1 Activities – CTML Lecturette (20 minutes)
(Mayer, 2009)

Needed Supplies

CTML Lecturette PowerPoint, Cognitive Theory of Multimedia Learning Handout

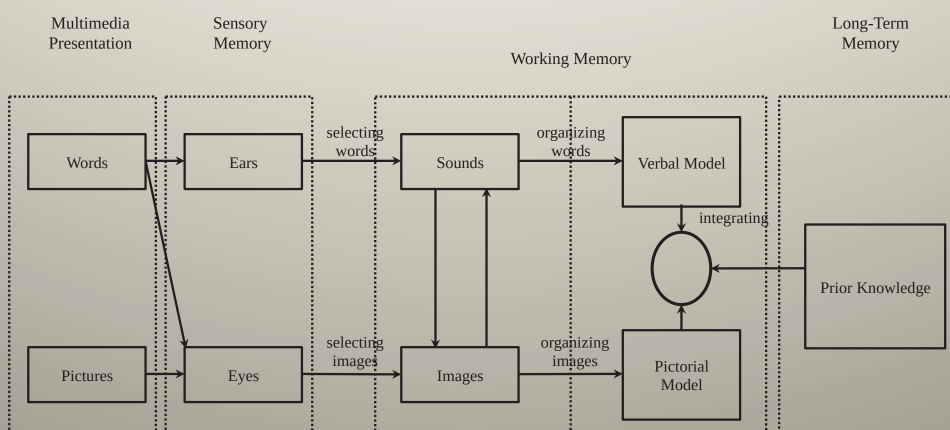
Directions

Present the CTML Lecturette to the participants.

Cognitive Theory of Multimedia Learning (CTML)

- People learn best from pictures and words, than from words alone.
- Two input channels for information: visual/ auditory (dual-channel).
- Too much information in one channel can overload the brain (limited-capacity).
- Properly designed lessons create ideal learning conditions (active processing).

Cognitive Theory of Multimedia Learning (CTML)



CTML Cognitive Loads

- While students learn, they are experiencing a cognitive process that places a stress or load on their mental faculties.
- Three types of cognitive load
  - Extraneous processing
  - Essential processing
  - Generative processing

Extraneous processing

- Learning of material that is not important to the instructional goal and can be exacerbated by poorly designed instruction.
- For effective learning to be achieved the instructional lesson must reduce extraneous processing.

Essential processing

- Learning of the most critical information; the learner is able to construct an effective mental model of the material.
- For effective learning to be achieved the instructional lesson must encourage essential processing.

Generative processing

- Organization and integration of new material with prior knowledge.
- For effective learning to be achieved the instructional lesson must foster generative processing.

CTML Promises

- CTML promises a set of instructional design principles that create meaningful learning, as depicted by good retention of the material and good transfer of information to new experiences.
- Extraneous processing can be decreased by the coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principle.
- Essential processing can be managed by the segmenting, pre-training, and modality principle.
- Generative processing can be increased by the multimedia, personalization, voice, and image principle

CTML Principles

	CTML Design Principle	Explanation	Assists Active Processing
1	coherence	Exclude extraneous material	Reduce extraneous processing
2	signaling	Highlight essential material	
3	redundancy	Remove on-screen text with narration	
4	spatial contiguity	Place printed text next to on-screen narration	
5	temporal contiguity	Present narration and animation simultaneously	
6	segmenting	Learner controlled pace	Increase essential processing
7	pre-training	Present essential material in an outline	
8	modality	Present text as spoken rather than printed words	
9	multimedia	Present word and pictures vs. words alone	Encourage generative processing
10	personalization	Conversational narration vs. formal narration	
11	voice	Human voice vs. computer voice	
12	image	Image of the narrator on the screen	

Cognitive Theory of Multimedia Learning Handout

Adopted from: Mayer, R. E. (2009). *Multimedia Learning: Second Edition*. Cambridge University Press. New York, New York.

- People learn best from pictures and words, than from words alone.
- Two input channels for information: visual/auditory (dual-channel).
- Too much information in one channel can overload the brain (limited-capacity).
- Properly designed lessons create ideal learning conditions (active processing).
- Three types of cognitive load
  - Extraneous processing - Learning of material that is not important to the instructional goal and can be exacerbated by poorly designed instruction.
  - Essential processing - Learning of the most critical information; the learner is able to construct an effective mental model of the material.
  - Generative processing - Organization and integration of new material with prior knowledge.

CTML Design Principles
Reduces extraneous processing
1) coherence - exclude extraneous material
2) signaling - highlight essential material
3) redundancy - remove on-screen text with narration
4) spatial contiguity - place printed text next to on-screen narration
5) temporal contiguity - present narration and animation simultaneously

Increases essential processing
6) segmenting - learner controlled pace
7) pre-training - present essential material in an outline
8) modality - present text as spoken rather than printed words

Encourages generative processing
9) multimedia - present word and pictures vs. words alone
10) personalization - conversational narration vs. formal narration
11) voice - human voice vs. computer voice
12) image - Image of the narrator on the screen

Day 1 Activities – CTML Crypto Cluster Game (40 minutes)
(Lawson, 2009; Stolovitich & Keeps, 2011)

Needed Supplies

Crypto Cluster Handouts, scratch paper, pencils/pens, candy

Directions

Pass out the Crypto Cluster Handouts to each group. Each group will receive a secret code that they will have to break. The letters in the code have been substituted with another letter. The groups will need to figure out the substitution to reveal the code. Provide hints when appropriate. Select a starting and stopping time. Reward the winning group with candy.

Key

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	a	b	c	d	e	f

People learn best from pictures and words, than from words alone
Vkuvrk rkgxt hkmz lxus voizaxkv gtj cuxjv, zngt lxus cuxjv grutk

While students learn, they are experiencing a cognitive process that places a stress or load on their mental faculties
Cnork vzajktzv rkgxt, znke gxk kdvkxoktiotm g iumtozopk vluikvv zngz vrgiky g yzxkyy ux rug jut znkox sktzgr lgiarzoky

For effective learning to be achieved the instructional lesson must reduce extraneous processing
Lux kllkizobk rkgxtotm zu hk ginokbkj znk otvzxaizoutgr rkvvut staz xkjaik kdzxgtkuay vxuikyyotm

For effective learning to be achieved the instructional lesson must encourage essential processing
Lux kllkizobk rkgxtotm zu hk ginokbkj znk otvzxaizoutgr rkvvut staz ktiuaxgmk kyyktzogr vxuikyyotm

For effective learning to be achieved the instructional lesson must foster generative processing
Lux kllkizobk rkgxtotm zu hk ginokbkj znk otvzxaizoutgr rkvvut staz luvzkx mktkxgzovk vxuikyyotm

The coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principle can decrease extraneous processing
Znk iunkxktik, vomtgrotm, xkjatjgtib, yvgzogr iutzomaoze, gti zksvuxgr utzomaoze vxotiovrk igt jkixkgvk kdzxgtkuav vxuikyyotm

Essential processing can be managed by the segmenting, pre-training, and modality principle
Kvvktzogr vxuikyyotm igt hk sgtgmkj he znk vkmsktzotm, vxk-zxgototm, znk sujgroze vxotiovrk

Generative processing can be increased by the multimedia, personalization, voice, and image principle
Mktkxgzobk vxuikyyotm igt hk otixkgykj he znk sarzoskjog, vkxyutgrofgzout, euoik, znk osgmk vxotiovrk

Handouts

Vkuvrk rkgxt hkmz lxus voizaxkv gtj cuxjv, zngt lxus cuxjv grutk

Cnork vzajktzv rkgxt, znke gxk kdvkxoktiotm g iumtozopk vluikvv zngz vrgiky g yzxkyy ux rug jut znkox sktzgr lgiarzoky

Lux kllkizobk rkgxtotm zu hk ginokbkj

znk otvzxaizoutgr rkvvut staz xkjaik

kdzxgtkuay vxuikyyotm

Lux kllkizobk rkgxtotm zu hk ginokbkj

znk otvzxaizoutgr rkvvut staz ktiuaxgmk

kyyktzogr vxuikyyotm

Lux kllkizobk rkgxtotm zu hk ginokbkj

znk otvzxaizoutgr rkvvut staz luvzkx

mktkxgzovk vxuikyyotm

Znk iunkxktik, vomtgrotm, xkjatjgtib, yvgzogr iutzomaoze, gti zksvuxgr utzomaoze vxotiovrk igt jkixkgvk kdzxgtkuav vxuikyyotm

Kvvktzogr vxuikyyotm igt hk sgtgmkj he znk vkmsktzotm, vxk-zxgototm, znk sujgroze vxotiovrk

Mktkxgzobk vxuikyyotm igt hk

otixkgykj he znk sarzoskjog,

vkxyutgrofgzout, euoik, znk osgmk

vxotiovrk

Day 1 Activities – Literature Review Jigsaw (45 minutes)

Needed Supplies

Multiple copies of CTML article

Mayer, R. E. (2010). Applying the science of learning to medical education. *Medical Education 2010*, *44*, 543-549. doi: 10.1111/j.1365-2010.03624.x

Directions

Use the Finding Famous Friends and Family cards to create new groups. Divide the article into sections so that each group gets a different part. Have each group read and summarize their part. The groups will present/teach their parts in order thus reviewing the entire article.

the cross-cutting edge

Applying the science of learning to medical education

Richard E Mayer

OBJECTIVE The goal of this paper is to examine how to apply the science of learning to medical education.

SCIENCE OF LEARNING The science of learning is the scientific study of how people learn. Multimedia learning – learning from words and pictures – is particularly relevant to medical education. The cognitive theory of multimedia learning is an information-processing explanation of how people learn from words and pictures. It is based on the idea that people have separate channels for processing words and pictures, that the capacity to process information in working memory is limited, and that meaningful learning requires appropriate cognitive processing during learning.

SCIENCE OF INSTRUCTION The science of instruction is the scientific study of how to help people learn. Three important instructional goals are: to reduce extraneous processing (cognitive processing that does not serve an instructional objective) during learning; to manage essential processing (cognitive processing aimed at representing the essential material in working memory) during learning, and to foster generative processing (cognitive processing aimed at making sense of the material) during learning. Nine evidence-based principles for accomplishing these goals are presented.

CONCLUSIONS Applying the science of learning to medical education can be a fruitful venture that improves medical instruction and cognitive theory.

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INTRODUCTION

Medical education should be informed by a research-based theory of how people learn (i.e. the science of learning) and evidence-based principles for how to design effective instruction (i.e. the science of instruction). Firstly, as an example of applying the science of learning to medical education, this article focuses on a research-based account of how people learn from words and pictures, namely, the cognitive theory of multimedia learning.[1,2] Secondly, as an example of applying the science of instruction to medical education, this article focuses on evidence-based principles for how to design multimedia instruction, including computer-based instruction.[3] Finally, in the conclusion, this article calls for future research that examines the conditions under which cognitive principles of multimedia instruction apply to medical education.

SCIENCE OF LEARNING: THE COGNITIVE THEORY OF MULTIMEDIA LEARNING

An introduction to the science of learning

An important goal of medical education is to foster learning in medical professionals. The science of learning is the scientific study of how people learn.[4] When the goal is to foster learning, it might be useful to understand how learning works.[4,5] In this article, one primary goal is to examine what it means to apply the science of learning to medical education.

Learning is a change in the learner's knowledge attributable to experience.[3–5] Changes in the learner's knowledge must be inferred by examining changes in the learner's performance. Knowledge includes facts and concepts (sometimes called knowledge in the narrow sense), procedures and strategies (sometimes called skills), and beliefs (sometimes called attitudes). Thus, whenever medical educators talk about learning, it is useful to pinpoint the knowledge that is to be changed in the learner.

Medical education often involves *multimedia learning*, which I define as learning from words and pictures.[1,3] In short, medical education often requires a combination of verbal and pictorial learning. *Verbal learning* involves learning with printed words (such as bullet points in a slide presentation or words printed in a textbook or on-screen text in a computer-based lesson) or spoken words (such as the speaker's voice in a slide presentation or the narrator's voice in a computer-based lesson). *Pictorial learning* involves learning with static graphics (such as illustrations, diagrams, photographs, drawings or charts) or dynamic graphics (such as animation or video).

A research-based theory of multimedia learning

Understanding how people learn from words and pictures has a special relevance for medical education. One of the most developed research-based theories of how people learn from words and pictures is the cognitive theory of multimedia learning.[1,3] This theory is based on three research-supported principles in cognitive science:

- the *dual channels principle*, which proposes that learners have separate channels for processing verbal and pictorial material;[6]
- the *limited capacity principle*, which proposes that learners can process only a few elements in each channel at any one time,[7,8] and
- the *active processing principle*, which proposes that meaningful learning occurs when learners engage in appropriate cognitive processing during learning, including attending to relevant material, mentally organising it into a coherent cognitive representation, and integrating it with prior knowledge activated from long-term memory.[5,9]

In short, human information processing has two channels, is limited in capacity and supports cognitive processing of incoming material.

Figure 1 shows the architecture of the human information-processing system as proposed by the cognitive theory of multimedia learning. There are three main boxes in Fig. 1:

- *sensory memory* holds an exact sensory copy of what was presented for a very brief time (i.e. < 0.25 second);
- *working memory* holds a more processed version of the input material for a short period (i.e. < 30 seconds) and can process only a few pieces of material at any one time, and
- *long-term memory* holds the learner's entire storehouse of knowledge for long periods of time.

Although sensory memory and long-term memory have unlimited capacity for holding information, working memory has limited capacity for processing information, which makes it act as a sort of bottleneck in the system. In working memory,

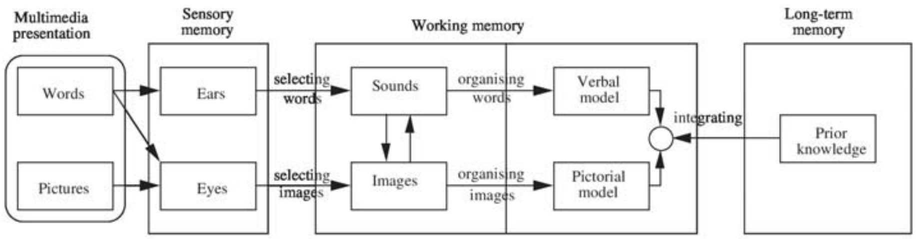

Figure 1 A cognitive theory of multimedia learning

material must be condensed and organised into meaningful chunks in order for the learner to work within the constraints of limited processing capacity. In short, people must be active learners who seek meaningful learning because they do not have the processing capacity to attend to every piece of information that is available to them.

Five main types of cognitive process are depicted in Fig. 1:

- *selecting words* refers to attending to important incoming spoken words for further processing in working memory;
- *selecting images* refers to attending to important incoming printed words and pictures for further processing in working memory;
- *organising words* refers to mentally rearranging the words into a coherent cognitive representation (i.e. a verbal model) in working memory;
- *organising images* refers to mentally rearranging the images into a coherent cognitive representation (i.e. a pictorial model) in working memory, and
- *integrating* refers to mentally connecting the verbal and pictorial models with one another and with relevant prior knowledge activated from long-term memory.

Meaningful learning from words and pictures occurs when the learner engages in these five cognitive processes during learning.

As indicated on the far left of the figure in the *instructional presentation* column, instructional material is presented that may contain spoken words, printed words and pictures. As indicated in the *sensory memory* column, the spoken words impinge on the ears and an auditory copy is briefly held in auditory memory, whereas the printed words and pictures impinge on the eyes and a visual image is briefly held in visual sensory memory. If the learner attends to some of the fleeting auditory representation in sensory memory, it moves to working memory, as indicated by the *selecting words* arrow. If the learner attends to some of the fleeting visual image in sensory memory, it moves to working memory, as indicated by the *selecting images* arrow. As indicated on the left of the *working memory* box, incoming spoken words are held as sounds, whereas incoming printed words and pictures are held as images; however, the arrow from Images to Sounds indicates that the printed words are converted to sounds for processing in the verbal channel. Next, as shown on the right of the *working memory* box, the learner mentally organises the words into a verbal model, indicated by the *organising words* arrow, and mentally organises the images into a pictorial model, indicated by the *organising images* arrow. Finally, relevant knowledge is activated from *long-term memory* and transferred to *working memory*; the learner connects the verbal and pictorial models with one another and with relevant knowledge activated from long-term memory, as indicated by the *integrating* arrow. As you can see, meaningful learning involves active cognitive processing (i.e. selecting, organising and integrating) within two information-processing channels (i.e. the auditory-verbal channel and the visual-pictorial channel) with limited capacity (i.e. working memory is limited in processing capacity).

SCIENCE OF INSTRUCTION: RESEARCH-BASED PRINCIPLES FOR MULTIMEDIA INSTRUCTION

An introduction to the science of instruction

Learners may need support and guidance in carrying out the cognitive processing described by the cognitive theory of multimedia learning in the previous section. Understanding how learning works is an important first step in medical education because instructional methods should be consistent with what we know about the human information-processing system. However, designing effective medical instruction also depends on understanding how instruction works, which is the focus of this section.

The science of instruction is the scientific study of how to help people learn.[4] Instruction is the teacher's manipulation of the learner's experiences in a manner intended to foster learning.[4] In short, instruction involves constructing situations for learners to experience that lead to an intended change in their knowledge.

The first step in designing effective instruction is to clearly specify the intended knowledge change in the learner.[10] An *instructional objective* is a clear statement of what knowledge is to be learned, the intended level of mastery, and how the learning will be assessed. For example, an instructional objective might be for the learner to be able to state the definition of 'instructional objective', which is an example of knowing a fact. Five kinds of knowledge are:

- *facts*: factual knowledge refers to knowledge about the characteristics of elements in the world, such as knowing that the right ventricle is a part of the heart;
- *concepts*: conceptual knowledge describes knowledge of models, principles, categories and schemas, such as knowing the cause-and-effect mechanism for how the human heart works;
- *procedures*: procedural knowledge consists of knowledge of step-by-step processes for how to carry out an action, such as knowing how to carry out long division computations;
- *strategies*: strategic knowledge consists of knowing general methods for approaching problems, such as by breaking a problem into parts, and
- *beliefs*: attitudinal knowledge refers to knowledge about how one's learning works or about one's competence as a learner, such as thinking: 'I am good at this.'

All of these types of knowledge are generally needed to be proficient in most cognitive tasks, such as arriving at a diagnosis.

Learning outcomes can be measured with retention tests and transfer tests. Retention tests measure how well the learner remembers the presented material, such as whether he or she is able to recall what was presented (e.g. 'Define retention test') or recognise what was presented (e.g. 'Remembering what was presented is an example of: [a] a retention test, [b] a transfer test'). Transfer tests measure how well the learner can apply what was learned to new situations (e.g. 'Generate a transfer test item for this section'). The learner's pattern of performance on retention and transfer tests indicates the quality of his or her learning outcome: *no learning* is indicated by poor performance on both types of test; *rote learning* is indicated by good performance on retention and poor performance on transfer, and *meaningful learning* is indicated by good performance on both types of test. My focus in this review is on meaningful learning.

In any learning situation there are three types of demands on the learner's cognitive system: extraneous processing; essential processing, and generative processing.[3,8] *Extraneous processing* is cognitive processing that does not support the learning objective and is caused by poor instructional design. For example, extraneous processing may be caused when text describing how the heart works is on one page of a book and the corresponding illustrations are on another page, so the learner has to waste precious cognitive processing resources by scanning back and forth between the words and the illustrations. An important instructional challenge is to reduce extraneous cognitive processing during learning, thereby freeing up cognitive capacity.

Essential cognitive processing describes the cognitive processing required to mentally represent the essential material from a lesson in working memory (mainly through the cognitive processes of selecting and minimal amounts of organising). It is caused by the inherent complexity of the essential material for the learner, so it is not appropriate to try to reduce essential processing. Instead, an important instructional goal is to manage essential processing so that it can be accomplished in ways that do not overload the learner's cognitive capacity.

Generative cognitive processing is cognitive processing aimed at making sense of the presented material (i.e. mainly the cognitive processes of integrating and organising) and is caused by the learner's motivation to understand the material. Even when learners have cognitive capacity available, they may not engage in deep learning because they are not motivated to do so. Thus, an important instructional goal is to foster generative processing.

In designing instruction, it is important to make sure that the learner's cognitive processing during learning does not exceed the learner's cognitive capacity. When there is too much extraneous processing because the instruction is poorly designed (which I call *extraneous overload*), the learner may not have enough remaining capacity to engage in needed generative processing and therefore does not achieve a meaningful learning outcome. An example of something that causes extraneous overload is a website on how to cope with cancer that presents an entire screen full of windows with flashing coloured frames, background photographs that are irrelevant, background sounds, animated words that fly across the screen and ongoing videos.

When extraneous processing is reduced but there is too much essential processing because the material is complex (which I call *essential overload*), the learner may not have enough remaining capacity to engage in meaningful learning. An example of something causing essential overload is a PowerPoint presentation on principles of genetics that goes at a fast pace for 20 minutes without pausing to allow the learner to digest the information delivered.

When extraneous processing is reduced and essential processing is managed, the learner may have processing capacity but not be motivated to use it to engage in meaningful learning (which I call *generative underutilisation*). Asking someone to take a computer-based course on how to use a new computer system when the person will never have to actually use the system and therefore has no interest in learning about it is an example of generative underutilisation. In short, these three types of instructional challenge suggest three major instructional goals, respectively: to reduce extraneous processing (in extraneous overload situations); to manage essential processing (in essential overload situations), and to foster generative processing (in generative underutilisation situations).

Research on instructional design of multimedia lessons

During the past 20 years, my colleagues and I at the University of California, Santa Barbara have been investigating evidence-based principles for how to accomplish these three instructional goals. We have conducted dozens of experimental comparisons in which we compare the retention and transfer test performance of people who learn from a lesson that is consistent with one of our principles versus from an otherwise identical lesson that is not consistent with the principle. The lessons are generally about how some biological, physical, or mechanical system works (such as how lungs work, how lightning storms develop, or how a tyre pump works) and are presented either on a computer screen (such as in a short narrated animation or a short PowerPoint presentation) or as a booklet (such as in eight pages of text and illustrations). The retention tests ask the learners to write down all they can remember in a limited amount of time (e.g. 'Please explain how the human respiratory system works'). We then tally the number of important idea units in the answer. The transfer tests ask the learner to write answers to troubleshooting questions (e.g. 'Suppose someone is having trouble breathing. What could have gone wrong?'), re-design questions (e.g. 'What could be done to improve on the human respiratory system?') or conceptual questions (e.g. 'Why does air enter the lungs?') in a limited amount of time. We then tally the number of acceptable solutions across all the transfer questions for each learner.

For each comparison, we compute the effect size – the difference between the mean test scores of the two groups divided by the pooled standard deviation – in order to create a common metric for expressing the strength of the effects. We are most interested in effect sizes ≥ 0.5 as these have practical significance for improving student learning. We include only experimental comparisons conducted in our laboratory and published in peer-reviewed original research journals.

Table 1 summarises evidence-based techniques for reducing extraneous processing, managing essential processing, and fostering generative processing. Each line presents the name, description, average effect size (ES) and number of comparisons (Tests) for an instructional design principle based on transfer test performance. The ES column contains the average of effect sizes across all the comparisons conducted for a particular principle. The Tests column indicates the number of positive effects out of the total number of comparisons made for each principle. For details about each experimental test and the specific instructional interventions, please see *Multimedia Learning*.[3]

The first section in Table 1 summarises three principles for reducing extraneous processing: the *coherence*, *signalling*, and *contiguity* principles. The coherence principle is that people learn better from multimedia lessons that exclude rather than include extraneous material. For example, people can learn better from black-and-white line drawings than from colour photographs, when interesting but irrelevant stories are deleted, or when stunning but irrelevant video is deleted. The signalling principle is that people learn better from multimedia lessons that highlight the essential material by using an outline, headings and

Table 1 Research-based principles for instructional design of multimedia lessons

Principle	ES	Tests
Principles for reducing extraneous processing		
Coherence principle: eliminate extraneous material	0.97	14 of 14
Signalling principle: highlight essential material	0.52	5 of 6
Contiguity principle: place printed words near corresponding graphics	1.19	5 of 5
Principles for managing essential processing		
Pre-training principle: provide pre-training in names and characteristics of key concepts	0.98	3 of 3
Segmenting principle: break lessons into learner-controlled segments	0.85	5 of 5
Modality principle: present words in spoken form	1.02	17 of 17
Principles for fostering generative processing		
Multimedia principle: present words and pictures rather than words alone	1.39	11 of 11
Personalisation principle: present words in conversational or polite style	1.11	11 of 11
Voice principle: use a human voice rather than a machine voice	0.78	3 of 3

ES = effect size

pointer words such as 'first,... second,... third'. For example, people will learn better from a lesson on how the heart works when it contains headings that correspond to each of the main steps in a process. The contiguity principle is that people learn better when printed words are placed near rather than far from corresponding portions of the graphic on the page or screen. For example, in a figure depicting the human heart, text describing each chamber should be placed next to the corresponding chamber.

The second section of Table 1 lists three principles for managing essential processing: the *pre-training*, *segmenting*, and *modality* principles. The pre-training principle is that people learn better from a multimedia lesson when they already know the names and characteristics of the key concepts. Thus, before receiving an explanation of the steps of how the human heart works, learners should receive pre-training in the names and characteristics of each major part. The segmenting principle is that people learn better when a continuous or large lesson is broken down into smaller, learner-paced segments. For example, in a computer-based, narrated animation on how the human heart works, the presentation can stop at major points and continue when the learner presses a CONTINUE button. The modality principle is that the words in a multimedia lesson should be spoken rather than printed, thereby offloading information from the visual-pictorial channel, which may be overloaded, onto the auditory-verbal channel, which is under-used.

The third section of Table 1 lists three principles for fostering generative processing: the *multimedia*, *personalisation* and *voice* principles. The multimedia principle is that people learn better from words and pictures than from words alone. For example, instead of explaining the steps in how the heart works solely in words, add a series of illustration frames showing each state of the heart. The personalisation principle is that people learn better when words are delivered in a conversational or polite form rather than in a formal or direct form. For example, people learn better when the narrator talks about 'your heart' rather than 'the heart'. The voice principle is that people learn better from computer-based multimedia lessons when the narrator speaks in a human voice rather than a machine voice. The rationale behind this is that people try harder to make sense of what a narrator is saying when they feel they are in a social partnership with the narrator.

CONCLUSIONS

My main goal in this article is to provide an example of what it means to apply the science of learning to medical education. This article is motivated by the idea that advances in cognitive science may have useful implications for how to design effective instruction in medicine.[11] For example, as medical education increasingly uses computer-based simulations of the human body, it is useful to conduct research on how to help people learn in simulated medical environments.[12] Overall, cognitive research on medical education is an important venue for improving both medical instruction and cognitive theories of multimedia learning.

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Day 1 Activities – Question Discussion (75 minutes)

Needed Supplies

Flip Chart Paper, Markers

Directions

Facilitate an open-ended discussion with the following questions. Make sure to pull thought provoking answers from the participants. Do not accept one word answers.

Questions

1) How do you think most planetarium lessons are designed in terms of student learning?
2) What could you do differently in a planetarium lesson to increase interest in astronomy?
3) What sort of structure should a planetarium lesson have?

Day 1 Activities – Planetarium Instruction (90 minutes)

Needed Supplies

Inflatable Planetarium, Digitalis Projection System running Nightshade Planetarium Software

Directions

Teach the following lesson in an inflatable planetarium to demonstrate a lesson without CTML design principles. The speaking script has been provided, the necessary files can be found at www.gillettelabs.com/planetarium_lessons.html

Lesson Speaking Script designed without CTML Design Principles (37:00)

View of the Night Sky
File: sky_view(SD).sts

This is a view of the night sky from Earth. The air in our atmosphere causes the twinkling of the stars. Stars do not twinkle by themselves. This is what our stars would look like if we didn't have an atmosphere. See no twinkle. Let's return our atmosphere and the twinkling before we continue our journey. [1 – twinkle star]

<pause for twinkle to return>

If we travel back in time, long before the Internet, before television, before radio, before electricity, artificial lightning, and before books we reach a time when entertainment consisted of stories, when the night sky was available to everyone and stories where told about the stars. To make the stories about the stars interesting we needed characters. So the characters were drawn amongst the stars. [2 – clock, 3 – computer, 4 – television, 5 – radio, 6 – electricity, 7 – light bulb, 8 – book]

<pause for constellations lines to appear>

It might be easier to see these characters if we draw lines between the stars like dot-to-dot pictures. These pictures are called constellations and serve the function of guides to finding the stars. [9 - dot-to-dot picture]

<pause for boundaries>

Today modern astronomers don't use the constellation pictures as a guide, but rather the boundaries of each constellation. You see each constellation has a border, much the same way as countries have borders or fences. If any sort of event or discovery is found it is said to exist within that constellation's boundaries. [10 – fence]

<pause for planets>

Within our night sky we also can see the planets that orbit our Sun. [11 – saturn pic]

<pause until Ursa Major appears>

One of the better constellations to know is known as Ursa Major, the Great Bear. You may be more familiar with an asterism with the Great Bear known as the Big Dipper. The two stars at the edge of the cup of the dipper, known as Debhe and Merak are known as pointer stars and can be used to point to the North Star known as Polaris. [12 – bear, 13 – big dipper]

<pause until Polaris appears>

Polaris is key to knowing the night sky. Polaris sits right above the North Pole, sometimes known as where Santa lives and appears to never move in our night sky. [14 – north pole] It is always visible in our night sky.

<pause until Ursa Minor appears>

Polaris sits at the tail of Ursa Minor, or the Little Bear. You might know this constellation as the Little Dipper. The cup of the Little Dipper pours it's water into the cup of the Big Dipper and the water in the Big Dipper pours it's water back into the Little Dipper. [15 – bear_cub]

<pause until Draco appears>

Now each star in our night sky has a different brightness and we have a scale to numerically measure that brightness. Now this scale works in reverse - the brighter the star the smaller the number. This scale is called apparent magnitude. Let's look in the constellation Draco the Dragon. Here is the star Rastaban. Rastaban has an apparent magnitude of 2.78. A dimmer star, also in Draco, named 17 Draconis is dimmer, but with a large apparent magnitude of 5.06. The brighter stars have smaller numbers. This is Vega found in the constellation Lyra. Vega is one of the brightest stars in our night sky and it has an apparent magnitude of 0.0. Weird isn't it! [16 – dragon, 17 - harp]

<pause until the clouds appear>

Think of the night sky as layers, like the layers of an onion. The closest layer to us on the surface of the Earth is the cloud layer. These clouds help to keep our temperatures constant during the night. Beyond that layer is the Moon. Beyond the Moon are the planets. Beyond the planets are the stars and beyond the stars are other galaxies, like our galaxy the Milky Way. These galaxies have stars of their own. All these layers are visible in our night sky.

Some are closer like the clouds and some are farther away like the galaxies. [18 – onion]

<pause until the stars move>

These layers appear to move in our night sky in different patterns. The stars all appear to move very slowly in the course of one night around the star Polaris. Polaris seems to stand still. Ancient civilizations thought that the stars were moving. Today we know that the stars are fixed and the Earth is the one doing the rotating. This is known as apparent motion. Notice how the stars are spread evenly throughout the sky. If you were to look at one specific star you would see it moves to the west over several hours.

<pause until noon>

Now lets take a moment to understand why summer is so hot and winter is so cold.

<advance when the Sun stops moving>

Seasons

Files: seasons1(SD).sts & seasons2(SD).sts

We are now sitting somewhere in France. The two lines placed on the dome will help us measure the path of the Sun.

This first measurement will take place on the Fall Equinox, which is on usually on September 22. On this day the Earth experiences 12 hours of day and 12 hours of night. You can see the path of the Sun on this day as it arcs across the sky. Notice how the rising Sun is in a different location than the setting Sun.

<pause until the next day>

The next measurement happens on the Winter Solstice, which takes place around December 21. On this day Earth experiences the shortest day of the year and the longest night. Notice how much lower the Sun is in the sky. The Earth is not experiencing the full effect of the Sun's rays. Also, the short day only allows the Sun to heat the Earth for a short amount of time. The reasons it is so cold in winter is that the angle of sunlight along with the short days provides little warmth to the Earth. You can make snowmen in winter. [19 – winter]

<pause until the next day>

Now lets look at what the Winter Solstice looks like from space.

<pause until the Earth starts rotating>

The Northern Hemisphere is located in this direction and we live about here. As the day progresses notice how little sunlight we are receiving. This translates to cold temperatures. Without the Sun shining on us, the planet Earth would be completely covered in ice.

<advance when the Earth stops rotating>

Let's return to Earth and look at two other dates.

This next measurement will take place on the Spring Equinox, which is usually on March 20. On this day the Earth experiences 12 hours of day and 12 hours of night. You can see the path of the Sun on this day as it arcs across the sky.

<pause until the next day>

This next measurement takes place on June 21, the first day of summer. On this day the Earth experiences the longest day and the shortest night. Notice how much higher the Sun is in the sky. The Earth is now experiencing the full effect of the Sun's rays. This longer day, amplified by the angle of sunlight allows the Earth to absorb more of the heat from the Sun producing hotter weather. School is canceled for summer. [20 – summer]

<pause until the Earth starts rotating>

Now lets look at what the Summer Solstice looks like from space.

The Northern Hemisphere is located in this direction and we live about here. As the day progresses notice how much more sunlight we are receiving. This translates to hot temperatures.

<advance when the Earth stops rotating>

Now lets talk about an interesting occurrence between the Sun, Earth, and Moon.

Eclipses

Files: Eclipses(SD).sts

Every few years the Sun, the Earth and the Moon will form a straight line that can obscure the view of either the Sun or the Moon. We call these alignments eclipses. Not to be confused with the movie Eclipse [21 – Eclipse_movie]. Does the fifth grade watch these movies, how many girls are on Team Edward [22 – team_Edward], how many are on Team Jacob [23 – team_Jacob]?

A Solar Eclipse occurs because the Moon is between the Sun and the Earth and casts a shadow on the Earth like this cat's shadow [24 – shadow]

<pause for rising Sun>

If you are standing on the Earth and it that shadow it looks something like this. See the Sun rising and causing daytime, but as the Moon passes in front of the Earth the shadow causes a brief moment of darkness.

<pause for zoom to Sun>

If we look closer at the Sun we can see the Moon passing in front of the Sun.

<pause for view from space>

From space the shadow upon the Earth looks something like this.

<pause for diagram>

A lunar eclipse occurs when the Earth is between the Sun and the Moon and casts a shadow upon the Moon just like Peter Pan has a shadow. [25 – peter pan]

<pause for view of the Moon>

On the surface of the Moon a Lunar Eclipse looks something like this. It takes several hours to progress through a Lunar Eclipse. At the peak of the eclipse the Moon appears red. That is caused by the Sunlight bending through the Earth's atmosphere [26 – lunar_eclipse2, 27 – bent_light]. As the light bends it turns to a red color. A Full Lunar Eclipse is sometimes called a Blood Moon. That sure sounds like a title for a Twilight Movie [28 – twilight].

<pause when the lunar eclipse is complete>

Now lets take a trip within our Solar System and see the major planets within it.

<advance when the edge of the Earth becomes visible>

The Solar System
Files: solar_system1(SD).sts & solar_system2(SD).sts

Here we see a view of our entire Solar System. At the center of our Solar System is our star named the Sun. The Sun is the ultimate source of heat and energy for all of Earth. Surrounding the Sun are eight planets. The closest planets are hard to see. They're very small compared to the other planets.

The four largest planets in the Outer Solar System are Jupiter, Saturn, Uranus, and Neptune.

<pause for zoom>

Now lets look at the closest planets in the Inner Solar System. The Inner Solar System has four planets named, Mercury, Venus, Earth, and Mars.

Let's look at each planet in greater detail.

At the center of our Solar System is our star named the Sun. It makes up 99.9% of all the mater in our Solar System. Our Sun may seem large to us, but it is small compared to other stars.

<pause for zoom>

The closest planet to our Sun is Mercury. Mercury is sort of an odd planet. Large collisions have ripper the outer layer away and Mercury is made of core material. [29 – mercury god]. Mercury is named for the messenger of the gods because Mercury zooms across our night sky.

<pause for zoom>

The next closest planet is Venus. Venus is the hottest planet. It has a thick layer of clouds that completely surround the planet and keep it warm. A lot like a thick blanket. [30 – venus god]. Venus is named for the god of love because in our night sky Venus is the brightest and most beautiful object.

<pause for zoom>

Next is Earth. Hopefully you are experts at Earth, since this is your home. [31 – earth cartoon]

<pause for zoom>

Our nearest neighbor is the Moon. [32 – moon cressent]. A crescent is sometimes used to represent the Moon.

<pause for zoom>

Past Earth is Mars. Mars is named for the god of war because Mars appears red due to the rusting iron on its surface. Red is the color of blood and war. We've visited Mars a lot recently. Right now a huge rover the size of a car, named Curiosity, is driving around exploring Mars. [33 – mars god, 34 – curiosity, 35 - martian].

<pause for zoom>

Now we leave the Inner Solar System and venture to the Outer Solar System.

The king of all the planets is Jupiter. Jupiter is the largest planet in our Solar System. [36 – Jupiter god]. Jupiter is the largest planet and is named after the Roman King of the Gods.

<pause for zoom>

Past Jupiter is the most beautiful planet in our Solar System Saturn. Saturn has wonderful rings that were made when a comet ventured to close to Saturn and Saturn's gravity ripped the comet to shreds and made the rings. [37 – saturn2 god]. Saturn is the Roman god of agriculture and time. It is the slowest planet to move across our night sky.

<pause for zoom>

Beyond Saturn is Uranus. Uranus is the Greek god of the sky and it has nothing to due with anyone's behind. Uranus can be pronounced 'Your-a-nus' or 'Your-anus'. Both are correct, but 'Your-a-nus' is more polite. [38 – uranus god, 39 – bart simpson, 40 – neptune god].

<pause for zoom>

Beyond Uranus is Neptune. Neptune was struck sometime in the past and now Neptune orbits on it's side.

Neptune is the Roman god of the sea. Scientists chose that name because of Neptune's blueish color.

<pause for zoom>

Way past Neptune is little dwarf planet called Pluto. [41 – pluto god, 42 – pluto dog, 43 – hades]. Pluto was thought to be the farthest and coldest planet and was named after the Roman god of the underworld. Pluto was not named after Mickey Mouses' pet dog Pluto. You may remember Hades from the Disney cartoon Hercules.

Lunar Cycle
Files: lunar_cycle(SD).sts

Now let's look at our nearest neighbor – the Moon. The Moon orbits the Earth and because it has a day and a night side, just like Earth, we see only part of the surface in a cycle that last about a month.

When we see only the night side of the Moon we can barely see anything. This part of the cycle is called the New Moon. It is nearly invisible like Harry Potter's cloak of invisibility. [44 – cloak]

When we see a small part of the day side of the Moon we call this phase a Crescent. It looks like a monster took a bit out of a cookie. [45 – cookie, 46 – cookie monster]

When we see half of the day side of the Moon we call this a quarter Moon because we are a quarter of the way through the cycle. It should be called a half Moon, but the name refers to the Moon being only ¼ or 1 quarter of the way around the Earth. Just like a quarter represents ¼ of a dollar a Quarter Moon represents ¼ of the lunar cycle. [47 – quarter]

As the Moon progresses around the Earth we see more of the dayside. When we see more dayside than night side we call this a Gibbous Moon. A Gibbous Moon sort of looks like a deflated soccer ball. [48 – soccer_ball]

When we see the entire day side of the Moon we call this a Full Moon. Many stories can be told about seeing a Full Moon. A Full Moon calls of tales of wolves or worse... werewolves! [49 – wolf, 50 – werewolf]

The cycle then continues, but in reverse order. We start seeing less of the day side of the Moon each time. When we see more day then night the Moon is called a Gibbous Moon. A Gibbous Moon resembles a deflated basketball. [51 – basketball]

When we see half day and half night the Moon is called a Three-Quarter Moon because it is three quarters through its cycle. Just like 3 quarters represent 75 cents, a Three-Quarter Moon represents 75% of the lunar cycle. [52 – 3 quarter]

When we see just a sliver of the day side of the Moon we call it a Crescent. A Crescent Moon looks like a French Croissant – YUM! [53 – croissant]

Finally the Moon returns to its start as a New Moon in a cycle that last about a month. It is no coincidence that the word month and moon sound alike.

This is what the cycle would look like from space. When the Moon is getting brighter we call it a Waxing Moon. When the Moon is getting darker we call it a Waning Moon.

Here we see a New Moon.

Waxing Crescent,

Waxing First Quarter,

Waxing Gibbous,

Full Moon,

Waning Gibbous,

Waning Third Quarter,

Waning Crescent,

and return to a New Moon.

This concludes our planetarium show.

Day 1 Activities – Summary (20 minutes)

Needed Supplies

Paper, pencils/pens

Directions

Have each participant create a mnemonic sentence to help remember the twelve design principles of CTML: 1) coherence, 2) signaling, 3) redundancy, 4) spatial contiguity, 5) temporal contiguity, 6) segmenting, 7) pre-training, 8) modality, 9) multimedia, 10) personalization, 11) voice, and 12) image. When completed participants can quickly read their sentence.

Example

Can someone remove silly temptations so papa may melt pretty violet ice?

coherence, signaling, redundancy, spatial contiguity, temporal contiguity, segmenting, pre-training, modality, multimedia, personalization, voice, image

Day 2 Activities – Review Objectives (15 minutes)

Needed Supplies

Paper, pencils/pens

Directions

Review the objectives of the training to focus the participants at the required learning. Identify any course objective that have been met or partially accomplished.

Course Objectives

1) Describe CTML theory with enough understanding to be able to use these principles in future planetarium lessons.
2) Recognize examples of poor planetarium lesson design to reinforce CTML theory in future planetarium lesson designs.
3) Construct a list of do's and don'ts, based on the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) that will guide the participants while generating planetarium lessons.
4) Explain the five chosen principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) with accuracy in order to use these principles to create an abbreviated planetarium lesson.

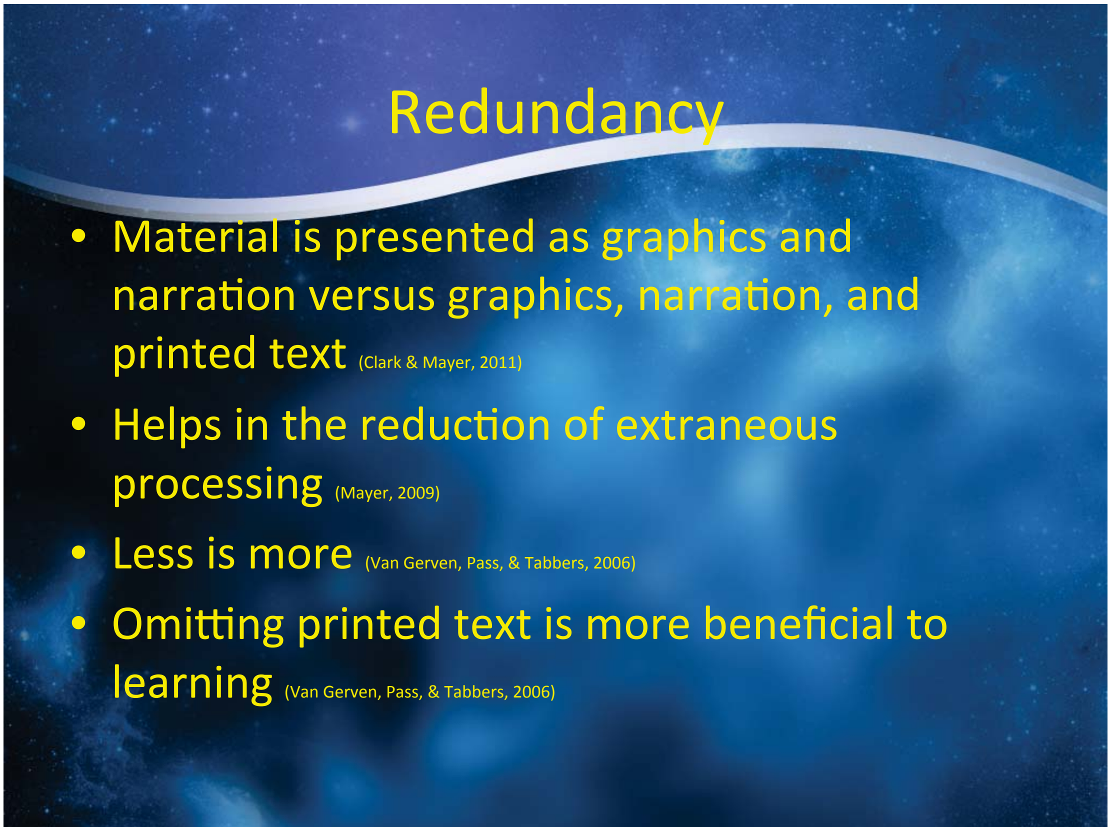
Day 2 Activities – Five CTML Principles Lecturette (60 minutes)

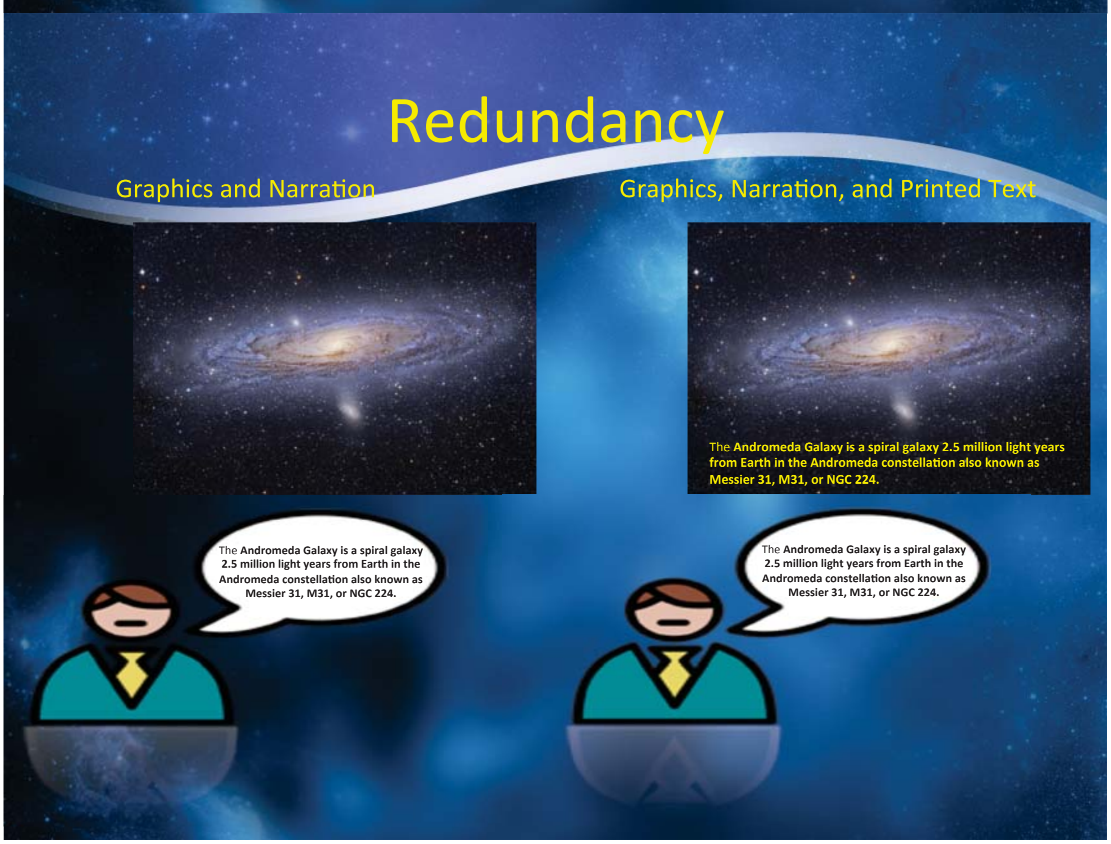
Needed Supplies

Paper, pencils/pens, Five CTML Principles Handout

Directions

Present the Five CTML Principles Lecturette to the participants.


Redundancy
Material is presented as graphics and narration versus graphics, narration, and printed text (Clark & Mayer, 2011)
Helps in the reduction of extraneous processing (Mayer, 2009)
Less is more (Van Gerven, Pass, & Tabbers, 2006)
Omitting printed text is more beneficial to learning (Van Gerven, Pass, & Tabbers, 2006)


Redundancy
Graphics and Narration
Graphics, Narration, and Printed Text
The Andromeda Galaxy is a spiral galaxy 2.5 million light years from Earth in the Andromeda constellation also known as Messier 31, M31, or NGC 224.
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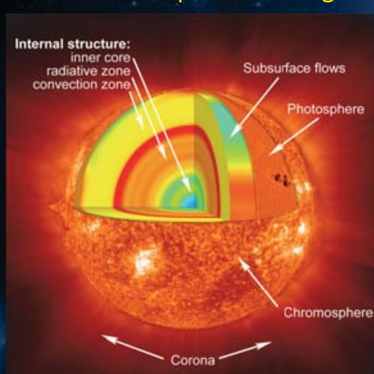
Spatial Contiguity

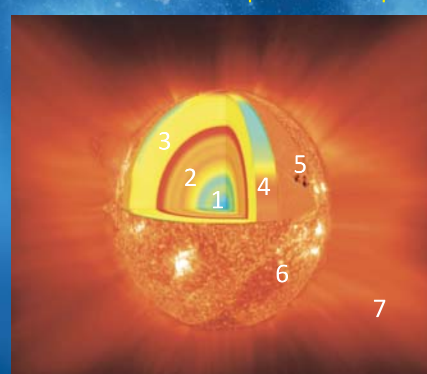
- Related words and pictures are presented closer together (Johnson & Mayer, 2012)
- Assists in the reduction of extraneous processing (Mayer, 2009)
- Applies more to new learners than high-knowledge learners (Mayer, 2009)

Spatial Contiguity

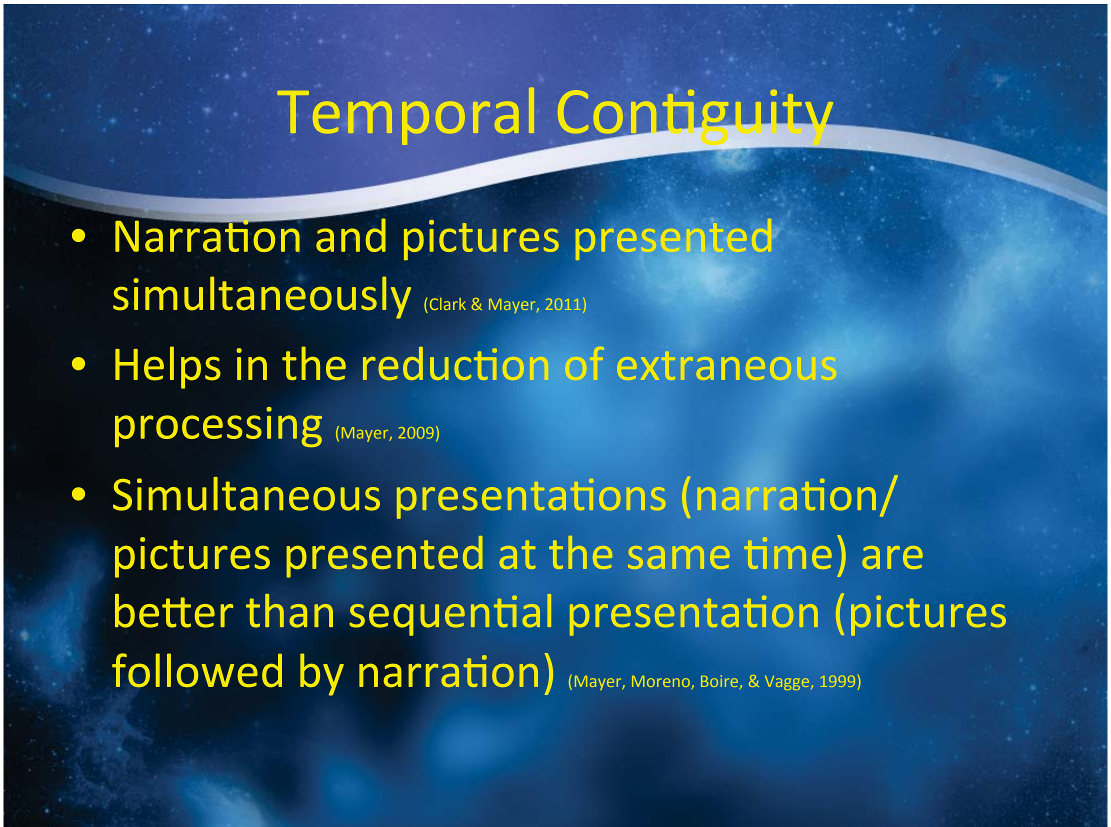
Words and Pictures presented together

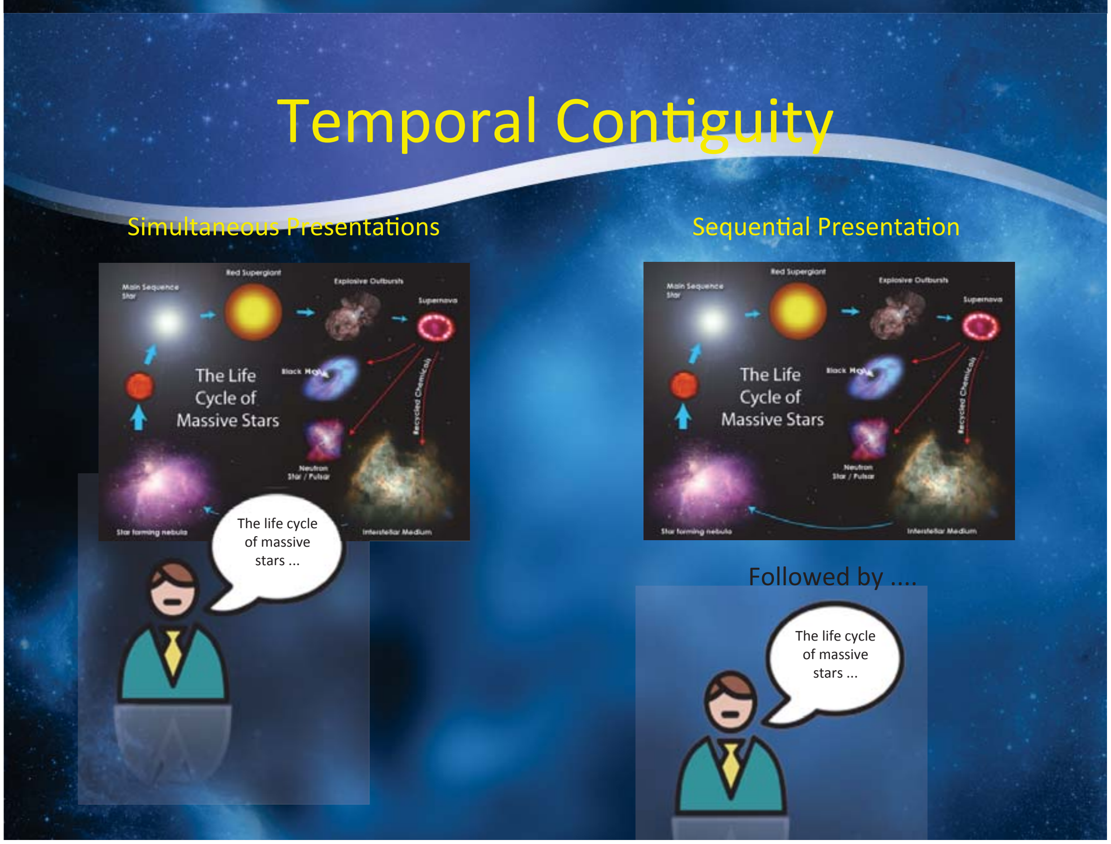


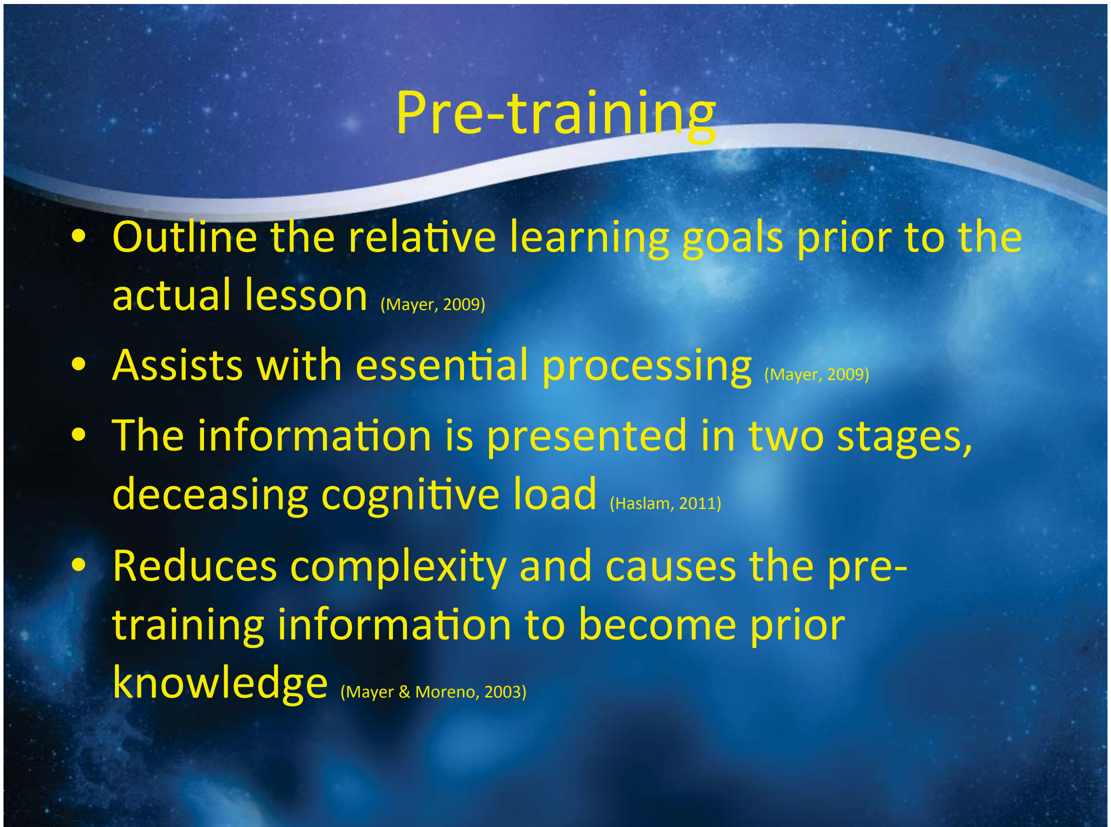
Words and Pictures presented apart



1 – Inner core
2 – Radiative zone
3 – Convection zone
4 – Subsurface flows
5 – Photosphere
6 – Chromosphere
7 – Corona


Temporal Contiguity
• Narration and pictures presented simultaneously (Clark & Mayer, 2011)
• Helps in the reduction of extraneous processing (Mayer, 2009)
• Simultaneous presentations (narration/ pictures presented at the same time) are better than sequential presentation (pictures followed by narration) (Mayer, Moreno, Boire, & Vagge, 1999)


Temporal Contiguity
Simultaneous Presentations
The Life Cycle of Massive Stars
The life cycle of massive stars ...
Sequential Presentation
The Life Cycle of Massive Stars
Followed by ....
The life cycle of massive stars ...


Pre-training
• Outline the relative learning goals prior to the actual lesson (Mayer, 2009)
• Assists with essential processing (Mayer, 2009)
• The information is presented in two stages, deceasing cognitive load (Haslam, 2011)
• Reduces complexity and causes the pre-training information to become prior knowledge (Mayer & Moreno, 2003)


Pre-training
Pre-training
1) Outline material
2) Planetarium Instruction
Instruction without Pre-training
1) Planetarium Instruction
Outline
1.
2.
3.
4.

Personalization

- Informal rather than a formal language style (Kartal, 2010)
- Fosters generative processing (Mayer, 2009)
- A conversational style of narration is better than formal style of narration (Clark & Mayer, 2011)
- Holds true with other language structures (Kartal, 2010)
- Narration should be practices until it sounds natural or use an outline and speak naturally (Kartal, 2010)

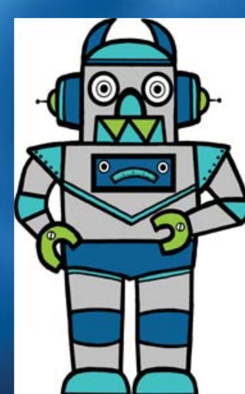
Personalization

Informal Narration

When studying astronomy it is important to remember that the investment made into telescopes provides more knowledge to the world.

Formal Narration

WHEN STUDYING ASTRONOMY IT IS IMPORTANT TO REMEMBER THAT THE INVESTMENT MADE INTO TELESCOPES PROVIDES MORE KNOWLEDGE TO THE WORLD.



Five CTML Principles Handout

Redundancy

- Material is presented as graphics and narration versus graphics, narration, and printed text (Clark & Mayer, 2011).
- Helps in the reduction of extraneous processing (Mayer, 2009).
- Less is more (Van Gerven, Pass, & Tabbers, 2006).
- Omitting printed text is more beneficial to learning (Van Gerven, Pass, & Tabbers, 2006).

Spatial Contiguity

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Personalization

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- Holds true with other language structures (Kartal, 2010).
- Narration should be practices until it sounds natural or use an outline and speak naturally (Kartal, 2010).

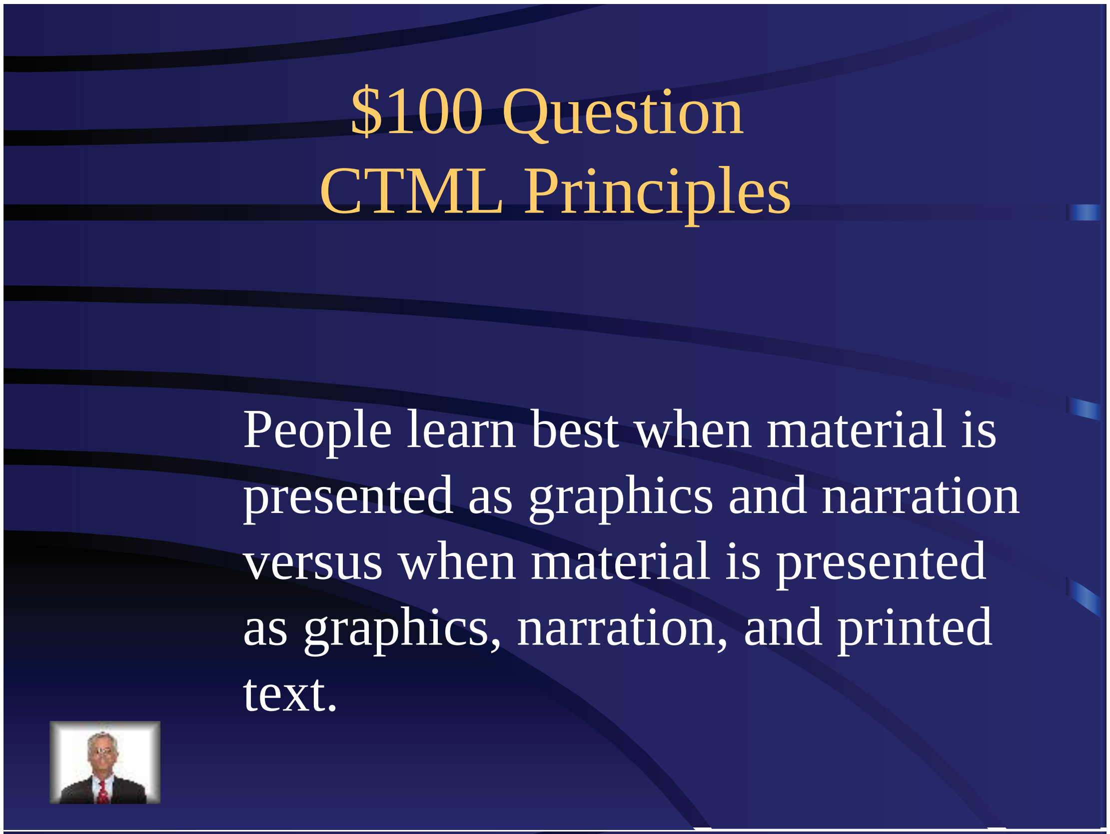
Day 2 Activities – Jeopardy Review Game (60 minutes)
(Stolovitch & Keeps, 2011)

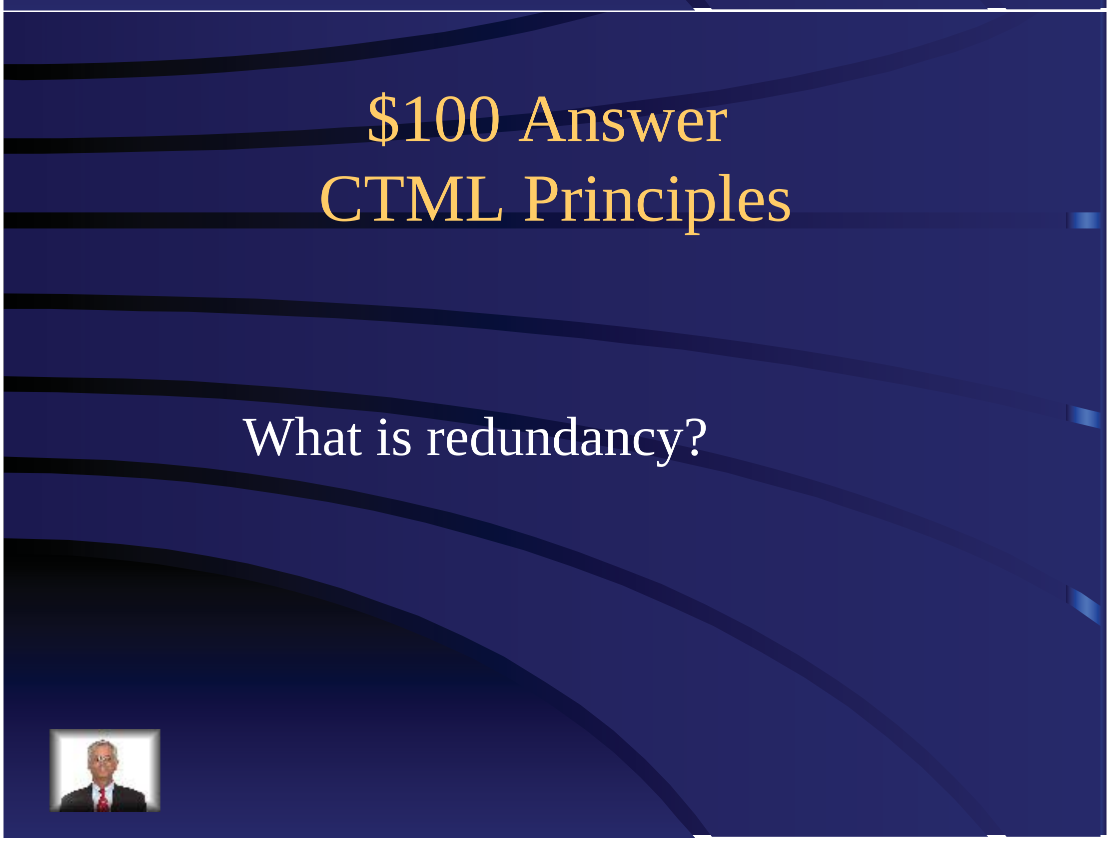
Needed Supplies

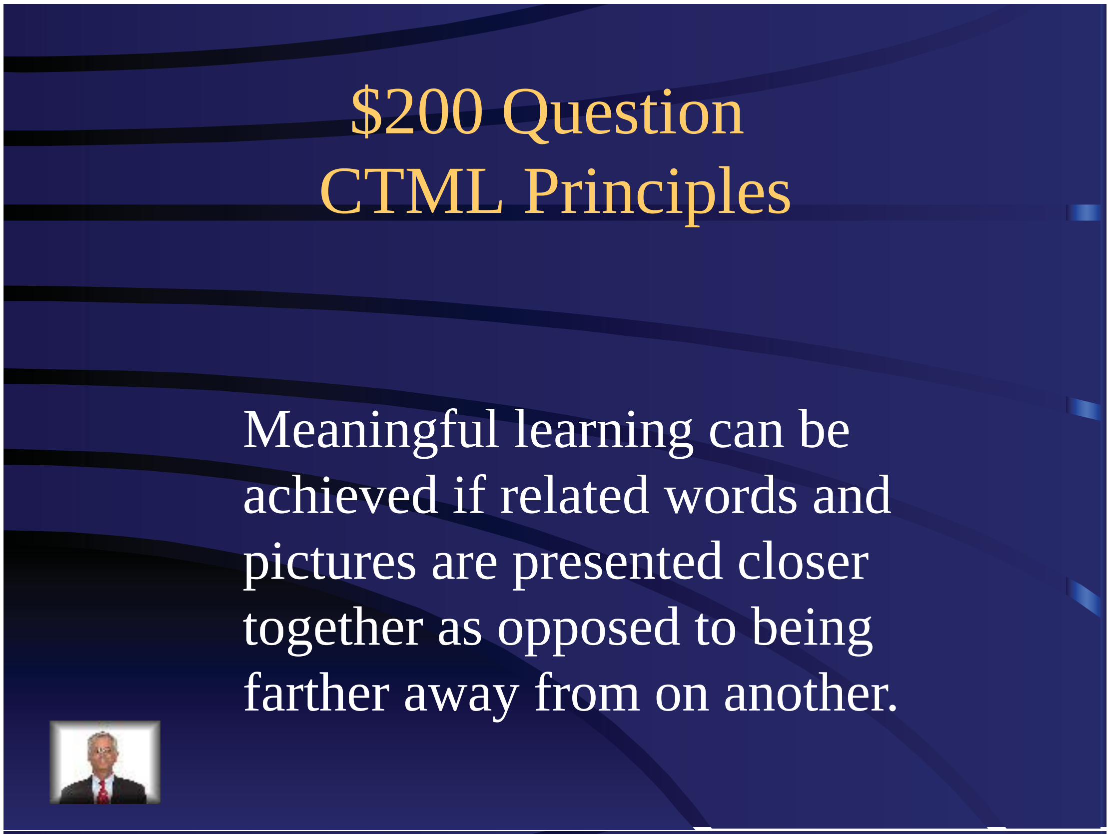
Jeopardy PowerPoint Game, Small hand bells, candy, flipchart, marker

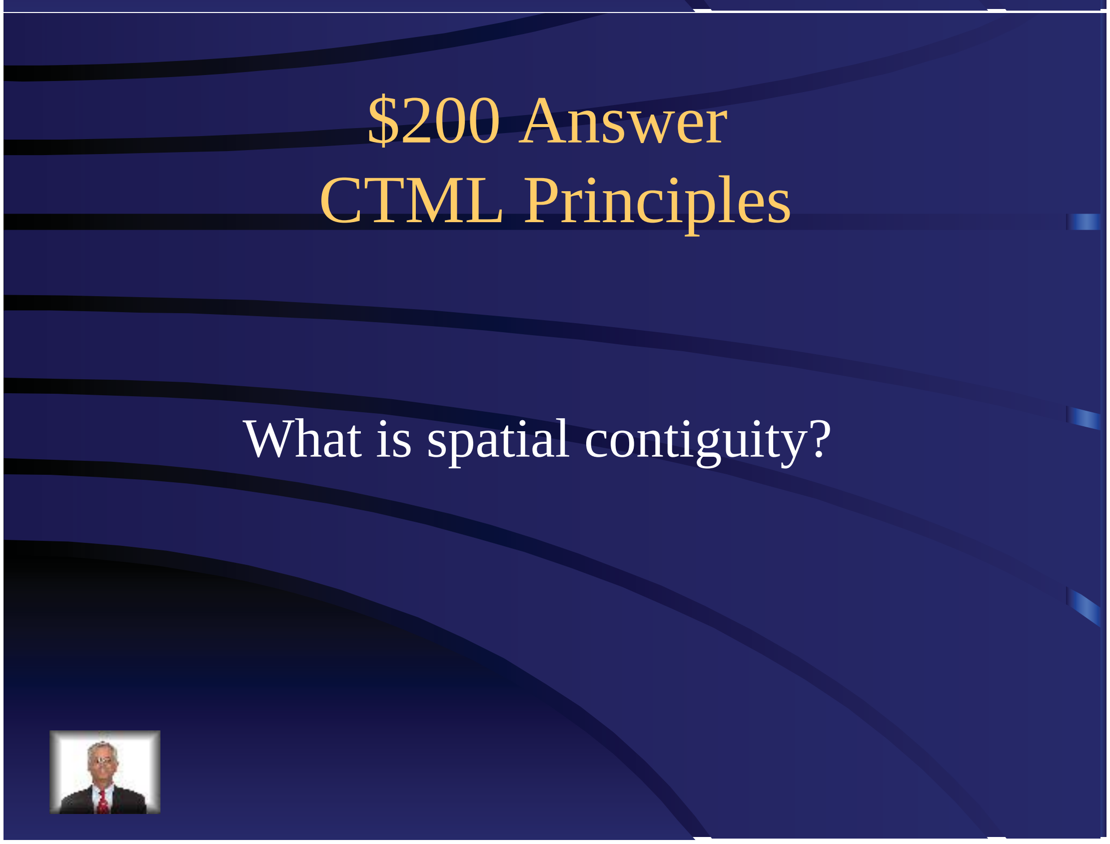
Directions

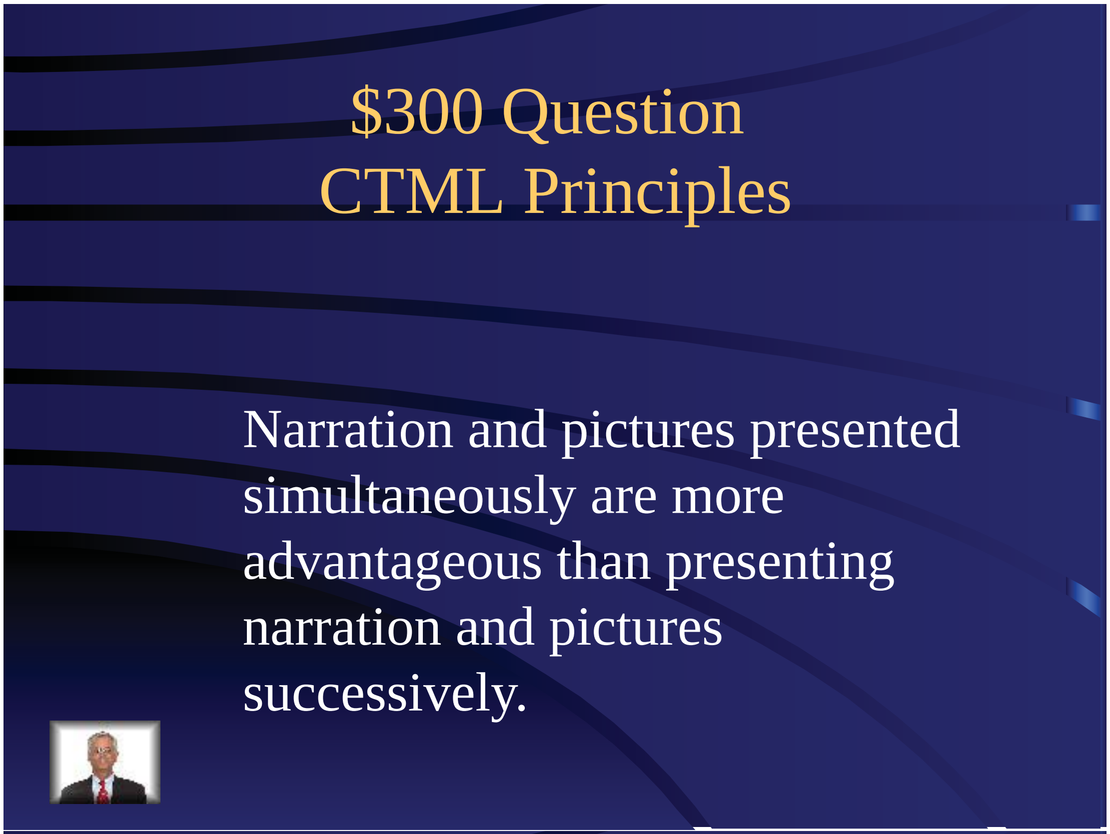
Allow the participants to divide into three groups of their own choosing. Decide which group will go first. The group that has control of the board selects a category and dollar amount. The trainer will read the question aloud; the group that can ring their bell first is allowed to answer the question. If the group gets the question right, they receive the dollar amount on the scoreboard. If the group gets it wrong, they will have the dollar amount subtracted from their score and another group will be given the chance to answer that question. This continues until all three groups have had a chance to answer the question, at which time the trainer reads the answer. When all the questions have been answered the group with the highest score will be given a chance to answer the final jeopardy question by wagering a dollar amount. The winning group will receive candy.

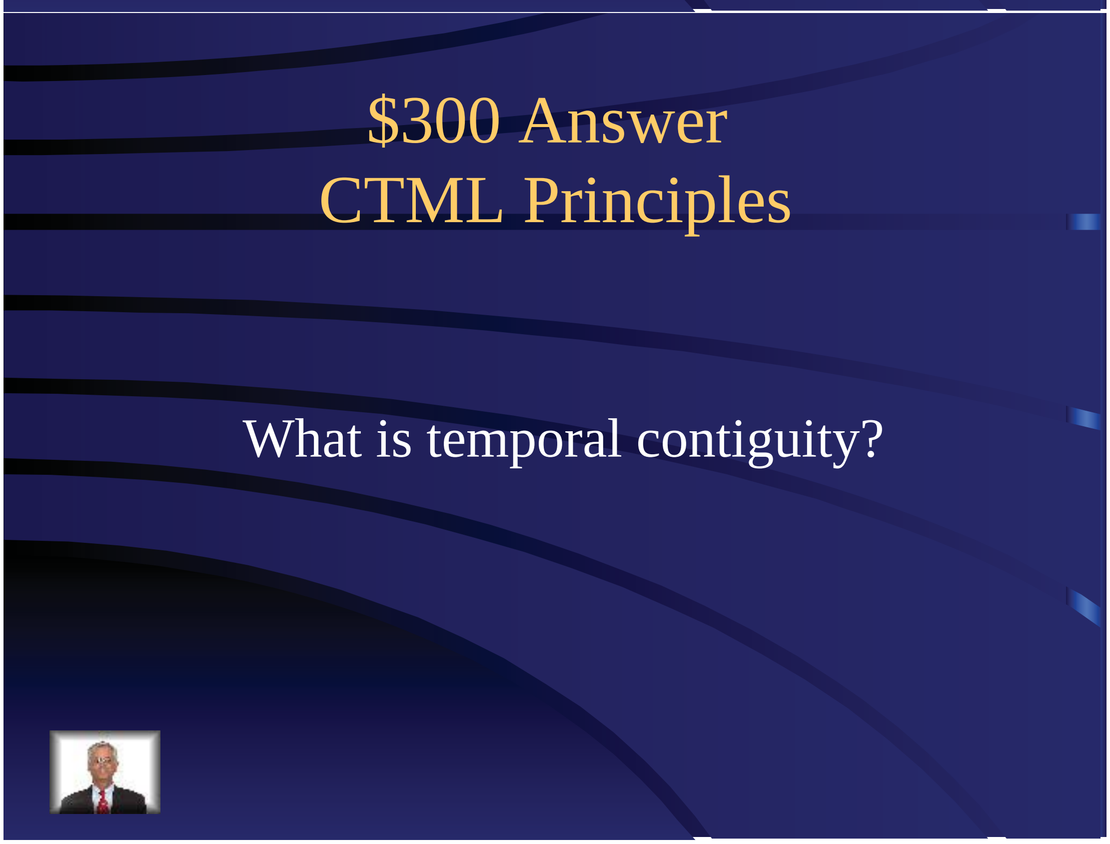

$100 Question
CTML Principles
People learn best when material is presented as graphics and narration versus when material is presented as graphics, narration, and printed text.


$100 Answer
CTML Principles
What is redundancy?


$200 Question
CTML Principles
Meaningful learning can be achieved if related words and pictures are presented closer together as opposed to being farther away from on another.


$200 Answer
CTML Principles
What is spatial contiguity?


$300 Question
CTML Principles
Narration and pictures presented simultaneously are more advantageous than presenting narration and pictures successively.


$300 Answer
CTML Principles
What is temporal contiguity?

$400 Question
CTML Principles

An outline is of the relative learning goals is provided prior to the actual lesson.

$400 Answer
CTML Principles

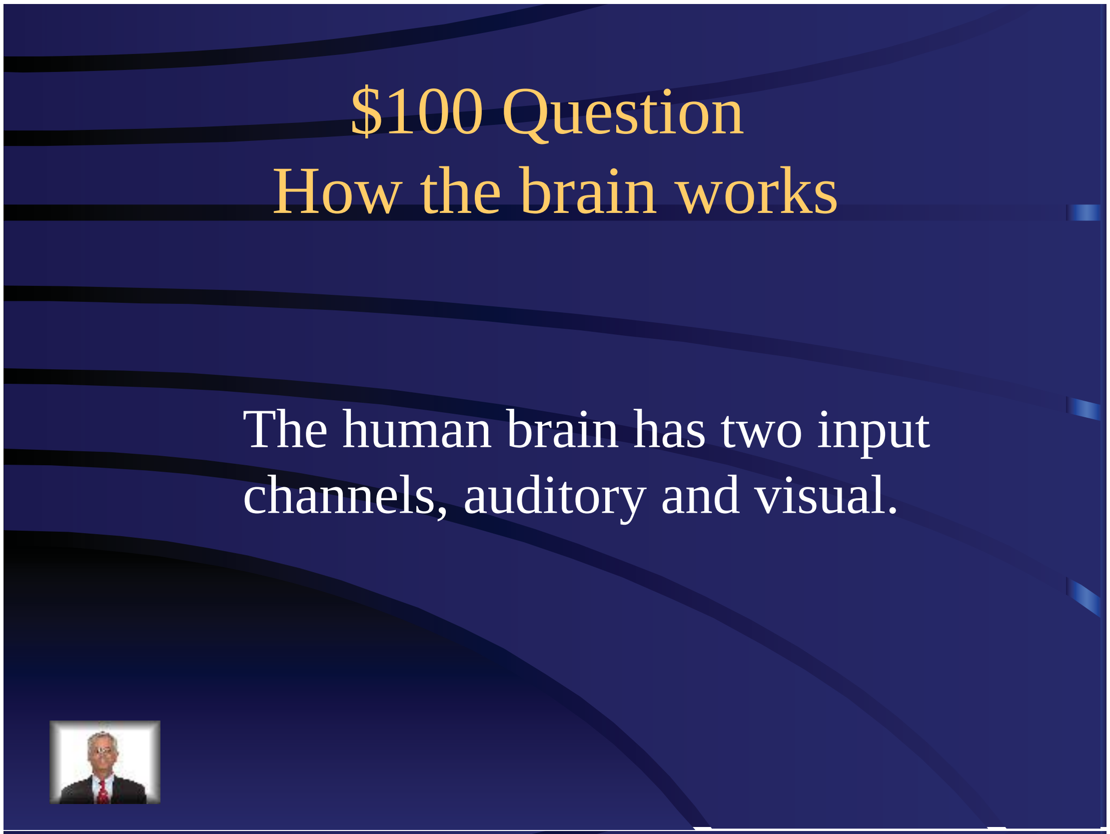
What is pre-training?

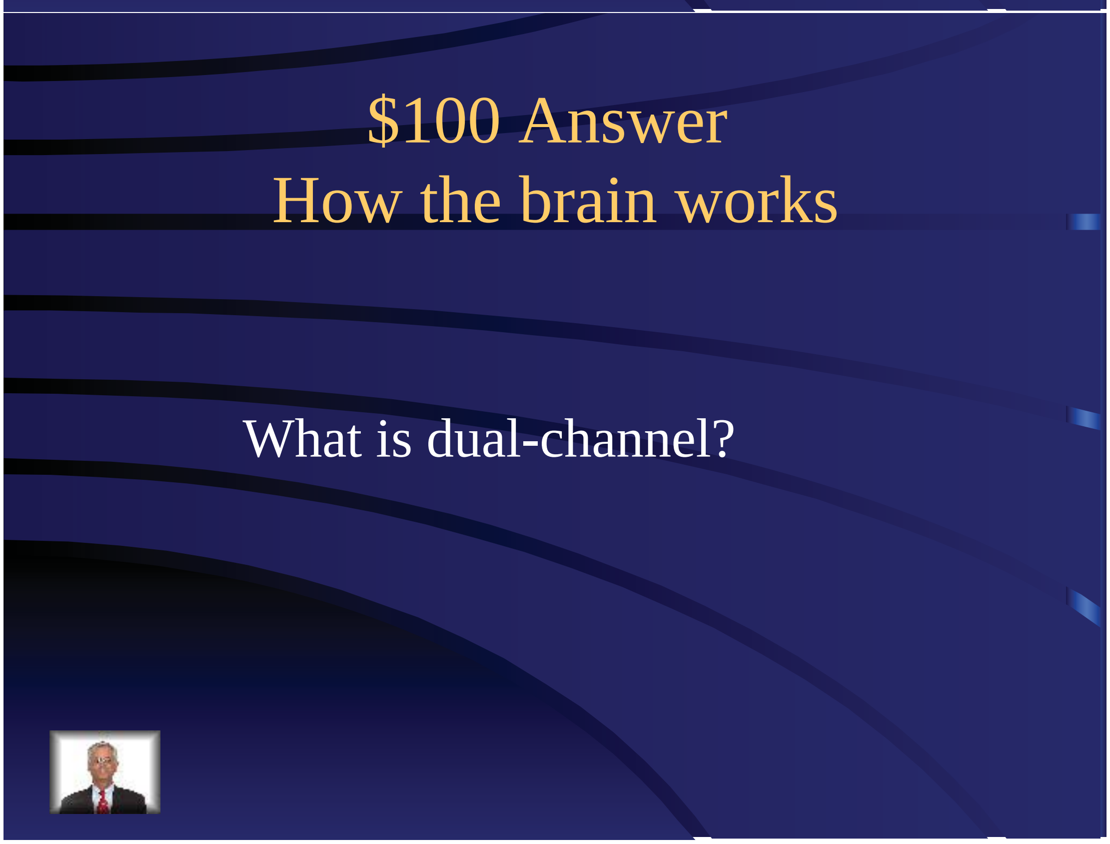
$500 Question
CTML Principles

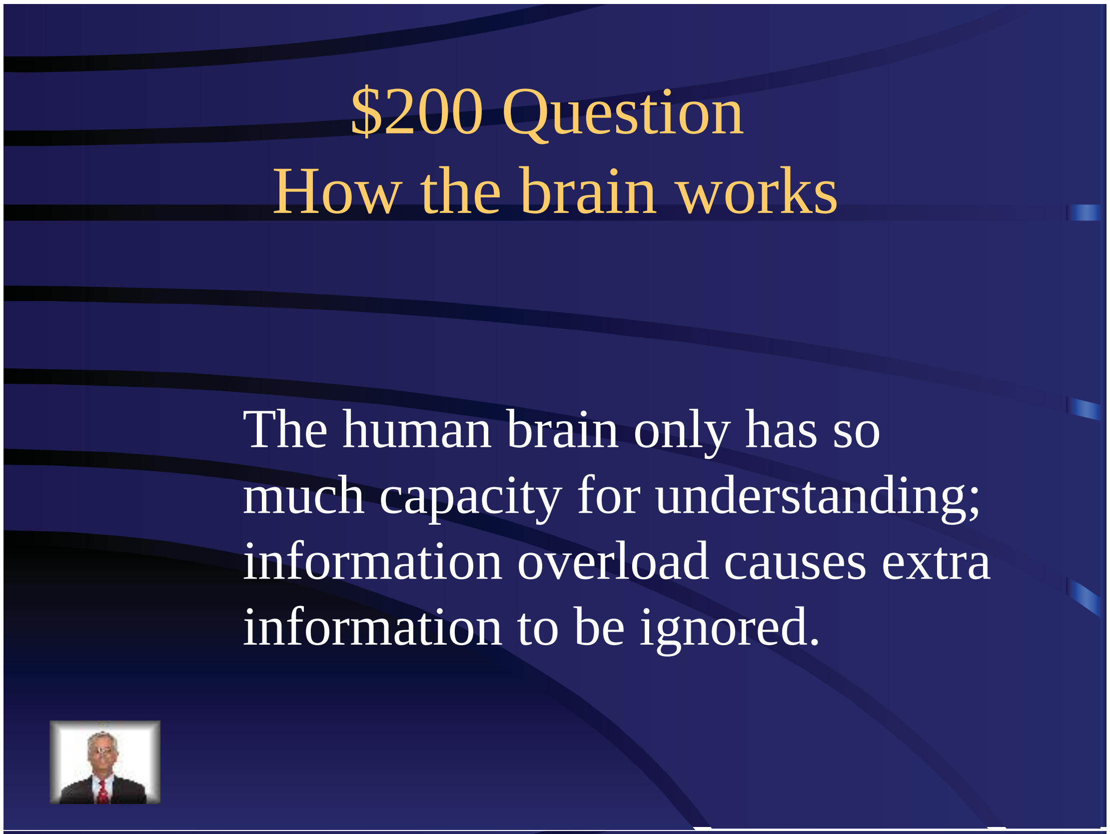
People learn best when information is written in an informal, rather than a formal language style.

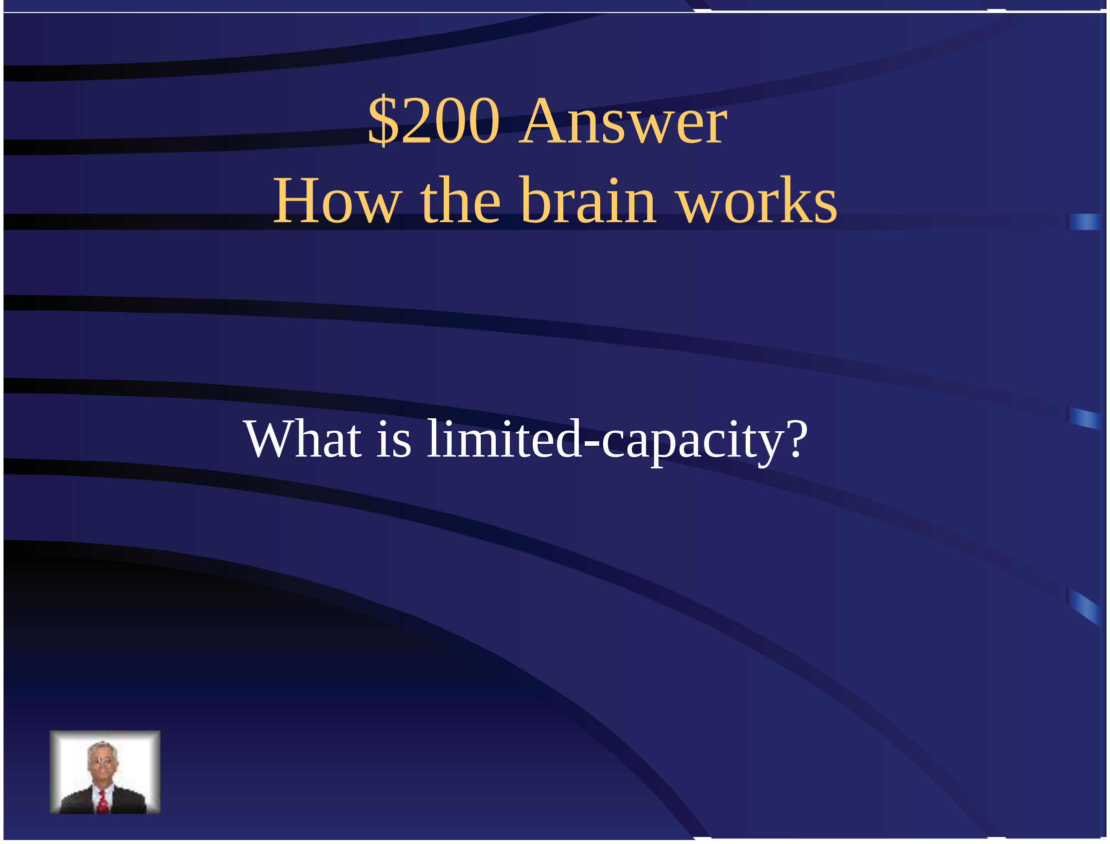
$500 Answer
CTML Principles

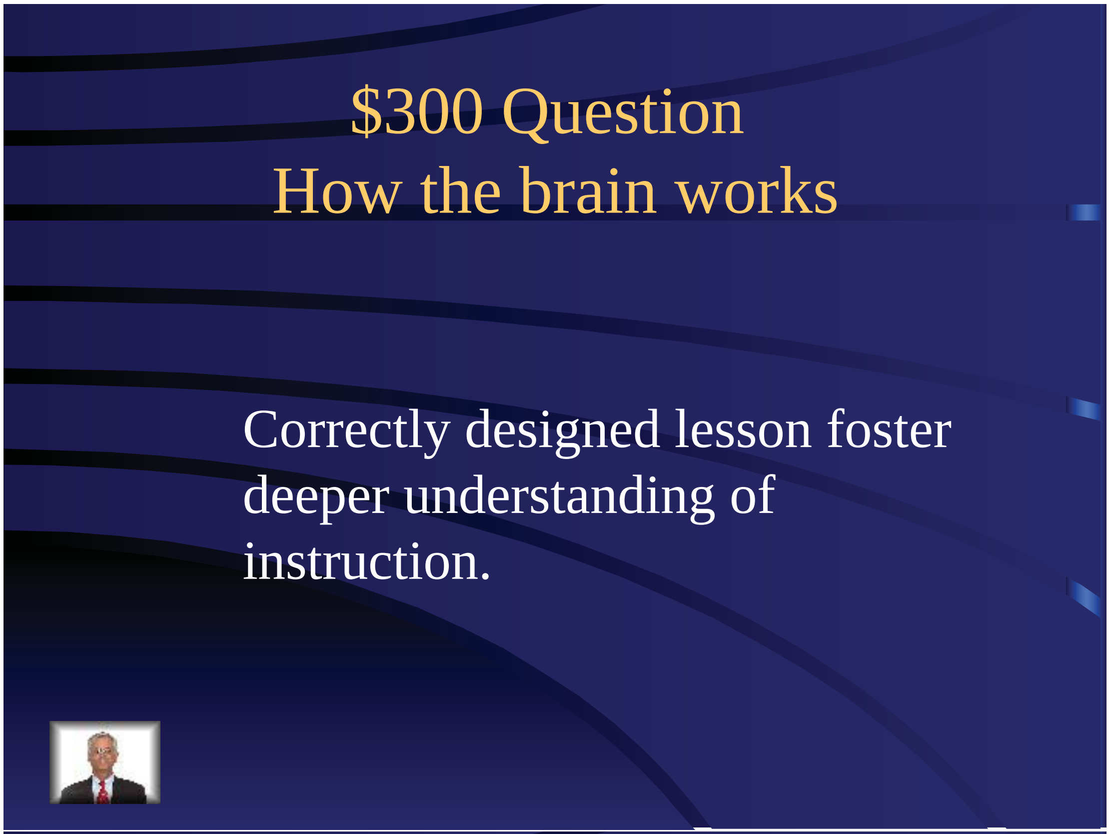
What is personalization?

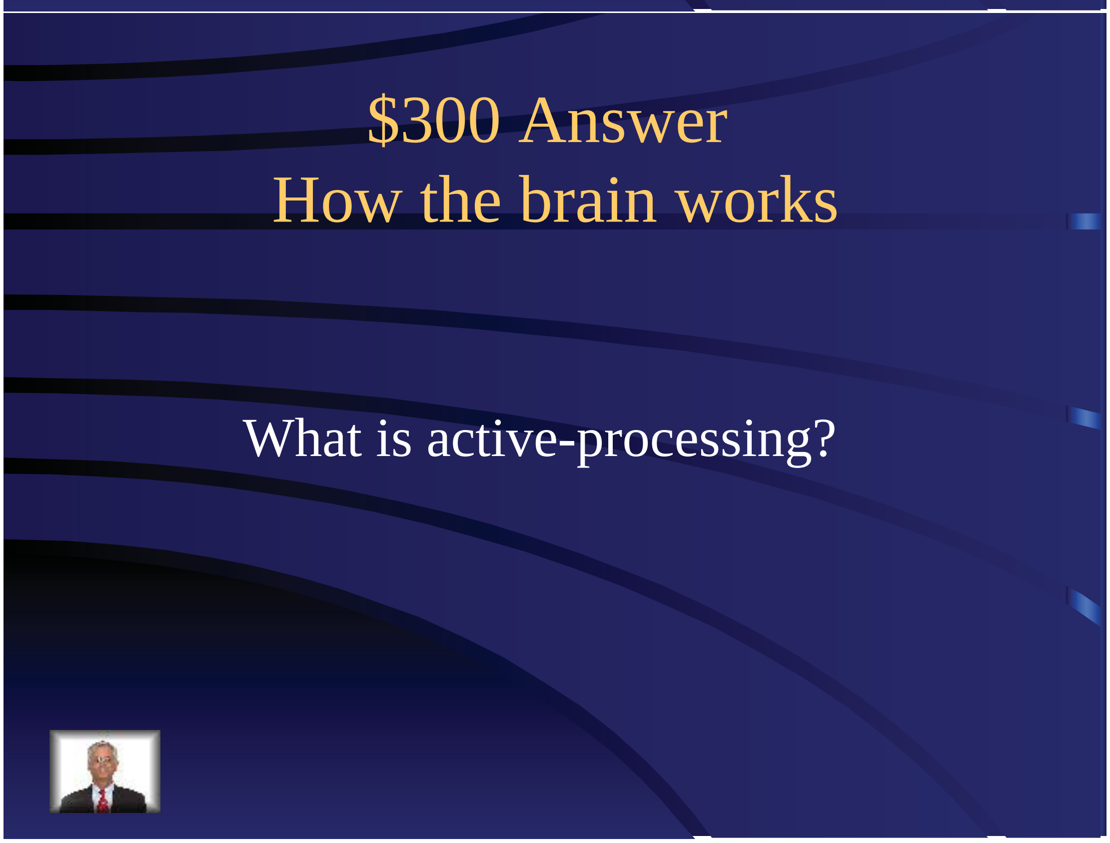

$100 Question
How the brain works
The human brain has two input channels, auditory and visual.

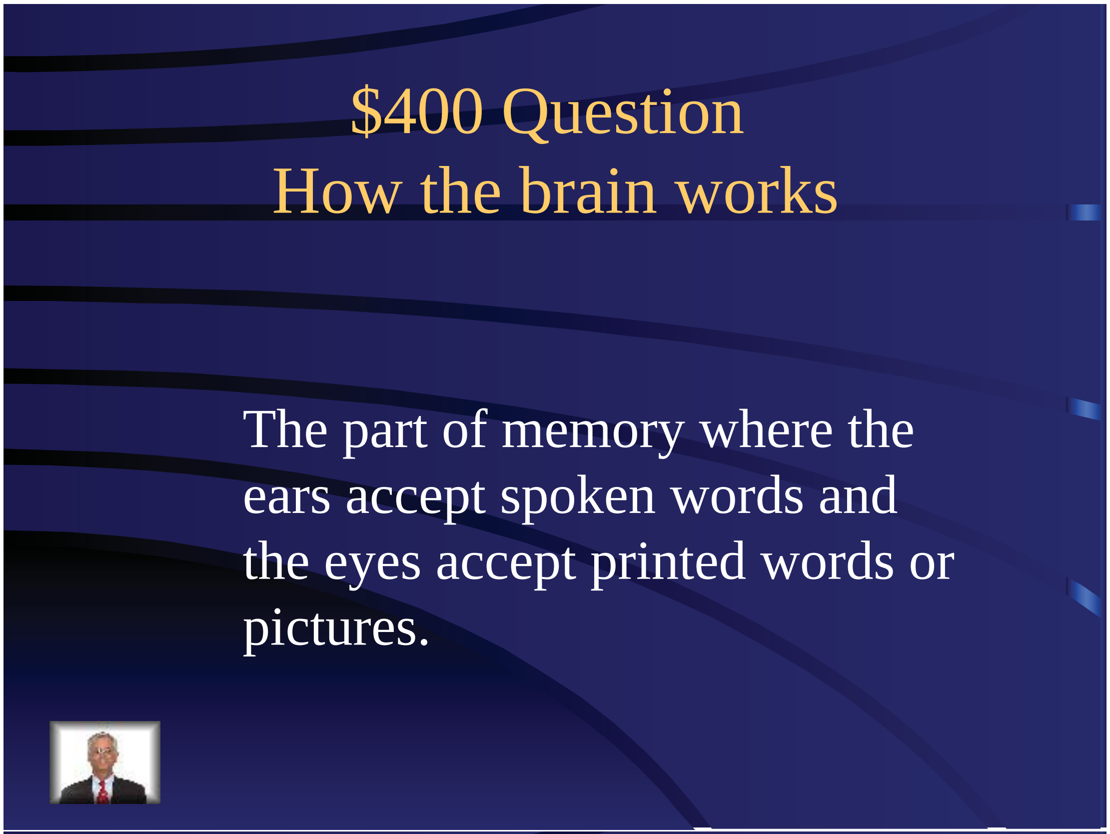

$100 Answer
How the brain works
What is dual-channel?

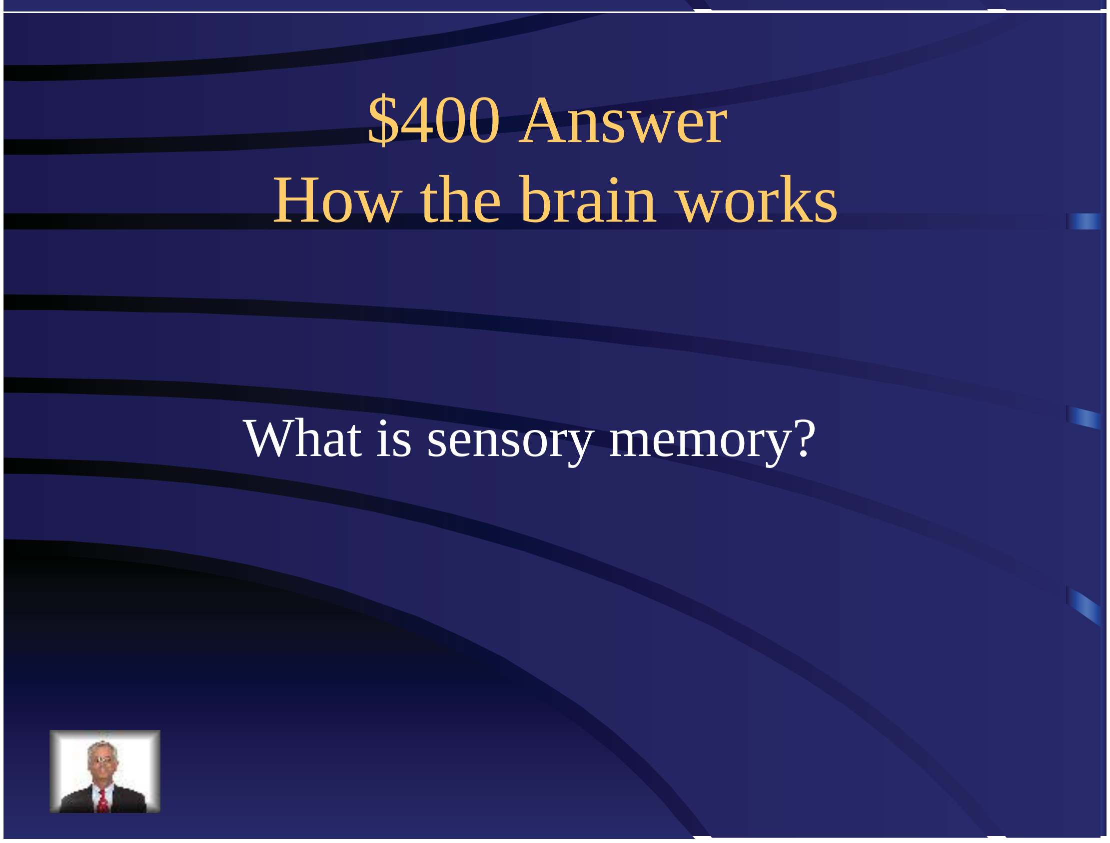

$200 Question
How the brain works
The human brain only has so much capacity for understanding; information overload causes extra information to be ignored.


$200 Answer
How the brain works
What is limited-capacity?


$300 Question
How the brain works
Correctly designed lesson foster deeper understanding of instruction.


$300 Answer
How the brain works
What is active-processing?


$400 Question
How the brain works
The part of memory where the ears accept spoken words and the eyes accept printed words or pictures.

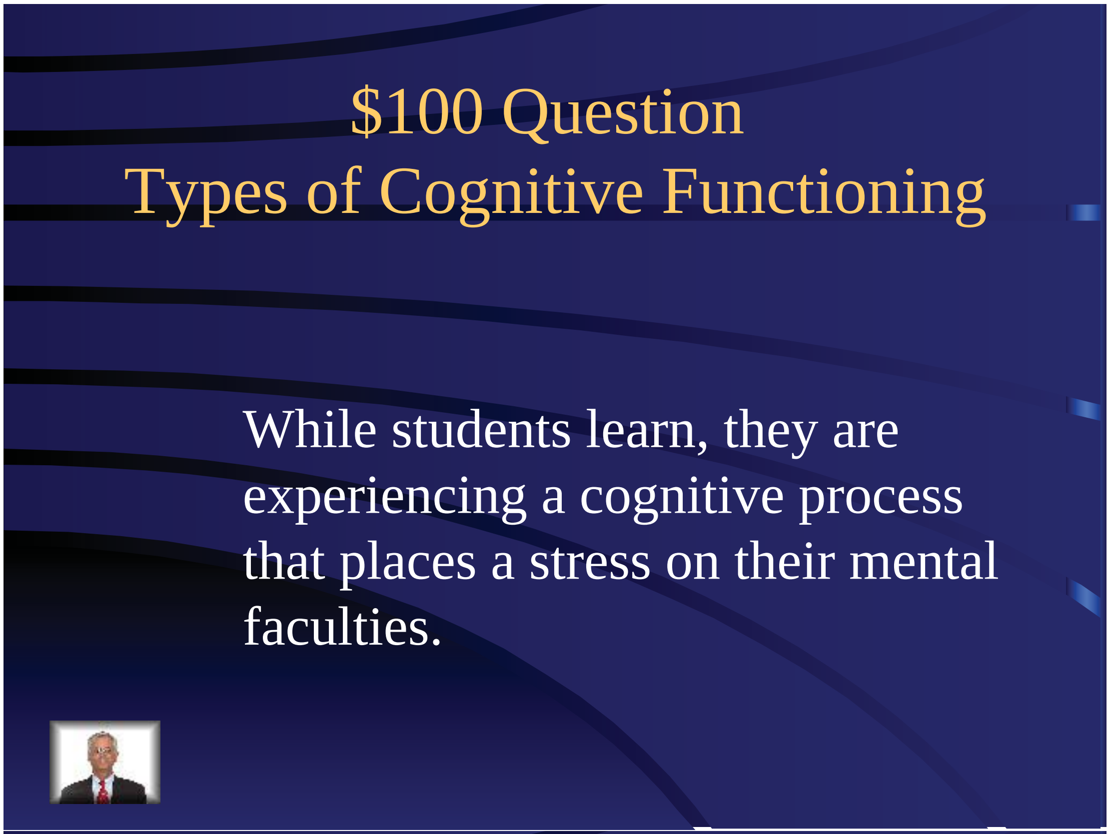

$400 Answer
How the brain works
What is sensory memory?

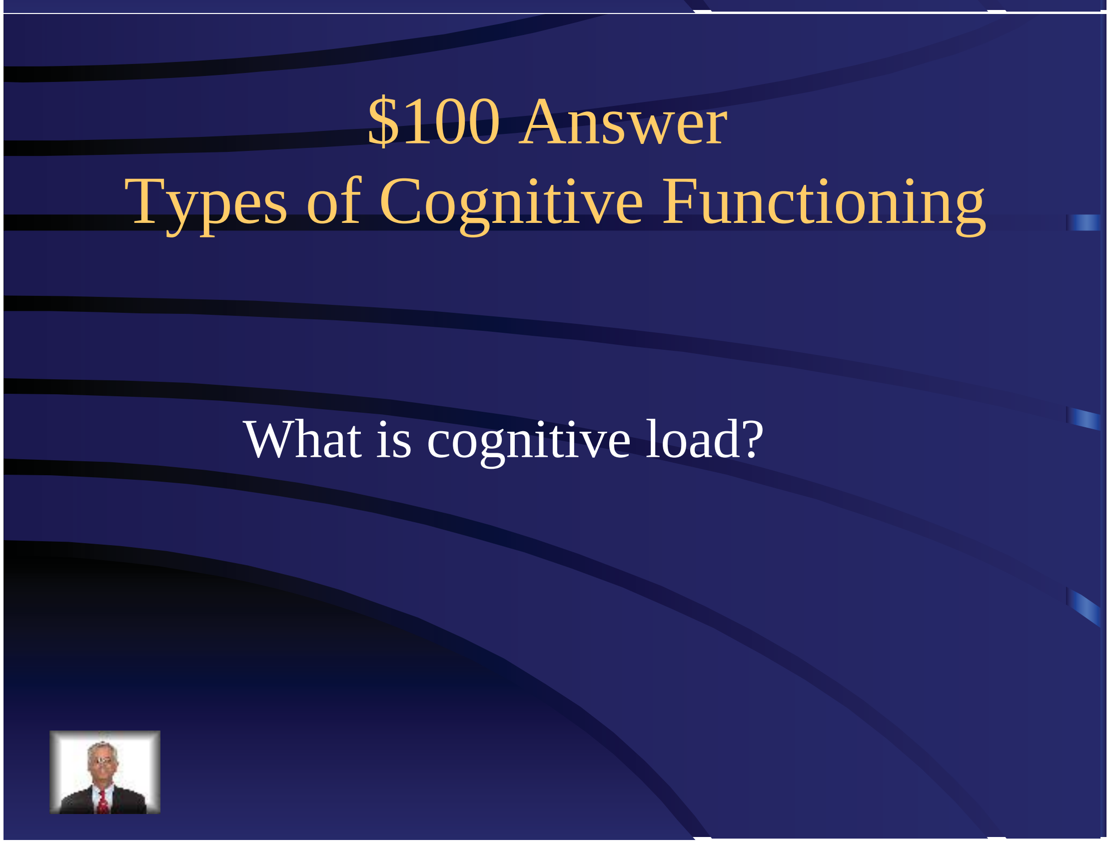
$500 Question
How the brain works

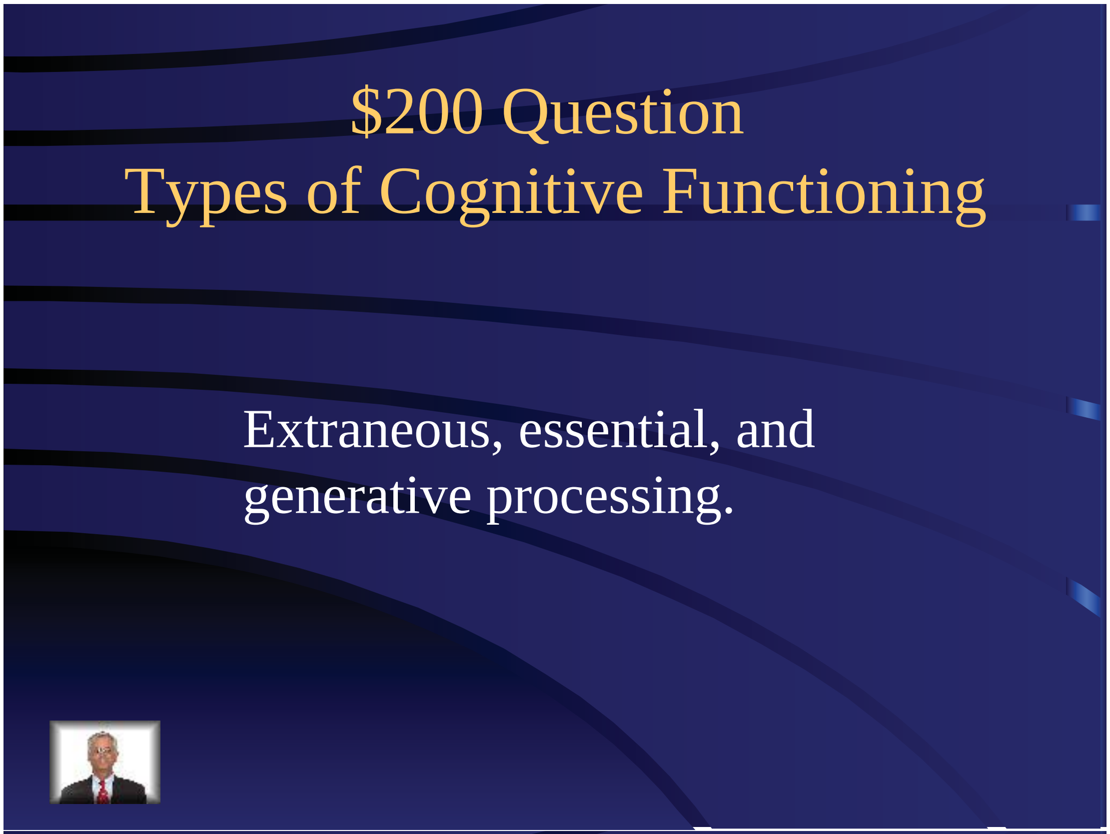
Is integrated with working memory from long-term memory.

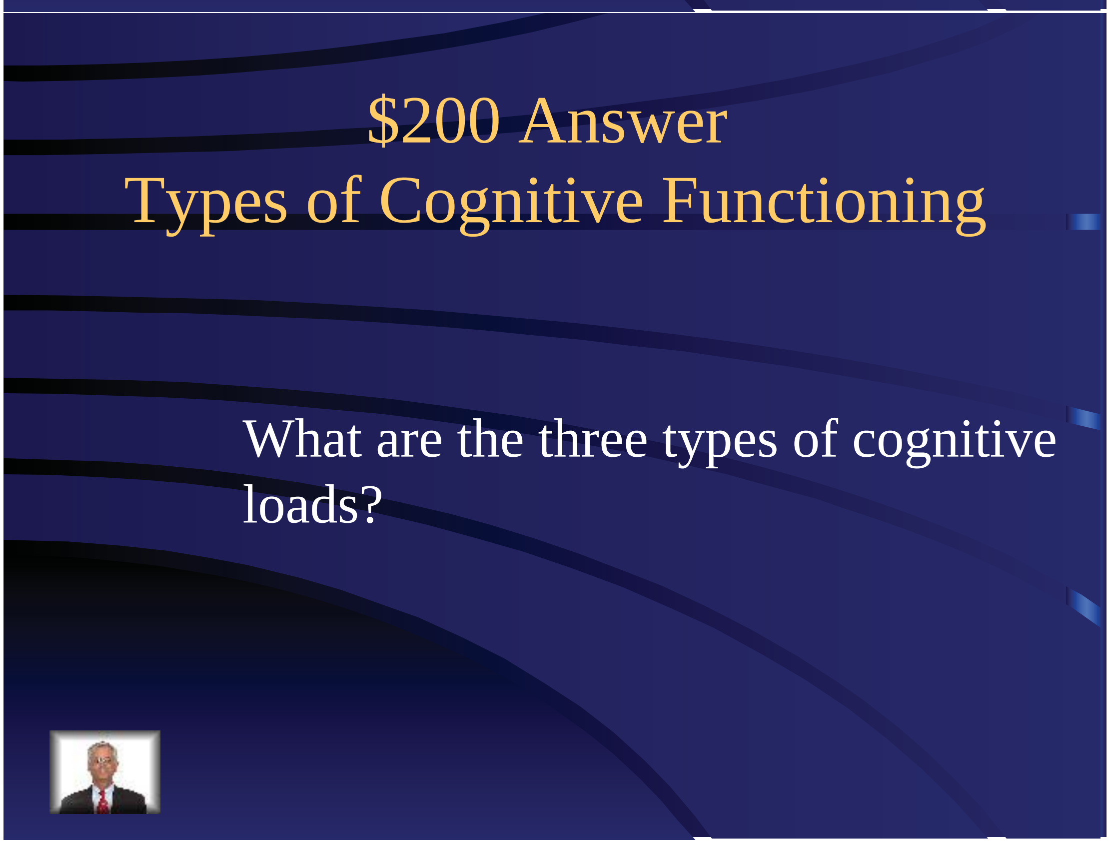
$500 Answer
How the brain works

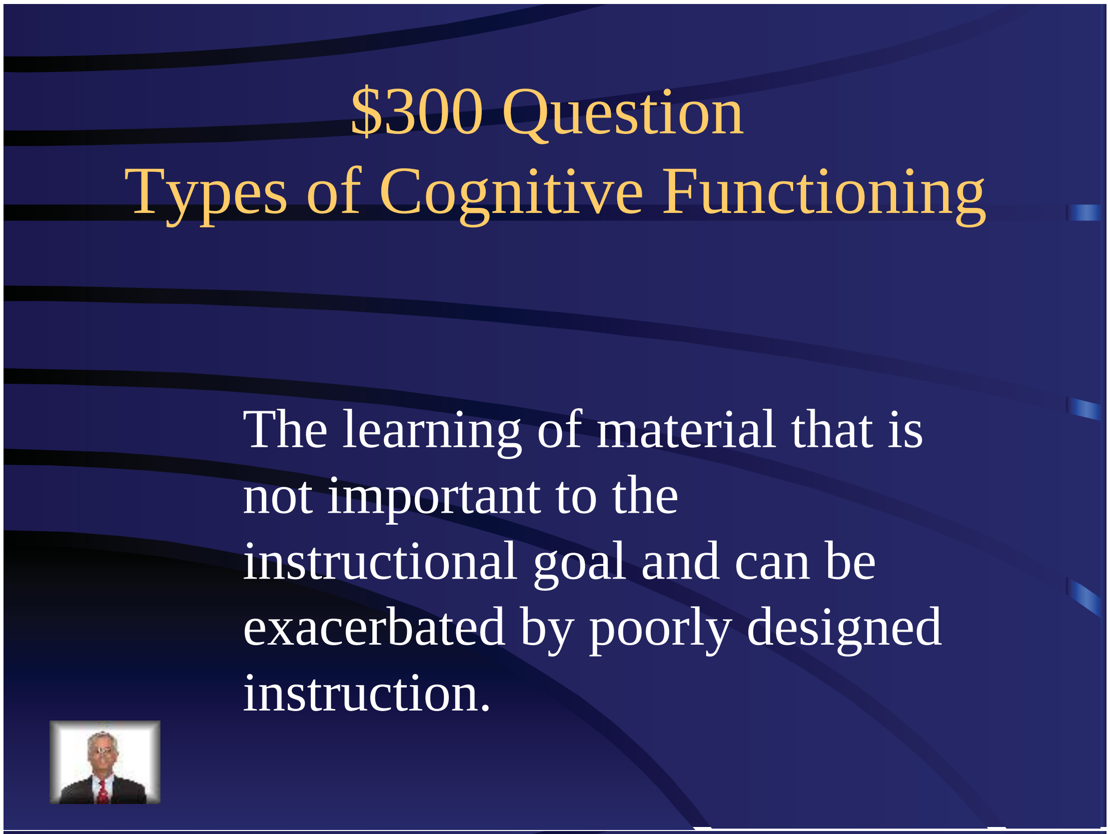
What is prior knowledge?

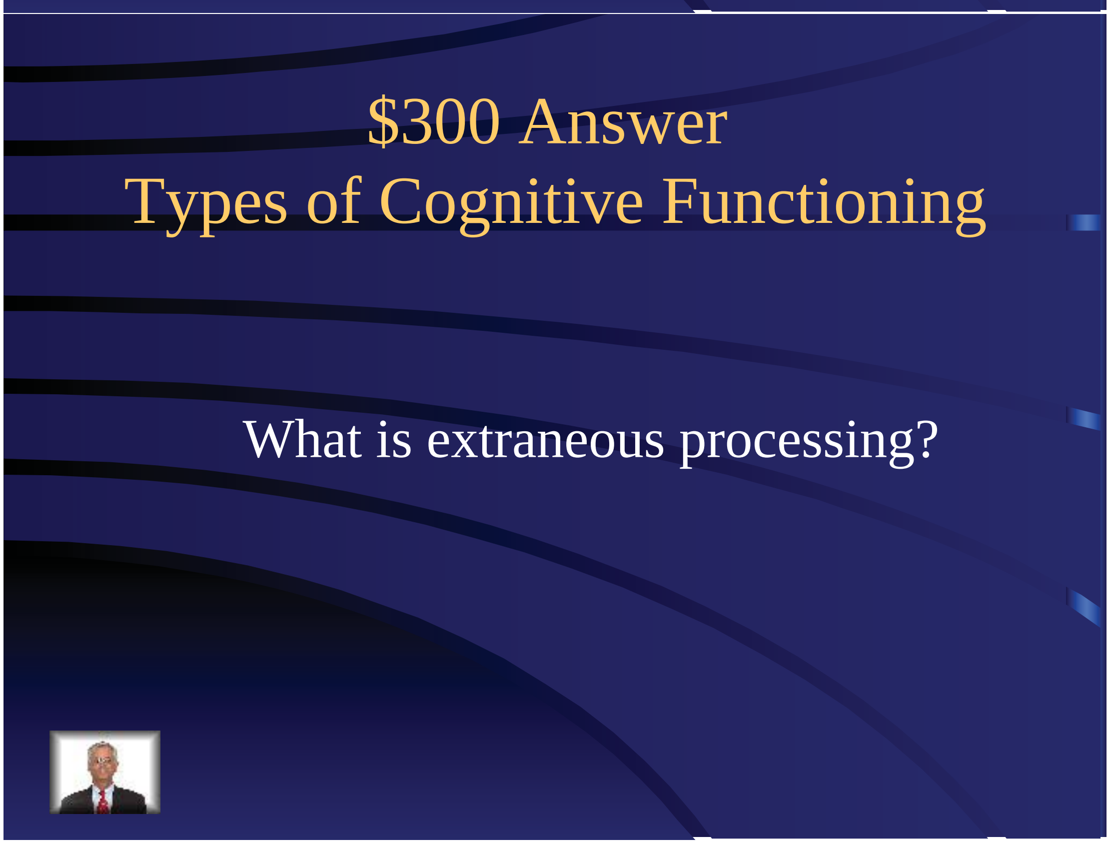

$100 Question
Types of Cognitive Functioning
While students learn, they are experiencing a cognitive process that places a stress on their mental faculties.

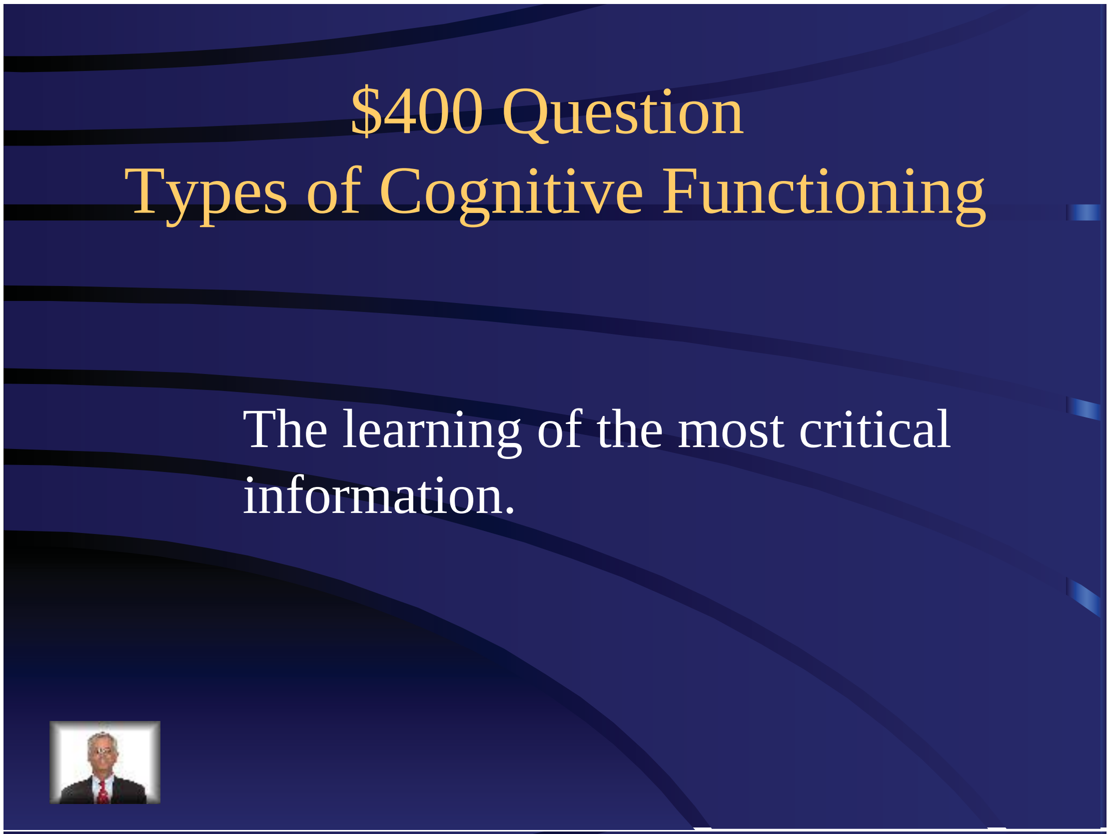

$100 Answer
Types of Cognitive Functioning
What is cognitive load?

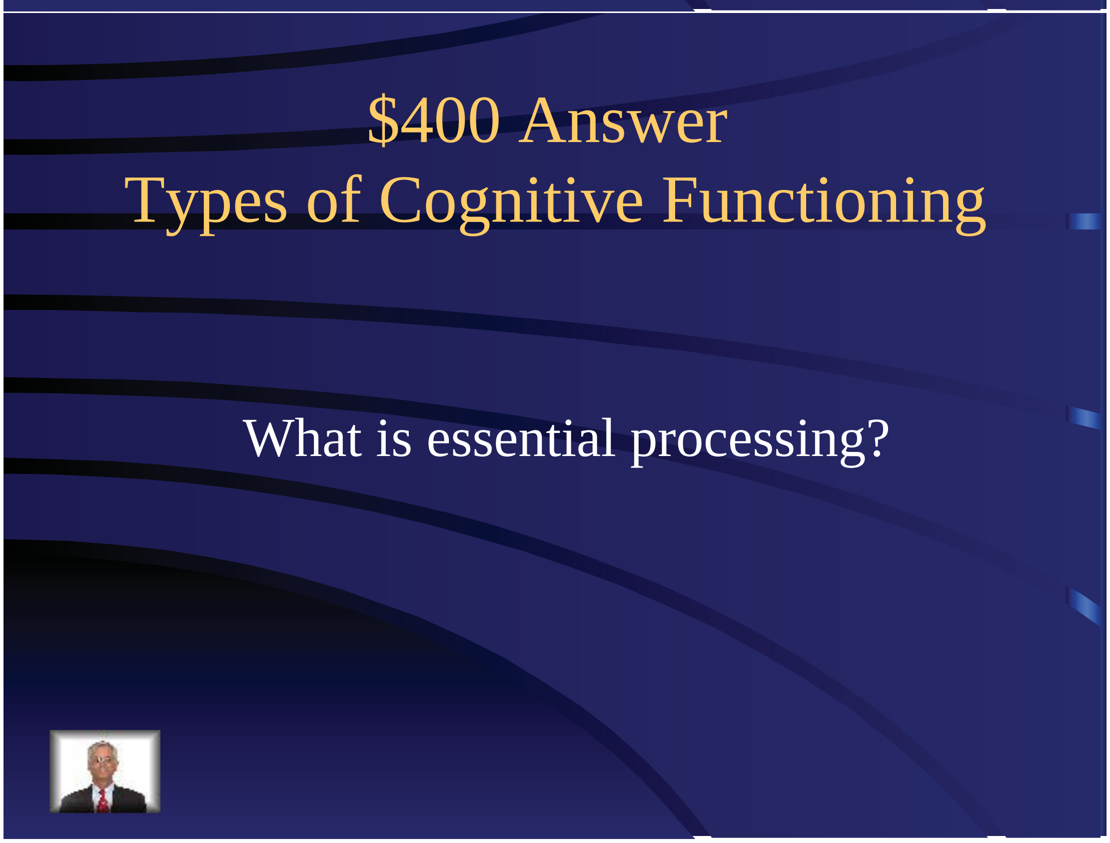

$200 Question
Types of Cognitive Functioning
Extraneous, essential, and generative processing.


$200 Answer
Types of Cognitive Functioning
What are the three types of cognitive loads?


$300 Question
Types of Cognitive Functioning
The learning of material that is not important to the instructional goal and can be exacerbated by poorly designed instruction.


$300 Answer
Types of Cognitive Functioning
What is extraneous processing?


$400 Question
Types of Cognitive Functioning
The learning of the most critical information.


$400 Answer
Types of Cognitive Functioning
What is essential processing?

$500 Question
Types of Cognitive Functioning

The organization and integration of new material with prior knowledge.

$500 Answer
Types of Cognitive Functioning

What is generative processing?

$100 Question
Learning Theory

Can be decreased by the coherence, signaling, redundancy, spatial contiguity, or temporal contiguity principle.

$100 Answer
Learning Theory

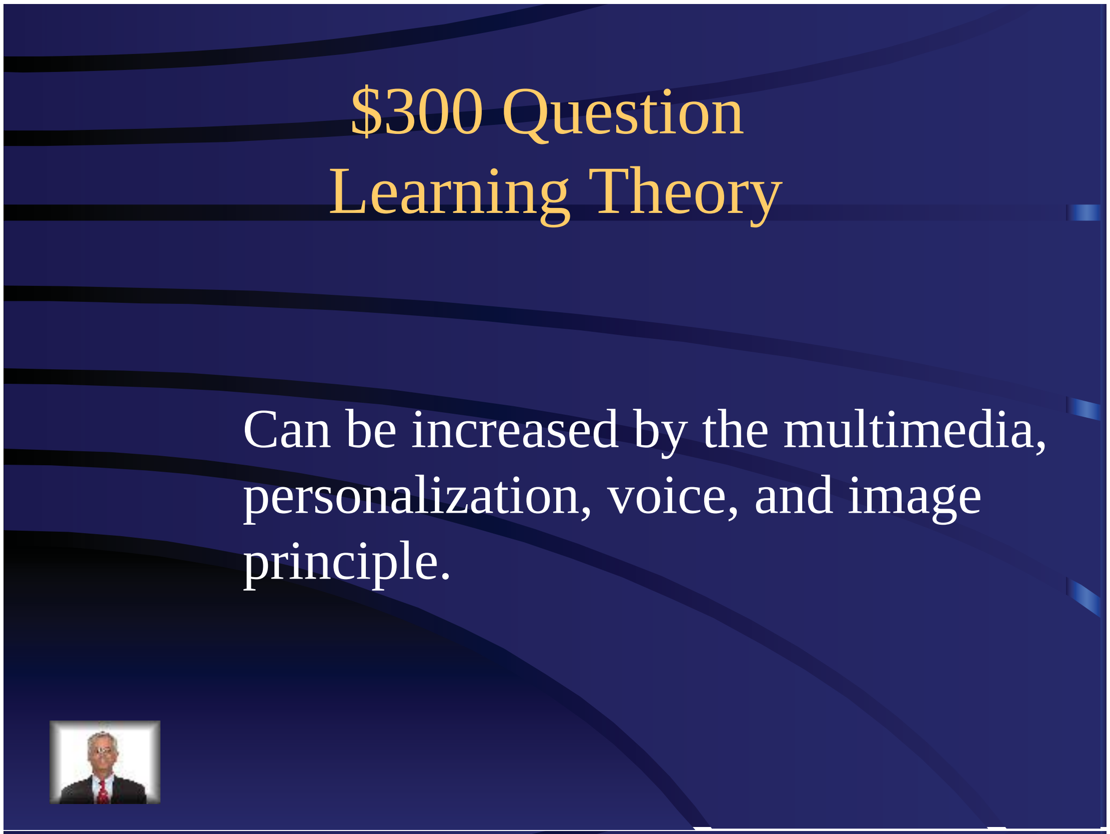
What is extraneous processing?

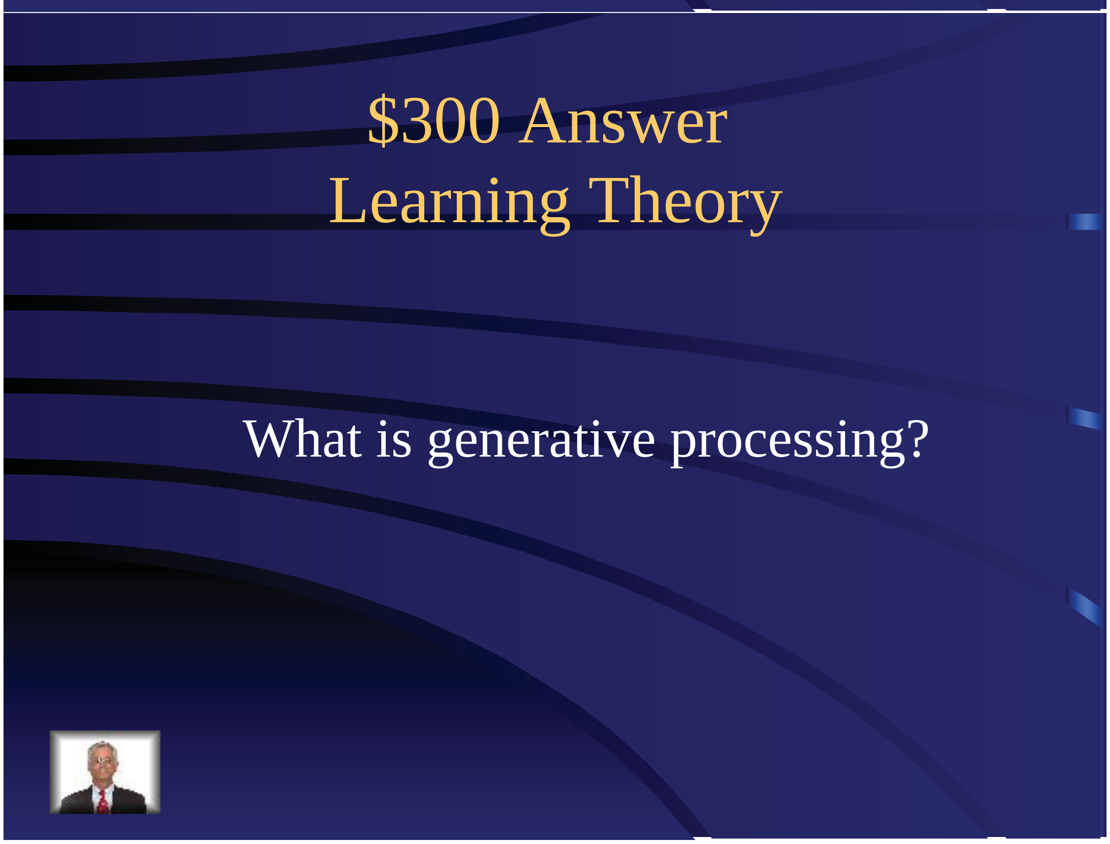
$200 Question
Learning Theory

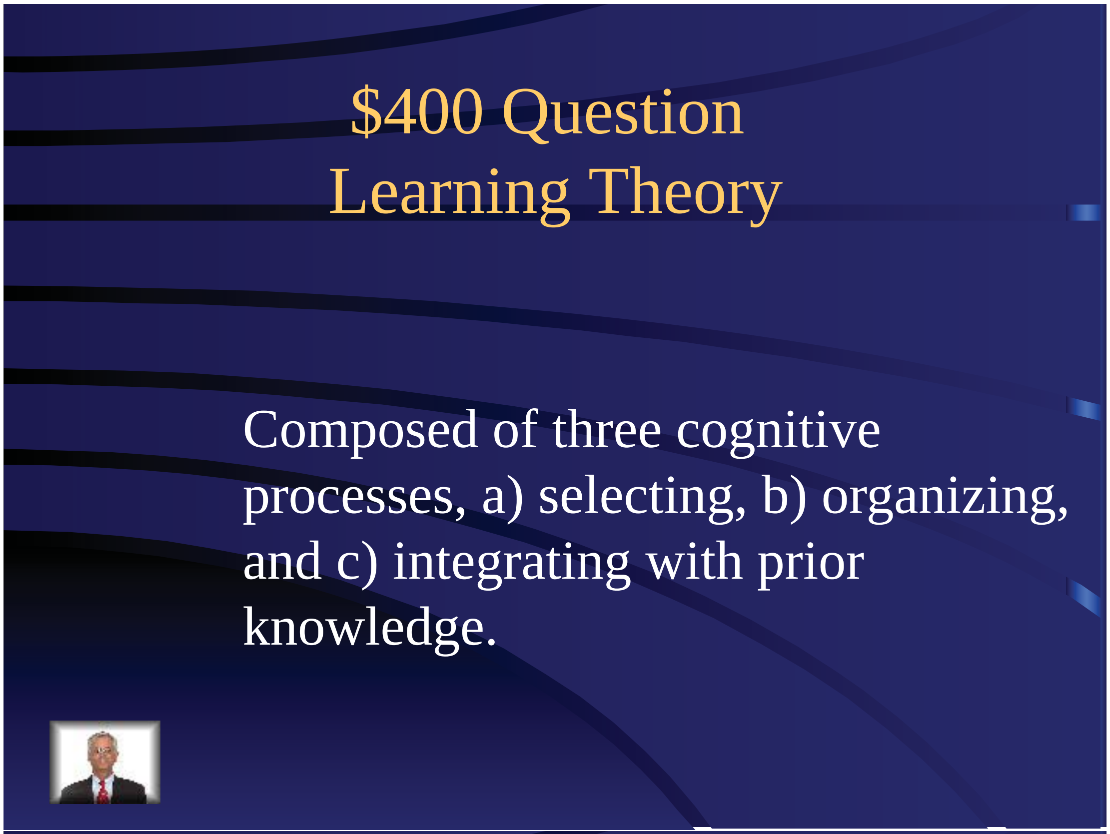
Can be managed by the segmenting, pre-training, or modality principle.

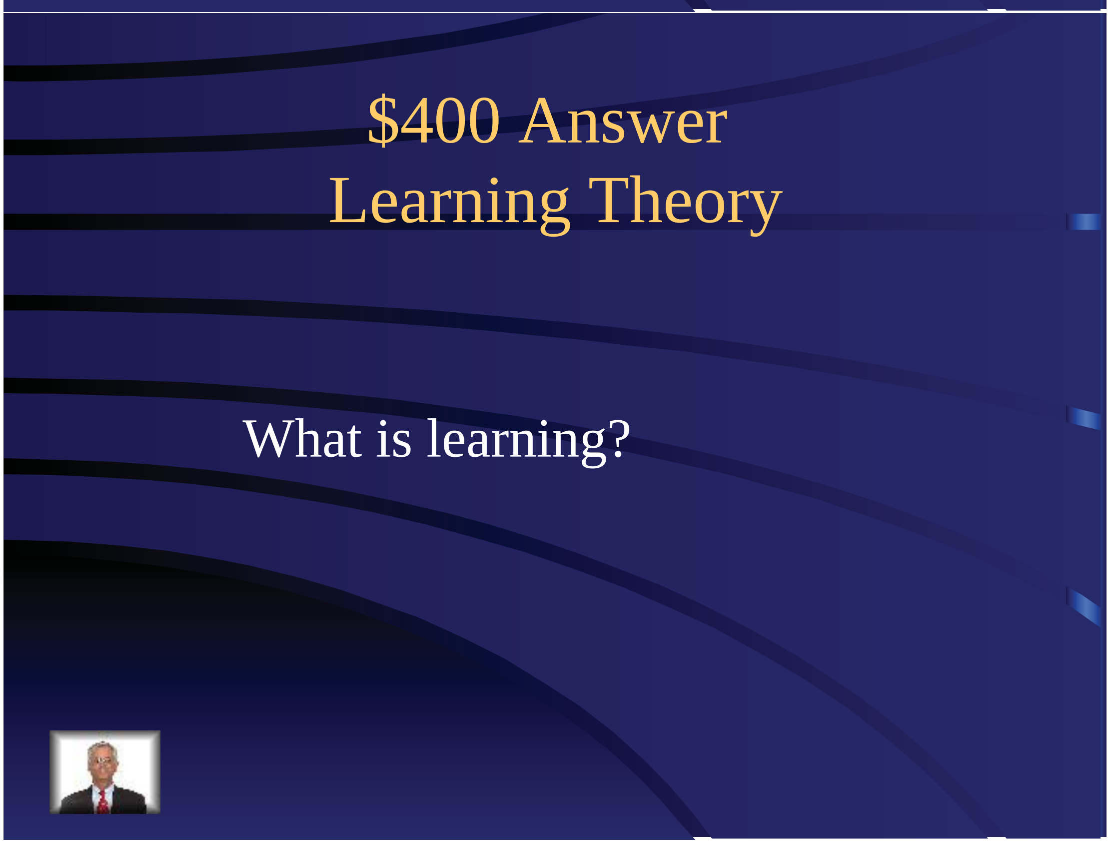
$200 Answer
Learning Theory

What is essential processing?


$300 Question
Learning Theory
Can be increased by the multimedia, personalization, voice, and image principle.


$300 Answer
Learning Theory
What is generative processing?


$400 Question
Learning Theory
Composed of three cognitive processes, a) selecting, b) organizing, and c) integrating with prior knowledge.


$400 Answer
Learning Theory
What is learning?

$500 Question
Learning Theory

A set of instructional design principles that create meaningful learning, as depicted by good retention of the material and good transfer of information to new experiences.

$500 Answer
Learning Theory

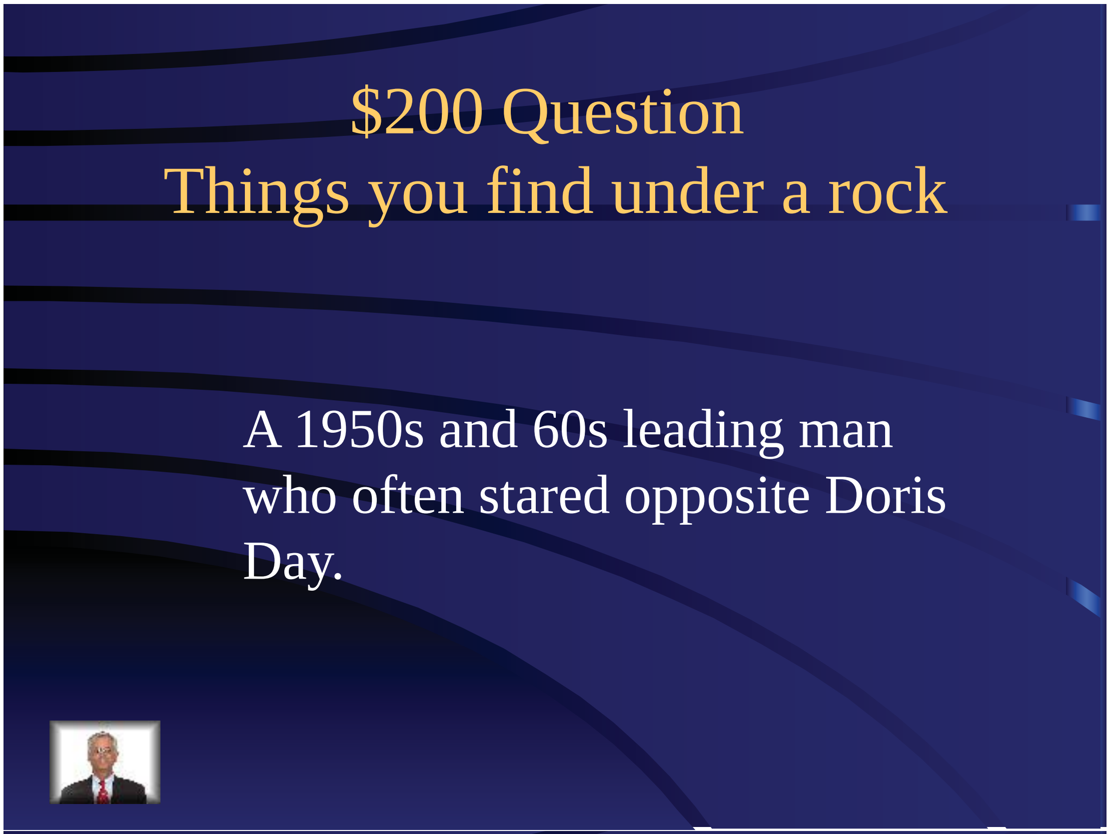
What is the promise of CTML?

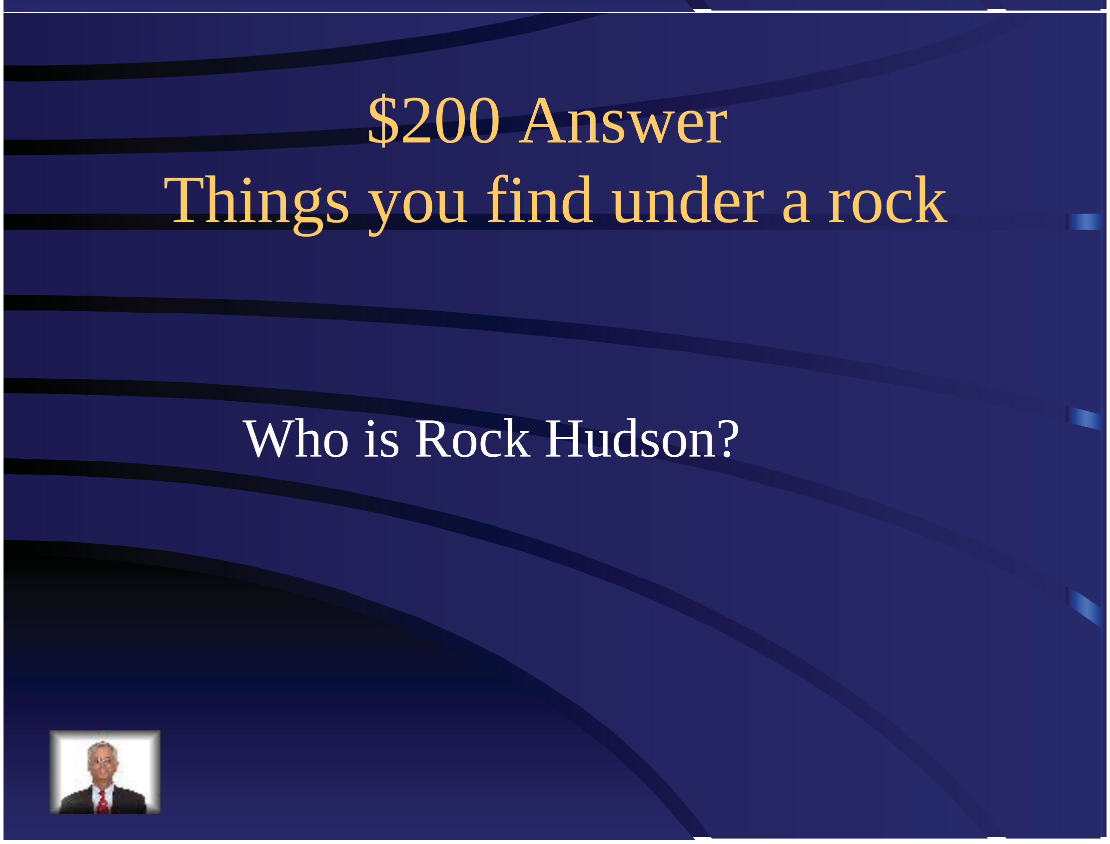
$100 Question
Things you find under a rock

A 1970s craze provided the perfect pet.

$100 Answer
Things you find under a rock

What is the ‘pet rock’?


$200 Question
Things you find under a rock
A 1950s and 60s leading man who often stared opposite Doris Day.


$200 Answer
Things you find under a rock
Who is Rock Hudson?

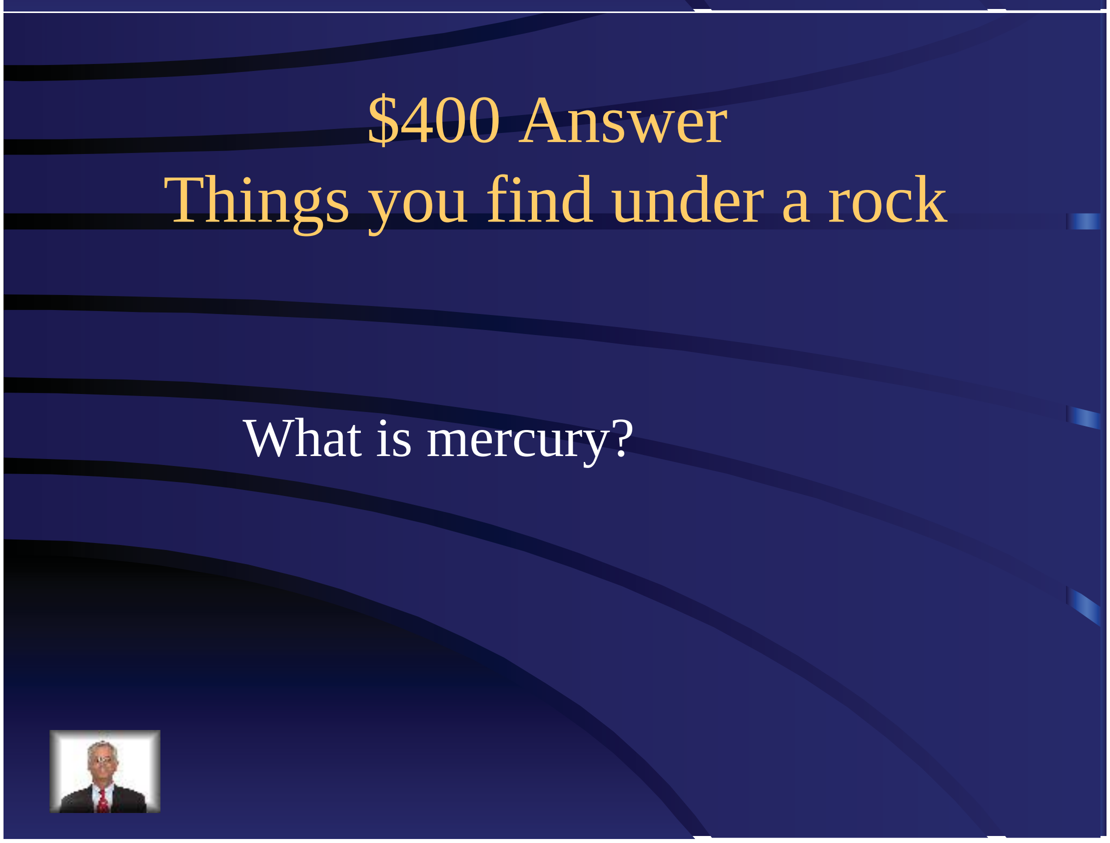
$300 Question
Things you find under a rock

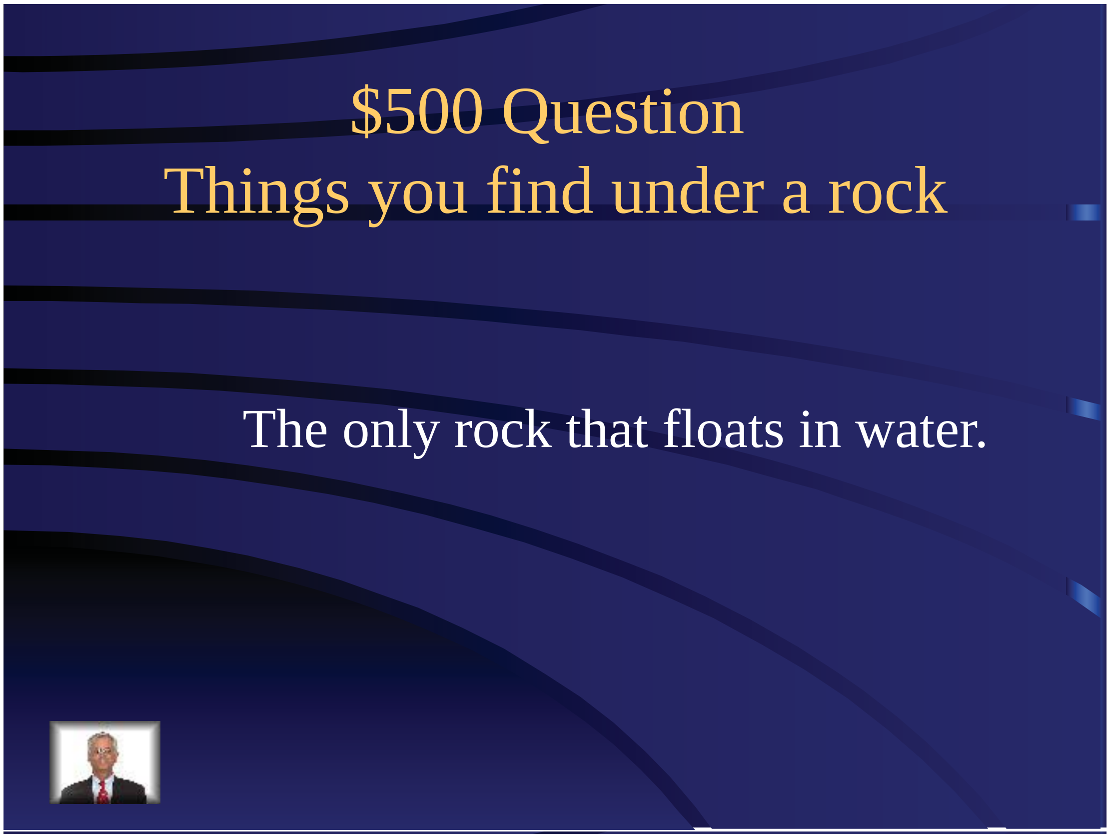
A English rock band, part of the British Invasion, who had hits such as ‘Sway’ and ‘Let it bleed’.

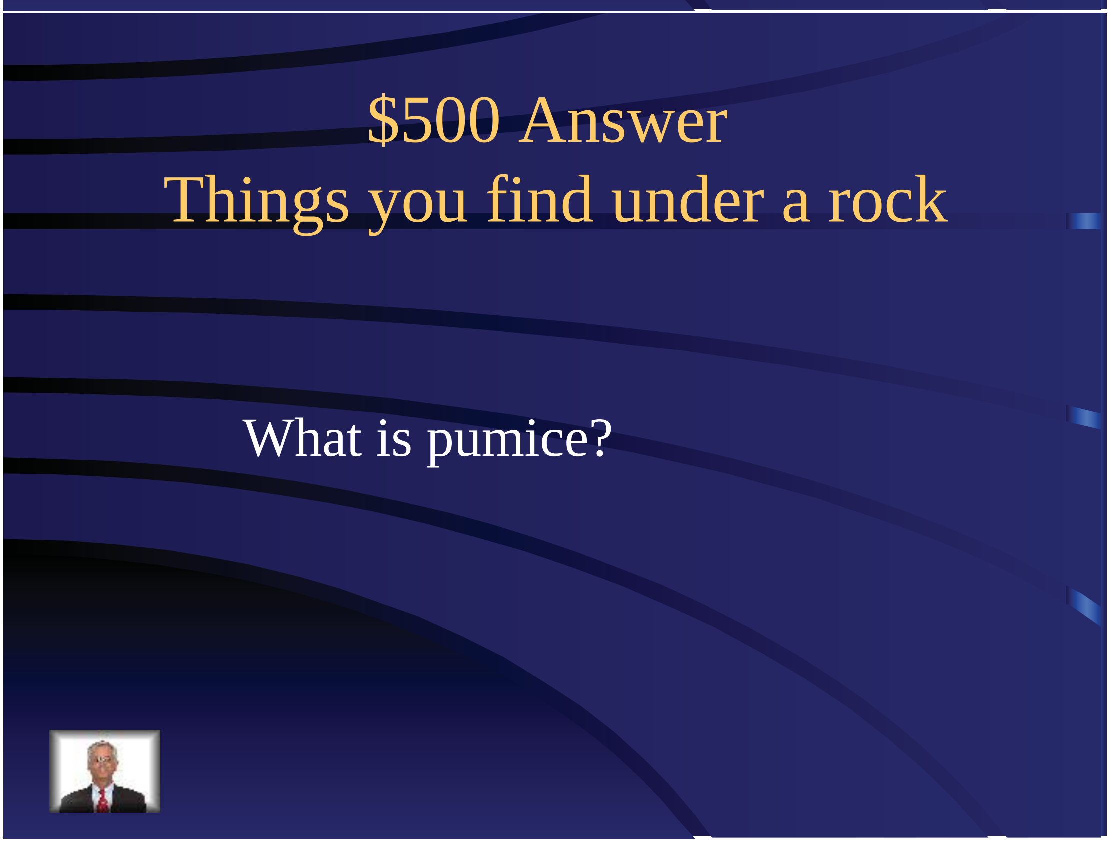
$300 Answer
Things you find under a rock

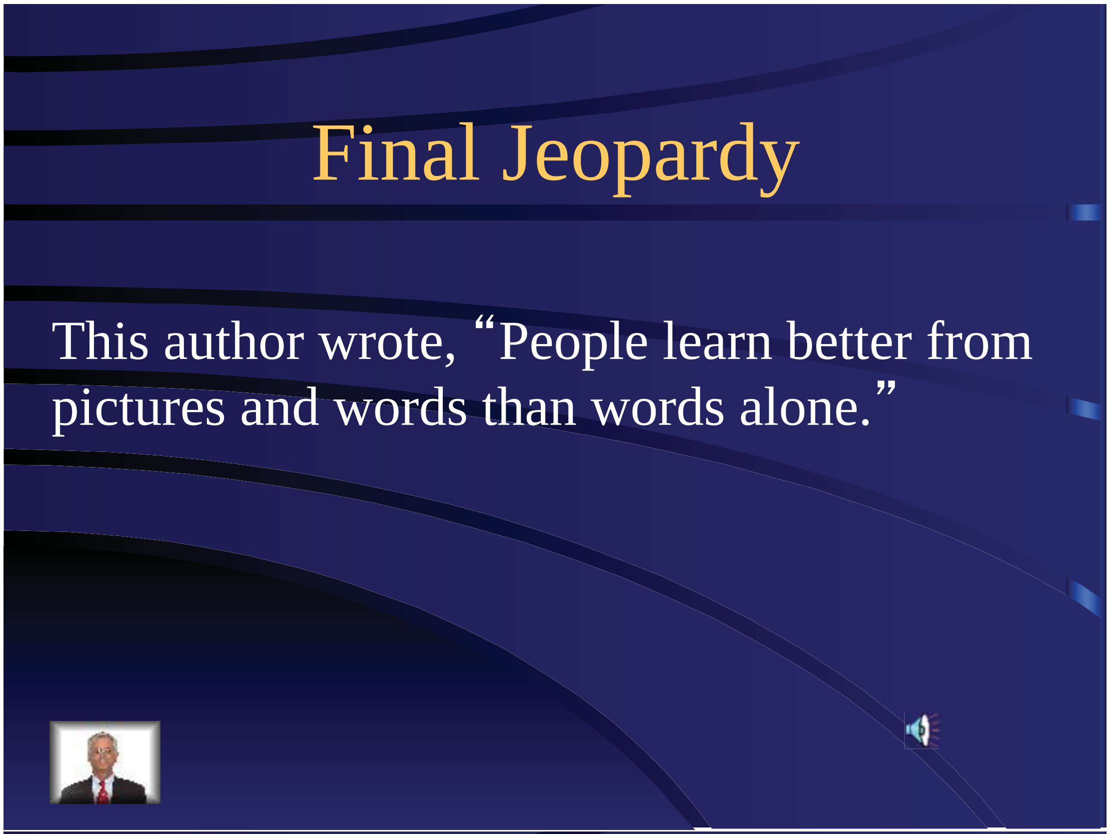
Who is the Rolling Stones?

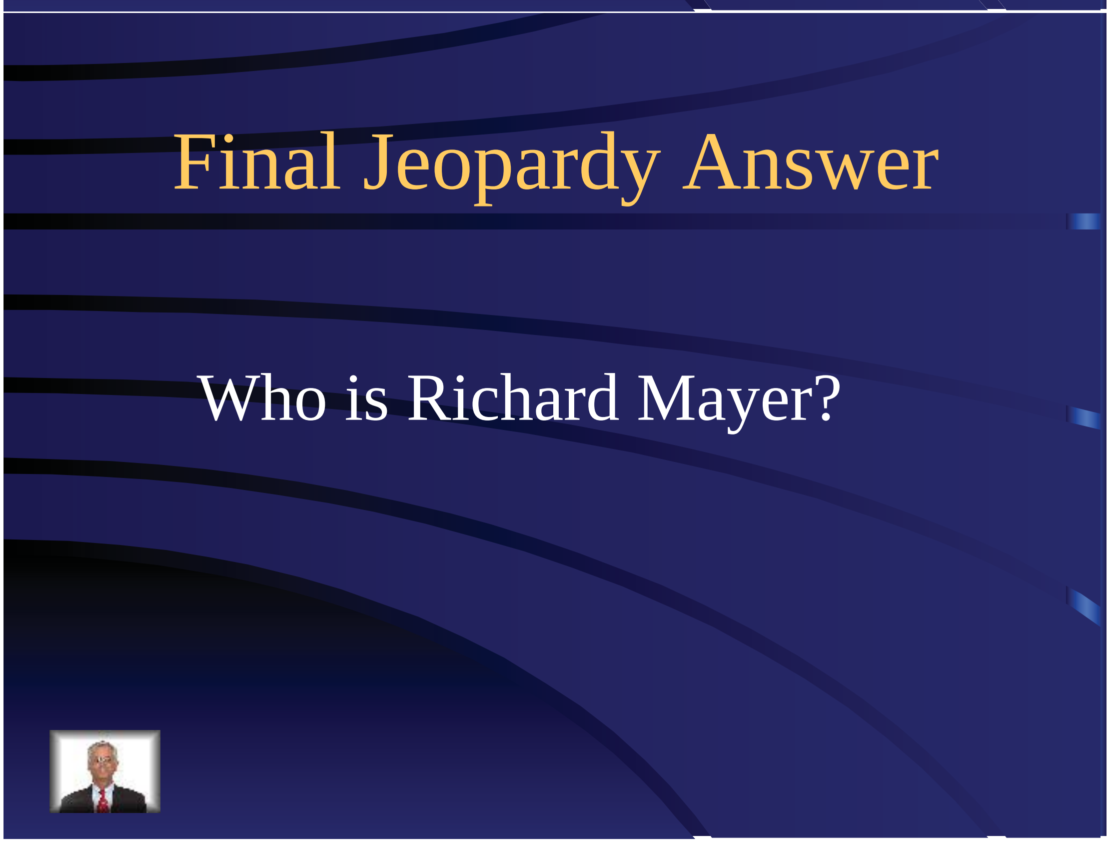

$400 Question
Things you find under a rock
The only metal at room temperature.


$400 Answer
Things you find under a rock
What is mercury?


$500 Question
Things you find under a rock
The only rock that floats in water.


$500 Answer
Things you find under a rock
What is pumice?


Final Jeopardy
This author wrote, “People learn better from pictures and words than words alone.”


Final Jeopardy Answer
Who is Richard Mayer?

Day 2 Activities – Hit or Myth (60 minutes)
(Stolovitch & Keeps, 2011)

Needed Supplies

Hit or Myth Handout, candy

Directions

Keep the participants in the same groups as was used during the CTML Jeopardy Game. Pass out the Hit or Myth Handouts and allow the groups time to determine which statements are true or false. Any statement that is considered false must be rewritten into a true statement. Each group should then develop a list of their own true or false statements. The list will read out loud, points will be awarded for correct answers and bonus points will be awarded for fooling other groups with their created lists.

Answer Key

1) false – CTML promises greater understanding and better retention during planetarium lessons.
2) true
3) false – The human brain has two input channels (visual and auditory).
4) false – Too much information can overload the brain.
5) true
6) true
7) false – The three types of cognitive loads are: extraneous, essential, and generative.
8) true
9) false – Essential processing is the learning of the most critical information.
10) true
11) true
12) false - The coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principle can decrease extraneous processing.
13) true
14) false - Generative processing can be increased by the multimedia, personalization, voice, and image principle.
15) false - The redundancy principle states that material should be presented as graphics and narration versus graphics, narration, and writen text.
16) true
17) false - The temporal contiguity principle states that narration and pictures should be presented simultaneously.
18) true
19) true

Hit or Myth Handout

Decide which statements are true or false. Create a list of your own.

1) CTML promises greater understanding and better participation during planetarium lessons.
2) People learn better from pictures and word than from words alone.
3) The human brain has two input channels (visual and phonetic)
4) Too much information can underwhelm the brain.
5) Properly designed lessons can create ideal learning conditions
6) While students learn, they are experiencing a cognitive load on their mental faculties.
7) The three types of cognitive loads are: extraneous, essential, general relativity.
8) Extraneous processing is the learning of material that is not important to the instructional goal.
9) Essential processing is the learning of the least critical information.
10) Generative processing is the organization and integration of old material with new knowledge.
11) CTML promises a set of instructional design principles that create meaningful learning experiences.
12) The coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principle can increase extraneous processing.
13) Essential processing can be managed by the segmenting, pre-training, and modality principle.
14) Generative processing can be increased by the multimedia, personalization, voice, and election principle.
15) The redundancy principle states that material should be presented as graphics and narration versus graphics, narration, and spoken text.
16) The spatial contiguity principle states that related words and pictures should be presented closer together.
17) The temporal contiguity principle states that narration and pictures should be presented sequentially.
18) The pre-training principle states that an outline should be handed out prior to the lesson.
19) The personalization principle states that am informal language style is better than a formal lingual style.
20)
21)
22)
23)
24)

Day 2 Activities – Do's and Don't Poster (90 minutes)

Needed Supplies

Finding Famous Fictional Friends and Family index cards, poster board, markers, scissors, glue, glitter, and construction paper

Directions

Groups will be rearranged using the Finding Famous Fictional Friends and Family index cards. Each new group will create a poster that outlines what should and should not be done during a planetarium lesson, based on the five chosen CTML design principles. When each poster is complete the groups will present to the whole class.

Day 2 Activities – Planetarium Lesson (90 minutes)

Needed Supplies

Inflatable Planetarium, Digitalis Projection System running Nightshade Planetarium Software

Directions

Teach the following lesson in an inflatable planetarium to demonstrate a lesson with CTML design principles. The speaking script has been provided, the necessary files can be found at www.gillettelabs.com/planeatrium_lessons.html

Lesson Speaking Script designed with CTML Design Principles (34:00)

View of the Night Sky
File: sky_view.sts

This is a view of the night sky from Earth. The air in our atmosphere causes the twinkling of the stars. Stars do not twinkle by themselves. This is what our stars would look like if we didn't have an atmosphere. See no twinkle. Let's return our atmosphere and the twinkling before we continue our journey.

<pause for twinkle to return>

If we travel back in time, long before the Internet, before television, before radio, before electricity, artificial lightning, and before books we reach a time when entertainment consisted of stories, when the night sky was available to everyone and stories where told about the stars. To make the stories about the stars interesting we needed characters. So the characters were drawn amongst the stars.

<pause for constellations lines to appear>

It might be easier to see these characters if we draw lines between the stars. These pictures are called constellations and serve the function of guides to finding the stars.

<pause for boundaries>

Today modern astronomers don't use the constellation pictures as a guide, but rather the boundaries of each constellation. You see each constellation has a border. If any sort of event or discovery is found it is said to exist within that constellation's boundaries.

<pause for planets>

Within our night sky we also can see the planets that orbit our Sun.

<pause until Ursa Major appears>

One of the better constellations to know is known as Ursa Major, the Great Bear. You may be more familiar with an asterism with the Great Bear known as the Big Dipper. The two stars at the edge of the cup of the dipper, known as Debhe and Merak are known as pointer stars and can be used to point to the North Star known as Polaris.

<pause until Polaris appears>

Polaris is key to knowing the night sky. Polaris sits right above the North Pole and appears to never move in our night sky. It is always visible in our night sky.

<pause until Ursa Minor appears>

Polaris sits at the tail of Ursa Minor, or the Little Bear. You might know this constellation as the Little Dipper.

<pause until Draco appears>

Now each star in our night sky has a different brightness and we have a scale to numerically measure that brightness. Now this scale works in reverse - the brighter the star the smaller the number. This scale is called apparent magnitude. Here is the star Rastaban, found in the constellation Draco the Dragon. Rastaban has an apparent magnitude of 2.78. A dimmer star, also in Draco, named 17 Draconis is dimmer, but with a large apparent magnitude of 5.06. The brighter stars have smaller numbers. This is Vega found in the constellation Lyra. Vega is one of the brightest stars in our night sky and it has an apparent magnitude of 0.0.

<pause until the clouds appear>

Think of the night sky as layers. The closest layer to us on the surface of the Earth is the cloud layer. These clouds help to keep our temperatures constant during the night. Beyond that layer is the Moon. Beyond the Moon are the planets. Beyond the planets are the stars and beyond the stars are other galaxies, like our galaxy the Milky Way. These galaxies have stars of their own. All these layers are visible in our night sky. Some are closer like the clouds and some are farther away like the galaxies.

<pause until the stars move>

These layers appear to move in our night sky in different patterns. The stars all appear to move very slowly in the course of one night around the star Polaris. Polaris seems to stand still.

<pause until night>

Today we know that the stars are fixed and the Earth is the one doing the rotating. This is known as apparent motion. Notice how the stars are spread evenly throughout the sky. If you were to look at one specific star you would see it moves to the west over several hours.

<pause until end of script>

Now lets take a moment to understand why summer is so hot and winter is so cold.

<advance when the Sun stops moving>

Seasons
Files: seasons1.sts & seasons2.sts

We are now sitting somewhere in France. The two lines placed on the dome will help us measure the path of the Sun.

This first measurement will take place on the Fall Equinox, which is on usually on September 22. On this day the Earth experiences 12 hours of day and 12 hours of night. You can see the path of the Sun on this day as it arcs across the sky. Notice how the rising Sun is in a different location than the setting Sun.

<pause until the next day>

The next measurement happens on the Winter Solstice, which takes place around December 21. On this day Earth experiences the shortest day of the year and the longest night. Notice how much lower the Sun is in the sky. The Earth is not experiencing the full effect of the Sun's rays. Also, the short day only allows the Sun to heat the Earth for a short amount of time. The reasons it is so cold in winter is that the angle of the sunlight along with short days provides little warmth to the Earth.

<pause until the next day>

Now lets look at what the Winter Solstice looks like from space.

<pause until the Earth starts rotating>

The Northern Hemisphere is located in this direction. As the day progresses notice how little sunlight we are receiving. This translates to cold temperatures. Without the Sun shining on us, the planet Earth would be completely covered in ice.

<advance when the Earth stops rotating>

Let's return to Earth and look at two other dates.

This next measurement will take place on the Spring Equinox, which is usually on March 20. On this day the Earth experiences 12 hours of day and 12 hours of night. You can see the path of the Sun on this day as it arcs across the sky.

<pause until the next day>

This next measurement takes place on June 21, the first day of summer. On this day the Earth experiences the longest day and the shortest night. Notice how much higher the Sun is in the sky. The Earth is now experiencing the full effect of the Sun's rays. This longer day, amplified by the angle of sunlight allows the Earth to absorb more of the heat from the Sun producing hotter weather.

<pause until the Earth starts rotating>

Now lets look at what the Summer Solstice looks like from space.

The Northern Hemisphere is located in this direction. As the day progresses notice how much more sunlight we are receiving. This translates to hot temperatures.

<advance when the Earth stops rotating>

Now lets talk about an interesting occurrence between the Sun, Earth, and Moon.

Eclipses
Files: Eclipses.sts

Every few years the Sun, the Earth and the Moon will form a straight line that can obscure the view of either the Sun or the Moon. We call these alignments eclipses.

A Solar Eclipse occurs because the Moon is between the Sun and the Earth and casts a shadow on the Earth.

<pause for rising Sun>

If you are standing on the Earth and it that shadow it looks something like this. See the Sun rising and causing daytime, but as the Moon passes in front of the Earth the shadow causes a brief moment of darkness.

<pause for zoom to Sun>

If we look closer at the Sun we can see the Moon passing in front of the Sun.

<pause for view from space>

From space the shadow upon the Earth looks something like this.

<pause for diagram>

A lunar eclipse occurs when the Earth is between the Sun and the Moon and casts a shadow upon the Moon.

<pause for view of the Moon>

On the surface of the Moon a Lunar Eclipse looks something like this. It takes several hours to progress through a Lunar Eclipse. At the peak of the eclipse the Moon appears red. That is caused by the Sunlight bending through the Earth's atmosphere.

<pause when the lunar eclipse is complete>

Now lets take a trip within our Solar System and see the major planets within it.

<advance when the edge of the Earth becomes visible>

The Solar System
Files: solar_system1.sts & solar_system2.sts

Here we see a view of our entire Solar System. At the center of our Solar System is our star named the Sun. The Sun is the ultimate source of heat and energy for all of Earth. Surrounding the Sun are eight planets. The closest planets are hard to see. They're very small compared to the other planets. The four largest planets in the Outer Solar System are Jupiter, Saturn, Uranus, and Neptune.

<pause for zoom>

Now lets look at the closest planets in the Inner Solar System. The Inner Solar System has four planets named, Mercury, Venus, Earth, and Mars.

Let's look at each planet in greater detail.

At the center of our Solar System is our star named the Sun. It makes up 99.9% of all the mater in our Solar System. Our Sun may seem large to us, but it is small compared to other stars.

<pause for zoom>

The closest planet to our Sun is Mercury. Mercury is sort of an odd planet. Large collisions have ripper the outer layer away. Now Mercury is made of core material.

<pause for zoom>

The next closest planet is Venus. Venus is the hottest planet. It has a thick layer of clouds that completely surround the planet and keep it warm.

<pause for zoom>

Next is Earth. Hopefully you are experts at Earth, since this is your home.

<pause for zoom>

Our nearest neighbor is the Moon.

<pause for zoom>

Past Earth is Mars.

<pause for zoom>

Now we leave the Inner Solar System and venture to the Outer Solar System.

Jupiter is the largest planet in our Solar System.

<pause for zoom>

Past Jupiter is Saturn.

<pause for zoom>

Beyond Saturn is Uranus.

<pause for zoom>

Beyond Uranus is Neptune.

<pause for zoom>

Way past Neptune is little dwarf planet called Pluto.

Lunar Cycle
Files: lunar_cycle.sts

Now let's look at our nearest neighbor – the Moon. The Moon orbits the Earth and because it has a day and a night side, just like Earth, we see only part of the surface in a cycle that last about a month.

When we see only the night side of the Moon we can barely see anything. This part of the cycle is called the New Moon.

When we see a small part of the day side of the Moon we call this phase a Crescent.

When we see half of the day side of the Moon we call this a quarter Moon because we are a quarter of the way through the cycle. It should be called a half Moon, but the name refers to the Moon being only ¼ or 1 quarter of the way around the Earth.

As the Moon progresses around the Earth we see more of the dayside. When we see more dayside than night side we call this a Gibbous Moon.

When we see the entire day side of the Moon we call this a Full Moon.

The cycle then continues, but in reverse order. We start seeing less of the day side of the Moon each time. When we see more day then night the Moon is called a Gibbous Moon.

When we see half day and half night the Moon is called a three-quarter Moon because it is three quarters through its cycle.

When we see just a sliver of the day side of the Moon we call it a Crescent.

Finally the Moon returns to its start as a New Moon in a cycle that last about a month.

This is what the cycle would look like from space. When the Moon is getting brighter we call it a Waxing Moon. When the Moon is getting darker we call it a Waning Moon.

Here we see a New Moon.

Waxing Crescent,

Waxing First Quarter,

Waxing Gibbous,

Full Moon,

Waning Gibbous,

Waning Third Quarter,

Waning Crescent,

and return to a New Moon.

This concludes our planetarium show.

Day 2 Activities – Summary (5 minutes)

Needed Supplies

Scratch paper, pencils/pens

Directions

Each participant will write one question on a sheet of scratch paper then crumble that paper into a ‘snowball’. The crumbled paper will be gently thrown around the room in a mock snowball fight. After the snowball fight has concluded each participant will grab the nearest snowball and attempt to answer the question out loud.

Day 3 Activities – Review Objectives (15 minutes)

Needed Supplies

Paper, pencils/pens

Directions

Review the objectives of the training to focus the participants at the required learning. Identify any course objective that have been met or partially accomplished.

Course Objectives

1) Describe CTML theory with enough understanding to be able to use these principles in future planetarium lessons.
2) Recognize examples of poor planetarium lesson design to reinforce CTML theory in future planetarium lesson designs.
3) Construct a list of do's and don'ts, based on the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) that will guide the participants while generating planetarium lessons.
4) Explain the five chosen principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization) with accuracy in order to use these principles to create an abbreviated planetarium lesson.

Day 3 Activities – Presentation Discussion (45 minutes)

Needed Supplies

none

Directions

Facilitate a discussion regarding what can be done to maximize the learning taking place in a planetarium. Encourage any suggestion and allow the participants to expand on the ideas.

Day 3 Activities - Critical List Pair Work (45 minutes)
(Stolovitch & Keeps, 2011)

Needed Supplies

Paper, pencils/pens

Directions

The participants will pair with their neighbors and create a list of why planetariums are important. This activity allows the participants to be subject matter experts (SME) and regain a sense of control over material they may already know. Each pair's list will be presented and the trainer will create a common list of between 10-15 items on a flip chart. Playing in rounds, a pair team will select the most important item on the master list and receive a point from other groups that have selected the same item. During succeeding rounds a different pair group will have an opportunity to play. The winning pair group will receive a candy prize.

Day 3 Activities - Past-Practices Discussion (45 minutes)

Needed Supplies

none

Directions

Facilitate a discussion asking if any of the participants have observed CTML principles in the past and were not aware of the significance. This discussion will tie into past observations and hopefully trigger insight into CTML based lesson development.

Day 3 Activities - Lecture Team Quiz (50 minutes)
(Stolovitch & Keeps, 2011)

Needed Supplies

Paper, pencils/pens

Directions

Use the Finding Fictional Friends and Family index cards to divide the participants into groups. Each team will create questions based on the lecturette and must prepare to answer questions themselves. Each group poses the question to the whole class. If the other group correctly answers the question than that group receives five points. If no group is able to answer the question, then the asking group receives two points. At the end of several rounds, the scores are totaled and the winning group earns a candy prize.

CTML

- CTML is a learning theory that attempts to explain how people best learn in environments of video, animation, narration, and text (Mayer, 2009)
- The human brain has one input channel for auditory and a second input channel for visual (dual-channel) (Clark & Mayer, 2011)
- If too much material is presented to the same input channel an overload can occur and the human brain cannot process this additional material (limited-capacity) (Mayer. 2010)
- Properly designed lessons create ideal learning conditions (active processing) (Mayer, 2009)

Cognitive Load

- The act of learning stresses the brain and places a cognitive load on the learner (Clark & Mayer, 2011)
- Three types of Cognitive Load (Mayer, 2010)
  - Extraneous – learning unnecessary information
  - Essential – learning the main idea
  - Generative – organizing new information with prior knowledge

CTML Design Principles

(Mayer, 2009)

- Reduces extraneous processing
  - coherence - exclude extraneous material
  - signaling - highlight essential material
  - redundancy - add on-screen text to narration
  - spatial contiguity - place printed text next to on-screen narration
  - temporal contiguity - present narration and animation simultaneously

CTML Design Principles

(Mayer, 2009)

- Increases essential processing
  - segmenting - learner controlled pace
  - pre-training - present essential material in an outline
  - modality - present text as spoken rather than printed words

CTML Design Principles

(Mayer, 2009)

- Encourages generative processing
  - multimedia - present word and pictures vs. words alone
  - personalization - conversational narration vs. formal narration
  - voice - human voice vs. computer voice
  - image - Image of the narrator on the screen

CTML Review Handout

CTML is a learning theory that attempts to explain how people best learn in environments of video, animation, narration, and text (Mayer, 2009).

Dual-channel - The human brain has one input channel for auditory and a second input channel for visual (Clark & Mayer, 2011).

Limited-capacity - If too much material is presented to the same input channel an overload can occur and the human brain cannot process this additional material (Mayer. 2010).

Active processing - Properly designed lessons create ideal learning conditions (Mayer, 2009)

Three types of cognitive load (Clark & Mayer, 2011)
1) Extraneous – learning unnecessary information
2) Essential – learning the main idea
3) Generative – organizing new information with prior knowledge

CTML Design Principles (Mayer, 2009)
Reduces extraneous processing
1) coherence - exclude extraneous material
2) signaling - highlight essential material
3) redundancy - add on-screen text to narration
4) spatial contiguity - place printed text next to on-screen narration
5) temporal contiguity - present narration and animation simultaneously

Increases essential processing
6) segmenting - learner controlled pace
7) pre-training - present essential material in an outline
8) modality - present text as spoken rather than printed words

Encourages generative processing
9) multimedia - present word and pictures vs. words alone
10) personalization - conversational narration vs. formal narration
11) voice - human voice vs. computer voice
12) image - Image of the narrator on the screen

Day 3 Activities – Planetarium Lesson (90 minutes)

Needed Supplies

Storyboard forms, pencils/pens

Directions

Create an abbreviated planetarium lesson using the five chosen CTML principles (redundancy, special contiguity, temporal contiguity, pre-training, and personalization). The group will need to decide on a topic to base the lesson on and what elements to include. The lesson will be created on paper as a storyboard, with each individual storyboard representing an individual event within the planetarium lesson. The lesson itself should be planned to occupy about ten minutes of time. When the groups have had adequate time to complete their storyboards they will present their lesson to the whole class.

Planetarium Lesson Storyboard Page #____

Description

Day 3 Activities – Evaluation (30 minutes)
(Goad, 2010)

Needed Supplies

Evaluation forms, pencils/pens

Directions

Pass out the evaluation forms and provide time for the participants to read and answer all the questions.

The Cognitive Theory of Multimedia Learning and Planetarium Instructional Training

Training Session: ____

Facilitator: ____________________________ Date: ____________________

For each item below, check the box under the number you believe best applies, using the criteria: 1 = strongly disagree; 2 = disagree; 3 = not sure; 4 = agree; 5 = strongly agree

Item		1	2	3	4	5
1	I will be able to use these skills (knowledge) on my job.					
2	Learning objectives where clear.					
3	I could easily relate to examples and problems used.					
4	Subject matter was presented in an orderly manner.					
5	The facilitator was well prepared.					
6	The facilitator was knowledgeable in the subject matter.					
7	The facilitator paid close attention to learners needs and questions.					
8	The material was useful.					
9	The audiovisuals added to the session.					
10	The training length was just about right.					
11	I would recommend this training to others.					

Your comments are appreciated for future improvements, so please add anything else you feel is pertinent, including any changes you recommend.

Thank you for taking the time to complete this evaluation!

Day 3 Activities – Closing (50 minutes)

Needed Supplies

Flipchart, markers

Directions

Facilitate a discussion on what CTML means to planetarium educators. Make sure to pull thought provoking answers from the participants. Do not accept one word answers.

Questions

1) Do you feel that CTML principles are worth integrating into planetarium lessons and how would you go about doing this?
2) How could you go about integrating CTML principles into existing planetarium lessons?

Post-Training Activity (six week follow up notice)

Needed Supplies

Email addresses

Directions

Send as an email approximately six weeks after the training.

The Cognitive Theory of Multimedia Learning and Planetarium Instructional Training

Thanks once again for attending! I wanted to provide a quick review and ask how you may be integrating CTML into you everyday work routines.

CTML is a learning theory that attempts to explain how people best learn in environments of video, animation, narration, and text (Mayer, 2009).

Dual-channel - The human brain has one input channel for auditory and a second input channel for visual (Clark & Mayer, 2011).

Limited-capacity - If too much material is presented to the same input channel an overload can occur and the human brain cannot process this additional material (Mayer. 2010).

Active processing - Properly designed lessons create ideal learning conditions (Mayer, 2009)

Three types of cognitive load (Clark & Mayer, 2011)
1) Extraneous – learning unnecessary information
2) Essential – learning the main idea
3) Generative – organizing new information with prior knowledge

CTML Design Principles (Mayer, 2009)
Reduces extraneous processing
1) coherence - exclude extraneous material
2) signaling - highlight essential material
3) redundancy - add on-screen text to narration
4) spatial contiguity - place printed text next to on-screen narration
5) temporal contiguity - present narration and animation simultaneously

Increases essential processing
6) segmenting - learner controlled pace
7) pre-training - present essential material in an outline
8) modality - present text as spoken rather than printed words

Encourages generative processing
9) multimedia - present word and pictures vs. words alone
10) personalization - conversational narration vs. formal narration
11) voice - human voice vs. computer voice
12) image - Image of the narrator on the screen

Appendix E: Curriculum Vitae

Sean Gillette
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Education:

Doctor of Education – Teacher Leadership
Walden University, Minneapolis, Minnesota — Expected 2013

Masters of Arts – Education
Azusa Pacific University, Azusa, California — 2002

Bachelor of Science – Business Administration
California Polytechnic University, Pomona, California — 1993

Teaching Credentials:

Clear Multiple Subject Teaching Credential — 1996 – Present
Business, Science, Computer Concepts and Applications

Relevant Professional Experience:

Teacher — 1998 - Present
Apple Valley Unified School District, Apple Valley, CA
Taught grades 4th – 8th focusing on science and mathematics

Teacher — 1994-1998
Pomona Unified School District, Pomona, CA
Taught grades 6th – 8th focusing on science and mathematics

Systems Analyst — 1992-1994
St. Joseph Heath System, Orange, CA
Assisted in the development of computer systems

Publications:

Brewer, M., Rogers, A., Harder, H., Lazak, R., Gillette, T., Gillette, S., Sweatt, M., Keele, R., Keele, M. Smith, B., Mercado, A., Cheske, H., Zoltan, K., & Stewart, E. (2012). Student Measurement of 3 Binary Star Systems. *Journal of Double Star Observations 8*(3).

Professional Presentations and Papers:

Fuge, B., Goodrow, B., Wolf, D., Gillette, S., Thielen, W., & Bell, D. (2013). Schools to Watch – Taking Center Stage Model Middle School Presentations. A paper presented at the California League of Middle School Conference. February 2013.

Honors and Awards: 2010
Apple Award (Teacher of the Year)
Apple Valley Unified School District

Professional Affiliations:
International Planetarium Society
High Desert Astronomical Society
National Science Teachers Association
California Science Teachers Association

References:
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