The Effect of Coloring on Retention and Transfer in Multimedia Learning

by

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ABSTRACT

The current study investigated the task of coloring static images with multimedia learning to determine the impact on retention and transfer scores. After watching a multimedia video on the formation of lightning participants were assigned to either a passive, active, or constructive condition based on the ICAP Framework. Participants colored static images on key concepts from the video, passive condition observed the images, active condition colored the images by applying the concepts, and the constructive condition colored the images by generating new ideas and concepts. The study did not support the hypothesis that the constructive condition would have increased retention and transfer scores over the active and passive conditions. The mental effort measures did not show significance among groups in relation to learning but perception measures did show an increase in participants enjoyment and engagement. Since the coloring craze has become more accepted for adults then could coloring be a way to increase participants learning through engagement.

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CHAPTER 1

INTRODUCTION

Learning is a process of obtaining knowledge through experience and through a system of being taught or systematic instruction. When it comes to learning people are reminded of taking exams or book learning. Learning can be measured by the recall and retention of information and the transfer of understanding the information. Active learning requires students to engage cognitively and implicitly with the materials (Chi, 2014) "to really think about it" where other variations of learning from active to interactive have resulted in constructive learning outcomes (Smart & Csapo, 2017). Mayer (1999) states that multimedia learning settings are where instructional learning material is presented in multiple forms such as visually (illustration) and verbally (text and narration). Constructivist learners are looking to make sense of presented materials by forming a coherent mental representation. When combining learning and the task of coloring we use both our creative and cognitive processes, which Mehta (2009) described as when we choose certain colors to draw or color in a book, performance is enhanced by both the creative and cognitive tasks. Colors can also influence learning in regard to retention of material, which is remembering, recalling or reorganizing of the presented information and the transfer, understanding, evaluating or using the information to solve new problems. According to Xia (2016) the effect of coloring on cognitive tasks can differ based on the type of task, with most of the studies being done on the colors red and blue. Since the adult coloring book 'craze' has hit the shelves, there is no turning back the pages and in 2015 over 12 million adult coloring books were sold (Halzack, 2016). Does the constructive task of coloring have an improvement on multimedia learning?

CHAPTER 2

LITERATURE REVIEW

Cognitive Theory of Multimedia Learning

Mayer (2003) showed that the human information processing system consists of two separate concepts that are important to the learning process. An auditory or verbal channel is for processing auditory input and a visual or pictorial channel is for processing visual input and pictorial representations (Clark & Paivio, 1991). Mayer's Cognitive Theory of Multimedia Learning or CTML (Mayer, 2001) in which three kinds of cognitive elements can create cognitive overload for a learner. These elements include: essential processing, incidental processing, and representational holding. Four criteria were used to build the cognitive theory of multimedia: theoretical plausibility, testability, empirical plausibility, and applicability. There are three assumptions in the model: *dual channels* when the visual-pictorial channel and auditory-verbal channel are processed in separate channels, *limited capacity* for holding and manipulating knowledge in each channel and *active processing* when learners engage in active processing to form an understanding of their experiences. Five cognitive processes: *selecting words* – when the learner receives the information and selects what is important to put into working memory (WM), *selecting images* – the learner receives the information into sensory memory (SM) and processes what is important into the WM, *organizing words* – this takes place in WM and is when the learner organizes the words into the verbal model, *organizing images* – the learner is still using WM to process and organize into a pictorial model, and *integrating* – the learner integrates the words and pictures together and then uses their prior knowledge to put into long-term memory (LTM).

The CTML focuses on three cognitive processes (Mayer, 2014) for the platform of multimedia learning: *selecting*, which is paying attention to relevant words and pictures and bringing information from SM into WM; *organizing*, the selected words and pictures into the mental representations which manipulates information into WM and *integrating*, which is connecting verbal and pictorial representations with each other and with prior knowledge and transfers knowledge from LTM to WM (See Figure 1).

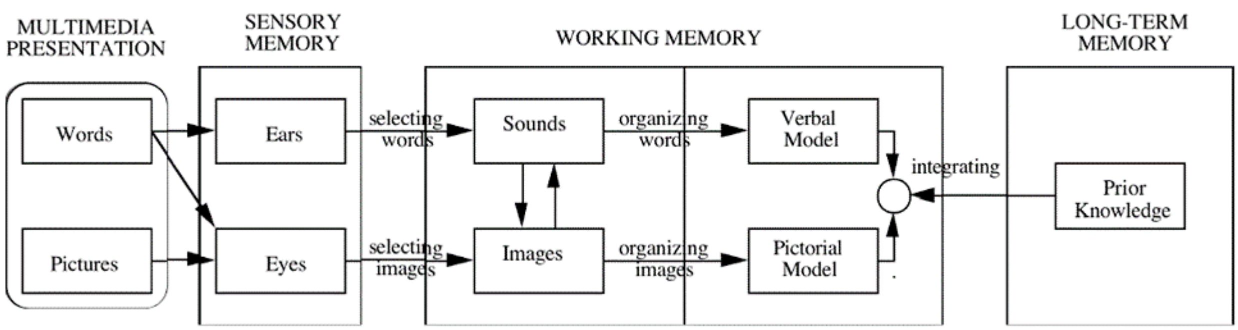

Figure 1. Cognitive theory of multimedia learning cognitive processes. Mayer, R. (2014). Research-based principles for multimedia learning. Harvard Institute for Learning and Teaching.

ICAP Framework

The ICAP Framework or I>C>A>P (Chi, 2014) is where each initial corresponds with a learning "mode" as follows, *interactive* mode, *constructive* mode, *active* mode, and *passive* mode. Each mode predicts a dissimilar level of learning which corresponds to student's overt behaviors that cause different knowledge changes in learning. Students engage differently with each mode, *passive* mode learners are receiving their information from instructional materials, *active* mode the learner takes the instructional material and applies an action or physical manipulation, *constructive* mode learners generate additional outputs beyond the provided learning materials, and *interactive* mode learners are interacting together. ICAP is a theory of cognitive engagement which has a behavioral metric (Chi, 2014) and focuses on the amount of cognitive engagement that can be discovered by smaller behavioral activities while students learn. The ICAP hypothesis predicted that activities move from *passive* >*active* > *constructive* > *interactive* modes where students have diverse processes of knowledge-change whereas, these students had an increase in their learning. Chi also states that when watching a video and then having to explain concepts or comparing to prior knowledge that this is a constructive mode of learning.

Students engagement with learning materials can be operationalized by the overt behaviors they take on while learning which is categorized into four behavioral modes – *passive, active, constructive and interactive* (Chi, 2014). Outputs of these behaviors should confirm new ideas that go outside the information given to be constructive activities which include: drawing concept maps, generating self-explanations and integrating text and diagrams. Menekse's (2013) Differential Overt Learning Activities or the DOLA Framework, claims that different modes of overt engagement have different success because they involve different cognitive processes. Active activities involve some maneuvering of materials where constructive activities generate new ideas.

CTML and ICAP

Multimedia materials become more operative when cues are added for a learner's attention which guides the learner to the appropriate elements of the material. The principle of signaling or cueing can be crucial for multimedia learning according to the CTML (van Gog, 2014). The active processing principle is when learners participate in cognitive processing during learning, which includes organizing the material mentally and integrating it with prior knowledge (Mayer, 2010). Participants watched a video on the formation of lightning from Mayer's work which falls into the passive learning mode from Chi's ICAP Framework. Based on Mayer's CTML the selecting or paying attention to words and pictures and bringing into WM involves constructive and active learning activities. Then the learner organizes the selected words and pictures to manipulate the information into WM which involves constructive and active learning activities. Then integrating which is connecting the verbal and pictorial representations with each other and prior knowledge involves constructive learning activities, presented in Table 1.

Table 1
Explanation of Mayer's CTML and how it fits into Chi's ICAP Framework.

	Interactive	Constructive	Active	Passive
Selecting		X	X	
Organizing		X	X	
Integrating		X		

Supporting Learning Through Active Processing

Students will remember more content if activities are introduced into the learning environment. Active learning is instructional and engages students into the process. Collaborative learning is instructional but requires the students to work together. Problem based learning is also instructional but the motivation for learning follows (Prince, 2004) and it involves active and collaborative learning but requires the student to be self-directed. Sweller's (1994) cognitive load theory examines how cognitive load during learning and how the mental model is represented in a learner's memory is a function of learning and stores automated schemas in long-term memory. Working memory can process and store a few items at a time and is very limited. Schemas which chunk individual elements increase the amount of information in working memory (Sweller, 1994). Multimedia learning is an insistent process with words and images and verbal and pictorial depictions. Graesser (2009) described the learning landscape as what, where, who and when to be essential for biological or neurological motivation and that learning is not an innate capacity mechanism or simple recall of prior material.

According to Evans (2006) there are several principles formulated by Mayer (2001) which include the *multimedia principle:* words and pictures, *coherence principle:* avoiding unnecessary media, and *modality principle:* using narration instead of text. The active learning hypothesis predicts learning increases from interactive systems, since learners are engaged more closely with the material. Passive learning has no special effect since the content does not differ from content in a non-interactive system. These both come from the constructivist model where learners construct their own knowledge based on prior knowledge and new information received (Jonassen, 1992).

Using the spatial contiguity principle, Mayer (2005) uses a series of static images which showed the major processes of lightning where the words are corresponding near each of the diagrams. The static media hypothesis states that learner's attention is limited. Attention can be used for extraneous processing where cognitive processing may not cultivate the instructional objective. Mayer stated that two explanations for learning from static illustrations and text can lead to deeper learning than from narration and animation – more germane processing (involves processing of key material by mental organization) and less load from intrinsic extraneous processing. Only presenting frames of the key processes, the static illustrations will encourage learners to focus on relevant information in the static illustrations. This will reduce the extraneous processing on the learner.

Active processing of the static illustrations is exemplified as elaboration, self-explanation, or mental animation and relates with Sweller's (2005) germane processing and Mayer and Moreno's (2003) essential processing. These showed better retention and transfer scores on tests. Although, there may be less cognitive load for animation or video learning than from static illustrations because learners do not need to engage in cognitive processing since the computer may do this for them (Mayer, 2005).

Constructivist learning is an active process where the learner is building and organizing knowledge (Mayer, 2004). The 1960's discovery methods by Bruner, where discovery of new ideas by the learner is allowed rather than required to memorize the material from the teacher. Shulman and Kaisler next found guided learning to be more effective for learning and transfer of new problems. In the 1970's Piaget introduced constructivist education where the learner could manipulate chosen situations. The 1980's introduced discovery learning through computer programs.

Levels of processing (Craik, 1972) are done through short-term store (STS) which requires attention and rehearsal of the information, and long-term store (LTS) which still has rehearsal of information but also includes repetition through organization of auditory and visual methods. The retention process is a function of depth and the amount of attention which is given to a stimulus along with the analyzing and depth of the processing. Memory is thought to being tied to levels of processing. These are grouped into stages: sensory analyses, pattern recognition and stimulus elaboration.

When students have to work out examples containing text and diagrams they have a deeper understanding of the material. Self-explaining is an effective metacognitive strategy (Ainsworth, 2003) which assists learners to develop greater understanding of the materials studied. Diagrams will reduce memory load, cognitive effort and encourage causal explanations. Graphical representations of the material can also benefit learning. Students performed significantly better on post-tests when given diagrams than with students given text.

Furthermore, learning is now becoming a staple online with many methods being utilized via multimedia learning. e-Learning or multimedia learning is a combination of words and graphics used for instructional methods for educational and job training. This type of learning is on the rise and accounts for 40% of workforce training (Clark, 2016). A person watches a video or series of videos and then answers questions or completes practice problems from what they just watched, demonstrating their transfer and retention of the material. Mehta (2009) stated that colors influence the retention and transfer of material from multimedia learning.

Coloring and Learning

In 2014, Plass replicated his previous research on the effects of design elements of color and shape. This study was interested in color and shape in multimedia learning and if the material would prompt a positive cognitive effect on emotions in learners. Mayer's CTML defines learning through visual and verbal materials and links them to visual and verbal depictions with prior knowledge. Participants of this study were randomized by the following 2x2 factorial design: color (warm or neutral) and shape (round face-like or neutral). Round shape and warm color caused an increased comprehension while color and shape showed the same results. Transfer of knowledge concluded that round shapes with face-like features impacted learning. Both shape and color were found not to add to cognitive load.

There are basic human factors and ergonomics principles (HF/E) that are used to assist with designing presentations. These include both cognitive and perceptual principles that are applicable to designing a good Power-Point presentation (Durso, 2011). Scientific criteria taken from Sanders and McCormick (1993) state the necessity for having a clear presentation for the audience. When taking into consideration color in a presentation, combining high-contrast with text-to-background is encouraged (e.g. black and white). Dark text on a light background makes reading easier, especially in a well-lighted room. Splitting complementary colors can aid with achieving high contrast (e.g. dark blue on pale red). It is highly suggested to avoid red and green contrasts in presentations due to some of the audience may have a color deficiency.

A study on the correlation between using emotional design principles to redesign the graphics in multimedia lessens and the improvement on student learning outcomes was done by Mayer and Estrella (2014). The intent to increase motivation in the learner was done with redesigning the graphics which was to prime the learning processes and may have improved learning outcomes.

Current Study – Hypotheses and Predictions

The ICAP (I>C>A>P) Framework (Chi, 2014) is where students are more engaged with the materials in the *interactive* mode than the *constructive* mode than the *active* mode and then the *passive* mode. As students go from the *passive* to *constructive* learning modes their learning increases. The current study did not have an *interactive* learning condition, however, did have *constructive*, *active* and *passive* learning conditions. The hypothesis that the *constructive* learning condition will have an increase in learning in the participants retention and transfer scores after watching a multimedia presentation on the formation of lightning and then coloring static images of the processes from the video is supported by Chi's ICAP Framework.

This research study used three of the four modes from the ICAP Framework along with the task of coloring to assist with cognitive engagement. Active learning enables students to engage cognitively along with (van Gog, 2014) the signaling and cueing principle of multimedia learning. Participants either colored a series of 4 black and white static images showing the key processes of the formation of lightning or just looked at the colored images on the formation of lightning. The signaling principle is when learners are alerted to cues on relevant elements of the material whether it be text or pictures or both (van Gog, 2014).

The experiment had three treatment conditions using the ICAP Framework (P<A<C) – the *constructive* group choose the colors to generate new ideas and map the concepts or key processes in the static images from the video on the formation of lightning, the *active* group were given the same set of static images to color the concepts of the key processes from the video, and the *passive* group were given just the set of static images already colored in and then asked to observe or look at them. The researcher was looking for an effect on learners in the *constructive* coloring task to have higher retention and transfer scores after watching the video on the formation of lighting. How does the task of coloring key images from the video on the formation of lightning impact the retention and transfer scores? The current study predicts that when participants are in the *constructive* task of coloring the static images from the video on the formation of lightning that the retention and transfer scores will be positively impacted. Also, the researcher predicts there will be low cognitive load in the *constructive* coloring task after

the retention and transfer tests with high enjoyment and engagement after the coloring task.

CHAPTER 3

METHODS

Participants

Sixty-one (N=61) participants who were undergraduate students were recruited to complete this study on the task of coloring and multimedia learning. Participants were recruited through the research pool of the Human Systems Engineering program at Arizona State University Polytechnic campus in Mesa, AZ. Participants were randomized during the selection process by signing up through the SONA system on the computer and selecting a specified time slot. Participants were given 1 hour of credit through their HSE 101 class. The researcher did not eliminate any of the subjects who enrolled for the study.

Eleven (N=11) participants were removed from the current study results. Participants gained access to markers during the *passive* coloring condition and used them to color on the static images. The data was removed from the study as to not show any bias or skewness of the data in the *passive* condition. Data analyses were done on fifty (N= 50) participants. There were 49 males and 12 females who participated in the study with 96% of participants having some college and 92% of participants being between the ages of 18-25 years old.

A power analysis using G*Power was conducted and a one-way ANOVA analysis was run with an α level of 0.05, effect size of 0.3, power level of 0.80 which yields a sample size of 111 participants. This will yield 37 participants per group which is higher than the standard number of participants used in multimedia learning of 25-30 (Mayer, 2009). Oversampling should provide a buffer for any bad data in the experiment.

Materials

Design. A multi-treatment with pretest and control condition (Shadish, Cook & Campbell, 2002) with dependent measures of recall, retention and transfer were implemented for this study. This study had one independent variable with three levels, *passive, active and constructive* coloring tasks with the *active* group being the control group. There were 4 dependent variables which were a continuous learning measure of recall, retention, transfer and mental effort.

The coloring task included four black and white static images on some of the key elements of the formation of lightning from the video, for both the *constructive and active* groups. Colored markers were provided for each participant. A set of four color static images with the same key elements were provided for the *passive* treatment group to observe or look at. Retention and transfer questions on the process of lightning were completed after the coloring task.

Treatment implementation. The first treatment is the *constructive* group which colored a series of four static images showing the key processes on the formation of lightning (see Appendix A) from the Mayer and Moreno's (1999) multimedia environment on the formation of lightning. The participants chose each of the colors for the key elements in the images. The second treatment is the *active* group which colored the same set of static images from the video and had a key for what to color each of the elements in the images. The third treatment is the *passive* group which observed or looked at the same set of static images (see Appendix B) with the elements of the images already colored.

Assessments. Measures were assessed from participants on their demographics, pretest, mental effort or cognitive load, perceptions, and multiple choice, retention and transfer tests.

Demographics and pretest measure. Demographics survey was assessed on gender, level of education completed, marital status and age range. Then a pretest with 2 questions, 7 items about knowledge of weather and then a 5-point scale on knowledge of meteorology from very little to very much knowledge (Appendix C). A non-equivalent pretest which taps into the students reported knowledge levels was given to test participants comprehension of meteorology. One point was received for each item checked (Moreno & Mayer, 1999).

Mental effort scale. Mental effort measures using a 9-point scale from very, very low effort to very, very high effort were completed after the video, the coloring task and then again after the retention and transfer questions (Appendix D). These were used to measure cognitive load. The scale is widely used according to Paas (1992) and is reliable.

Perception measure. Two perception measures using a 6-point scale from extremely enjoyable to extremely unenjoyable and extremely unengaging to extremely engaging were completed after the coloring task (Appendix E). Questions were: "Did you find the task of coloring or looking at the pictures enjoyable?" "Did you find the task of coloring or looking at the pictures engaging?"

Recall and retention. Recall questions consisted of 6 multiple choice questions (Appendix F) about the key parts on the formation of lightning from the video and measured deep level knowledge and shallow conceptual knowledge (Craig, 2017). Then a one question test was used to record the number of major idea units (Mayer & Moreno,

2009) ex. “Write down your explanation of lightning.” Participants scores were based on the 19-point rubric from Mayer & Moreno (2009).

Transfer. Participants were given four problem solving questions one at a time in an essay type format, ex. “What causes lightning?” Transfer questions on key processes from the video on the formation of lightning (Appendix G) were also assessed using the 12-point rubric by Mayer and Moreno (2009).

Procedures

Participants entered the lab where they were greeted by the researcher and seated at a computer and then read and agreed to the treatment consent (Appendix H). The study was conducted in Qualtrics and participants completed a sound check and demographics questions and then the researcher explained that they would be watching a video on the formation of lightning (Mayer & Moreno, 2001) for approximately 4 minutes.

A pretest was assessed on the knowledge of weather and meteorology and then a mental effort question about the video. Participants then moved from the computer to the coloring task where they were randomly placed into one of the three treatment groups for the coloring task – *passive, active, and constructive.*

Instructions (Appendix I) were given to each of the treatment groups on how to complete the task of coloring for that specific group. Each group was given a series of four static images showing the key processes on the formation of lightning and asked to either color the images or observe the images. The *constructive* group chose the colors they associated with each of the elements in the static images, the *active* group were given the same images and then asked to color the pictures with the colors chosen for each of the key elements and the *passive* group were asked to look at or observe the images. All groups had a total of 4 minutes. Another mental effort question was asked and then 2 questions on the perceptions of the coloring task.

Participants completed a posttest and one recall question and then moved to the questions on retention and transfer on the formation of lightning from the video, where they had 5 minutes for the retention questions and 3 minutes for the transfer questions. After the retention and transfer tests participants then completed another mental effort question. Once completed they were thanked for their time and given 1 credit for the study in the SONA system.

Scoring

The researcher scored the retention and transfer questions based on the rubric by Moreno and Mayer (1999) (Appendix J). A random selection of 10% of the data was coded by two raters and Cohen’s Kappa interrater reliability scores were calculated. This scoring produced a reliability score of $\kappa = 0.79$ for the retention test and $\kappa = 0.72$ for the transfer test. After reliable coding was established the remaining answers were scored.

Data Analysis

Participants cognitive load from the mental effort questions were measured using the mental effort scale (Paas, 1992). The mental effort questions were assessed three times, after the learning video, coloring task and then after the recall and transfer questions. An ANCOVA analyses was used to measure differences among the treatment groups for the recall and transfer questions with the pretest being the covariate variable which is measured for prior knowledge using a non-equivalent pretest. A Levene’s test was conducted to verify assumptions and to make sure there are equal variances.

$$E= (Zperformance - ZMentalEffort/\sqrt{2}) \quad (1)$$

CHAPTER 4

RESULTS

The current study used the alternative treatment with pretest and control condition (Shadish, Cook & Campbell, 2002) with dependent measures of recall, retention and transfer. There was one independent measure with three levels - *passive*, *active* and *constructive*. An analysis of covariance, ANCOVA was conducted on the multiple-choice, retention and transfer with the pretest as a covariate and separate analysis of variances, ANOVA's were conducted on the pretest, mental effort and perceptions measures using a Levene's test of equality of error variances.

Learning Measures

An ANOVA was conducted on the participants pretest score which did not indicate significant differences among groups ($F(2, 47) = .69$, $p = .51$; $=^2_p = .03$. A series of ANCOVA's were conducted on the participants data for the multiple-choice, retention and transfer tests using the pretest as a covariate to examine the differences among each group. These analyses did not indicate significant difference for the multiple-choice test ($F(2, 46) = .08$, $p = .93$; $\eta^2_p = .00$), retention test ($F(2, 46) = 1.18$, $p = .32$; $\eta^2_p = .05$), and transfer test ($F(2, 46) = 1.23$, $p = .30$; $\eta^2_p = .05$). Means and standard deviation measures by condition are presented in Table 2 for pretest, multiple-choice, retention and transfer scores.

Table 2
Means and standard deviations for participant's scores on multiple-choice, retention, and transfer tests.

Coloring Condition	N	Pretest M(SD)	Multiple-choice M(SD)	Retention M(SD)	Transfer M(SD)
Passive	8	5.50(0.93)	.60(.32)	2.50(1.77)	2.13(1.13)
Active	21	4.48(2.32)	.60(.29)	3.24(2.43)	2.29(1.15)
Constructive	21	5.10(2.66)	.63(.21)	4.05(3.12)	2.81(1.47)

Cognitive Load (Mental Effort)

Cognitive load (mental effort) measures were done during three intervals during the study the mental effort scale from (Paas, 1992), after the video, $F(2, 47) = .87$; $p = .43$; $\eta^2_p = .04$, after the coloring task, $F(2, 47) = .51$; $p = .60$; $\eta^2_p = .02$, and after the retention and transfer tests, $F(2, 47) = 1.47$; $p = .19$; $\eta^2_p = .07$ no significant differences were found among groups. Means and standard deviations by condition are presented in Table 3. LSD post-hoc indicated no significance between groups.

Table 3
Means and standard deviations for participant's scores on cognitive load.

Coloring Condition	N	Video M(SD)	Coloring Task M(SD)	Retention & Transfer M(SD)
Passive	8	.28(0.90)	.15(1.51)	.11(1.10)
Active	21	-.24(0.92)	.07(0.90)	.28(1.01)
Constructive	21	.01(1.07)	-.21(1.10)	-.28(0.94)

Perception Measures

An ANOVA was performed on participant's ratings of enjoyment and engagement to determine differences among groups. These analyses showed significance among groups for enjoyment measure, $F(2, 47) = 6.08$; $p = .00$; $0^2_p = .21$. Post-hoc analyses using LSD group comparisons indicated that the active participants (Cohen's d = .72; $p = .00$) performed the same as the constructive participants (Cohen's d = 1.04; $p =$

.00), but the passive participants did not differ significantly between the active and constructive participants (Cohen's d = 1.86; *p* = .11).

There were also significant differences among groups for participant's perception ratings, $F(2, 47) = 3.60$; $p = .04$; $\eta^2_p = .13$. LSD post-hoc comparison tests indicate that active participants (Cohen's d = .13; *p* = .02) performed the same as constructive participants (Cohen's d = 2.04; *p* = .02), but passive participants did not differ significantly among participants (Cohen's d = 1.70; *p* = .08). Means and standard deviations by condition are presented in Table 4.

Table 4
Means and standard deviations for participant's scores on perception measures.

Coloring Condition	N	Enjoyment M(SD)	Engagement M(SD)
Passive	8	3.50(.53)	2.90(.40)
Active	21	2.90(1.11)	2.23(.62)
Constructive	21	3.90(0.90)	2.90(1.14)

CHAPTER 5

DISCUSSION

The study found no significant differences among the groups, *passive*, *active* and *constructive* for learning on the multiple-choice, retention, and transfer tests. There were mental effort measures taken during three points in the study, after the video, after the coloring task and after the retention and transfer tests; none of these were found to be significant among the groups. However, perception measures taken after the coloring task, which were on participants enjoyment and engagement showed significance amongst the groups.

The current study had predictions for learning, mental effort and perceptions. Based on the ICAP Framework, the current study predicted that learning would be best for the *constructive* coloring condition and worst for the *passive* coloring condition, with the *active* coloring condition learning performance in the middle. For mental effort it was predicted that after watching the video that low mental effort was expected for each of the three conditions. After the coloring task, the *passive* condition would have low mental effort, the *active* condition, medium mental effort, and the *constructive* condition, high mental effort. After the retention and transfer tests, the *passive* condition would have high mental effort, *active* condition would have medium mental effort and the *constructive* condition would have low mental effort, presented in Table 3. Predictions for perceptions of the coloring task were that all conditions would have increased enjoyment and engagement from the task.

Coloring and the ICAP Framework

The data from the current study did not strongly support the ICAP predictions for the coloring conditions. The ICAP hypothesis predicts that learning would increase for students from *passive*, to *active,* to *constructive* with the *constructive* group having better learning by generating new ideas and concepts. The current study did not find significant differences to support this relationship. However, the predicted pattern for the mean scores was present with an observed $\eta^2_p = .05$ effect size. This moderate effect size paired with the decreased sample size raises the possibility of a type II error. Participants for the study were reduced since the subject pool of undergraduate students available in the HSE 101 classes were limited in size. With a larger subject pool to the meet the needs of power size this study could have seen significance among groups based on the means patterns were in the right direction, presented in Table 2.

The mental effort measures did not impact participants learning outcomes for the multiple-choice, retention and transfer. Predictions were not supported that the *passive* condition would have higher mental effort than the *active* and *constructive* groups. However, there was an improvement in perceptions for both enjoyment and engagement measures as presented in Table 4. Further research may need to be completed to see if engagement has an impact on multimedia learning when having a larger sample size.

Limitations

Sample size problems. The findings in this study suffered from a limited sample size. An initial analysis indicated the need for 111 participants. However, the current study was only able to collect 61 participants due to the limited participants which resulted in an underpowered study and could be a plausible explanation for the null effects found in this study. The number of participants was additionally limited by experimental procedure error. Due to experimental set-up problems, initial participants in the *passive* coloring condition could get access to markers placed close to them and some participants used them to color on the already colored static images. Interestingly, these spontaneously *active/constructive* participants have similar means and standard deviations when compared to the *constructive* participants. To avoid contamination these participants data were removed from the analyses. Since this removal was all from one condition, this was not random data loss and the resulting attrition could have also been a threat to the randomization procedure.

The sampling problem could have been further impacted by the 11 participants removed from the *passive* condition that were exposed to markers during the coloring task. During data collection some participants had access to markers in the *passive* condition and used them to color on the already colored static images. These participants generated new ideas and concepts and acted like the *constructive* condition. These participant's data were removed from the analyses.

Internal validity of constructive condition. The current *constructive* condition as implemented may not have been fully a *constructive* task. A *constructive* task produces additional outputs which contain new ideas that go beyond the presented information or the presented materials. If this is not done then this means the *constructive* task becomes an *active* task (Chi, 2009). The instructions provided to the participants in the *constructive* condition only asked them to color and connect the concepts from the video with the provided static images. The process participants went through during the coloring task was not analyzed so the researcher cannot be certain the given instructions implemented a *constructive* learning environment. Participants colored concepts or manipulated what they saw in the video, so these participants were more *active* then *constructive*. If the participants had been given instructions to color new ideas or produce outputs that were not covered or presented in the learning material on the formation of lightning, then this may be considered a *constructive* task.

Chi does state that with explicit identification of overt activities, ways to elicit desired activities remains challenging (Chi, 2009). Although, the study did not strongly support the ICAP Framework due to the *constructive* task may not have been a truly *constructive* task, the study really had two *active* conditions and per the ICAP Framework the *active* conditions should perform the same and there would then be a support for the ICAP Framework.

Future studies may need to look at coloring and learning in a different way. Such as, coloring by adding a component of creating a flow chart that infers new knowledge with some type of an educational activity, ex. like an anatomy and physiology coloring book and with the learner explaining the process of how an organ works by constructing concept maps. The participants could map the concepts and go beyond the given information and color the process of how a heart pumps and the flow of blood through veins and arteries.

Conclusion

The current study investigated if adding coloring as a secondary task to multimedia learning, mental effort and perceptions of the learning task that there would be an increase in learning. The current study did not support the hypothesis that the coloring task would increase learning or impact cognitive load. However, it was able to support perceptions of learning as predicted. There were significances for enjoyment and engagement measures between the *active* and *constructive* conditions.

This current research was an important first step to investigate if there was a relationship between a secondary task of coloring and multimedia learning. Initial results are promising, if limited. The sample size of the current study could have limited the findings and a larger sample size has the potential for producing significant differences among groups based on the current means and standard deviations. Further research is needed to further investigate this relationship.

Multimedia learning videos can become a more engaging experience according to Ulbig (2009) by adding images such as coloring static images could show an acceleration of participants engagement levels and therefore, increase learning outcomes. While learning is a process of obtaining knowledge through experience and through a system of being taught; coloring static images of the key concepts from multimedia learning videos increased learner's perceptions of the learning task making it more enjoyable and engaging. While additional follow-up studies are needed to establish the stability of the observed enjoyment effect and further study colorings relationship with learning, the current findings indicate that coloring can be used after already effective multimedia learning videos as an active engagement task that increased the learning enjoyment.

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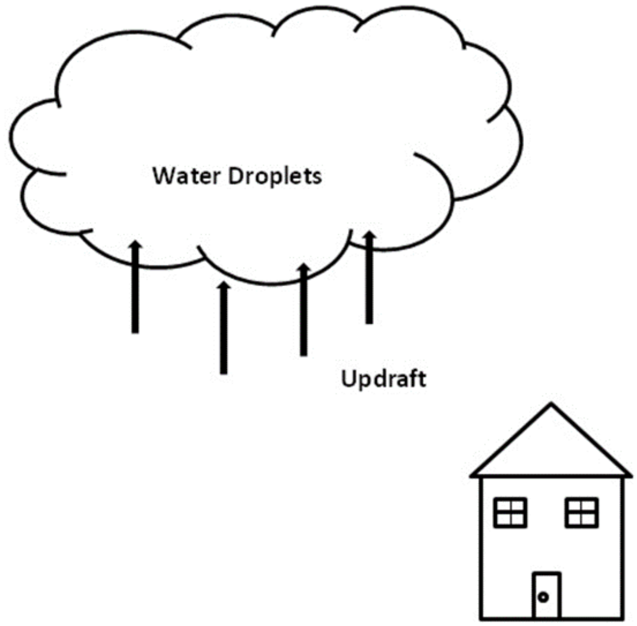
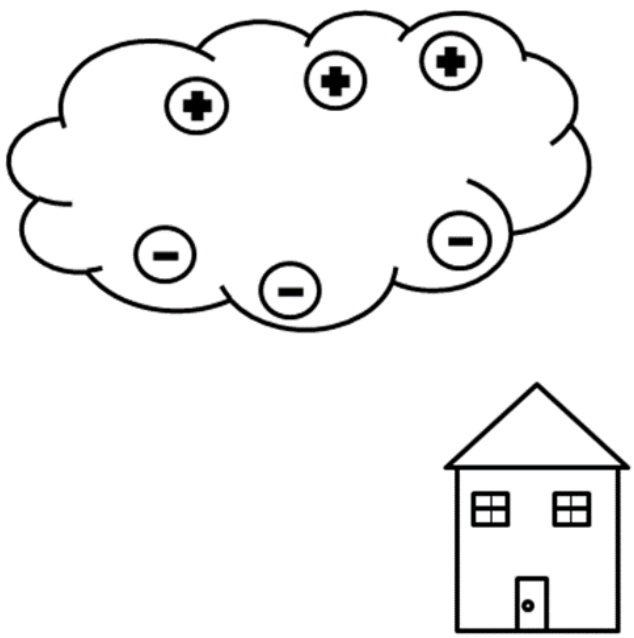
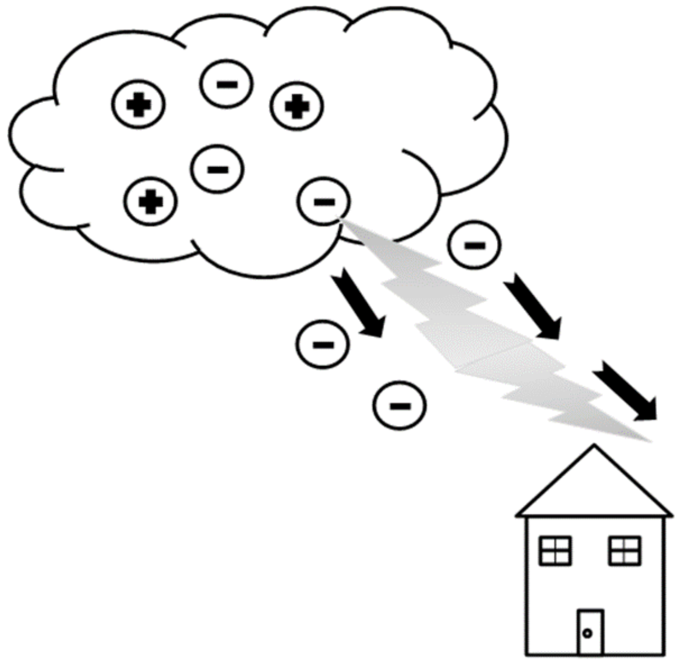
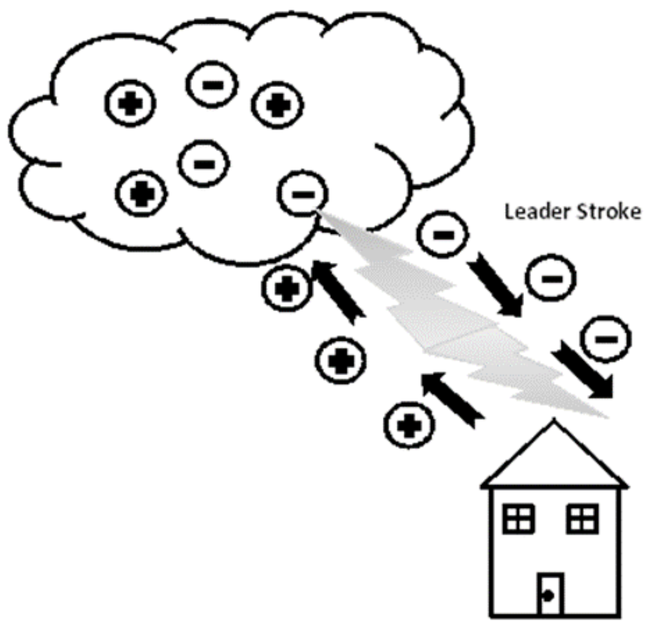
APPENDIX A

BLACK AND WHITE STATIC IMAGES


Water Droplets
Updraft

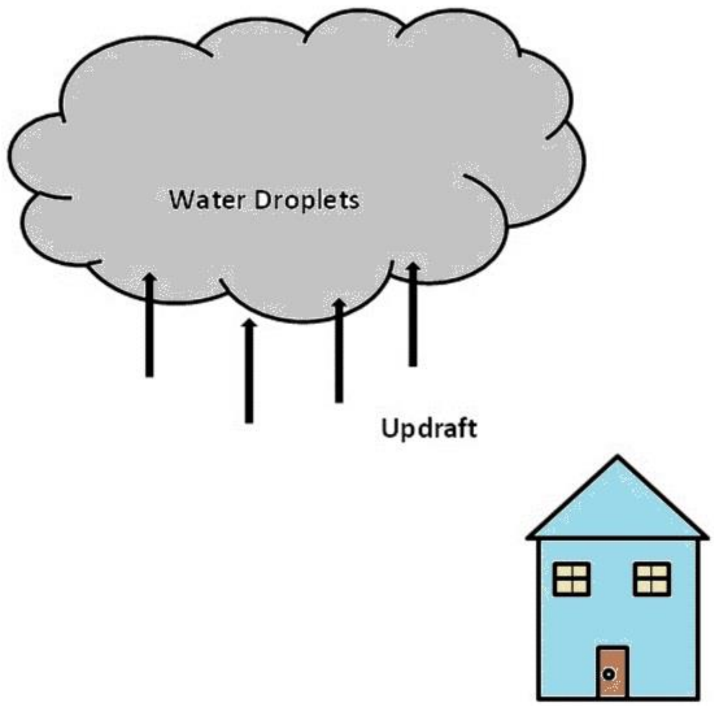


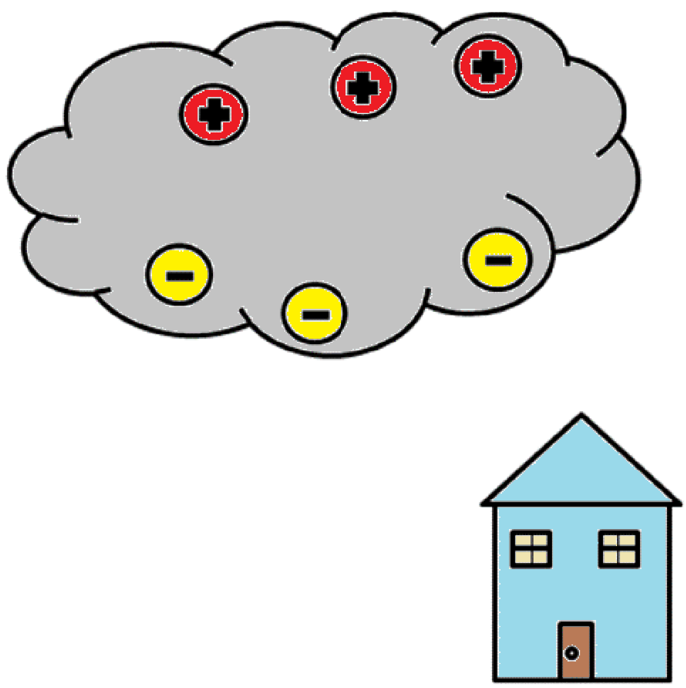


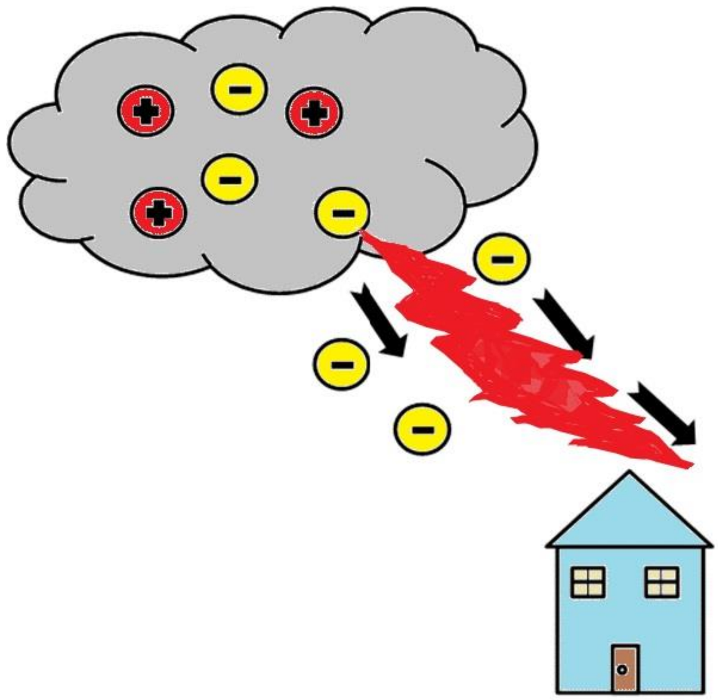

Leader Stroke

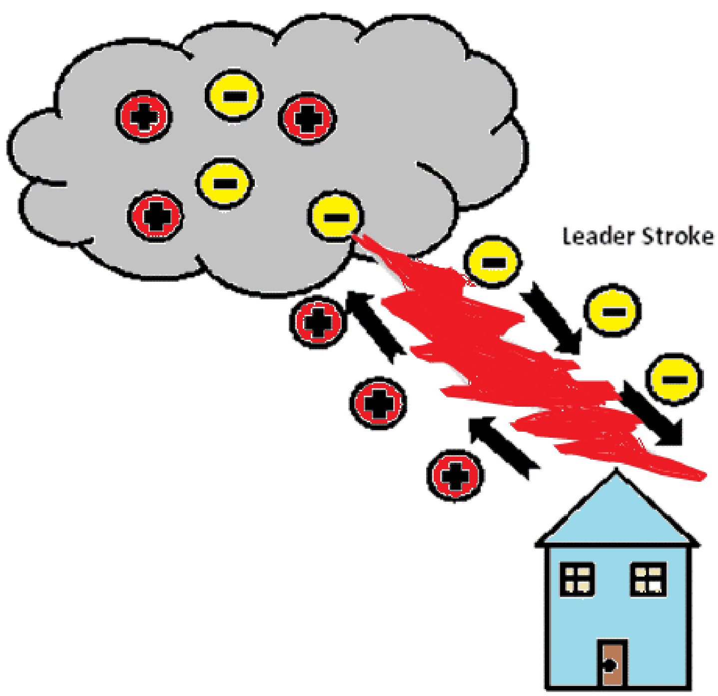
APPENDIX B

COLOR STATIC IMAGES


Water Droplets
Updraft






Leader Stroke

APPENDIX C

DEMOGRAPHICS AND PRETEST

What is your gender?

Male

Female

Please indicate the highest level of education completed.

Grammar School

High School or equivalent

Vocational/Technical School (2 year)

Some College

College Graduate (4 year)

Master's Degree (MS)

Doctoral Degree (PhD)

Professional Degree (MD, JD, etc.)

Other

What is your current marital status?

Rather not say

Divorced

Living with another

Married

Separated

Single

Widowed

How old are you?

Under 13

13-17

18-25

26-34

35-54

55-64

65 or over

Please place a check mark next to the items that apply to you:

I regularly read the weather maps in a newspaper

I know what a cold front is.

I can distinguish between cumulous and nimbus clouds.

I know what low pressure is.

I can explain what makes the wind blow.

I know what this symbol means:

I know what this symbol means:

Please put a check mark indicating your knowledge of meteorology (weather):

Very Little Knowledge

Little Knowledge

Average

Greater than Average Knowledge

Very Much Knowledge

APPENDIX D

MENTAL EFFORT QUESTIONS

In studying the preceding video I invested:

Very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

In studying and/or coloring the preceding pictures I invested:

Very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

In solving or studying the preceding problems I invested:

Very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

APPENDIX E

PERCEPTION QUESTIONS

Did you find the task of coloring or looking at the pictures enjoyable?

Extremely high enjoyment

Very high enjoyment

High enjoyment

Low enjoyment

Very low enjoyment

Extremely low enjoyment

Did you find the task of coloring or looking at the pictures engaging?

Extremely engaging

Engaging

Somewhat engaging

Somewhat unengaging

Unengaging

Extremely unengaging

APPENDIX F

RECALL AND RETENTION QUESTIONS

What causes a flash of lightning?

The return stroke (1)

Negatively charged leader (2)

Positively charged leader (3)

Negative Charges rushing from the cloud (4)

When do downdrafts occur?

When air is dragged down by rain (1)

When air currents cool and fall back to earth (2)

When cold air hits the ground (3)

When there are unbalanced electrical charges between the ground and clouds (4)

The upper portion of the cloud is made up of what?

Water droplets (1)

Cold air (2)

Ice crystals (3)

Water Vapor (4)

What part of the cloud are the positively charged particles located in?

Bottom part (1)

Center of the cloud (2)

Outside edge (3)

Top part (4)

Why does lightning strike buildings and trees?

They are higher than the ground (1)

A build-up of positive charges (2)

It is the pint where the negative leader ends (3)

Positive leader starts at these points (4)

Why does it get colder right before it rains?

Positive charges are absorbed into the clouds (1)

Warm moist air rushes upward into the clouds (2)

Cold downdrafts of air fall from the clouds (3)

Warm surface air rapidly cools (4)

APPENDIX G

TRANSFER QUESTIONS

Please write down an explanation of how lightning works.

What could you do to decrease the intensity of lightning?

Suppose you see clouds in the sky but no lightning. Why not?

What does air temperature have to do with lightning?

What causes lightning?

APPENDIX H

CONSENT FORM

CONSENT FORM

The task of coloring on the improvement of retention and transfer in multimedia learning.

RESEARCHERS

Arizona State University Human Systems Engineering Program's Scotty D. Craig, Ph.D., along with Jennifer Williams graduate student has invited your participation in a research study.

STUDY PURPOSE

This study will look at the improvement of retention and transfer on multimedia learning by using the task of coloring. Studies have not been conducted on the multimedia learning environment on the formation of lightning while adding the task of coloring and then looking at learning outcomes on the recall of the information.

DESCRIPTION OF RESEARCH STUDY

If you decide to participate, then you will join a study involving research of self-paced learning in a multimedia setting. Your participation in this online study will last for 45 minutes to 1 hour. You will be asked to take a brief questionnaire, watch a presentation on the formation of lightning and color some pictures and then asked complete another series of questionnaires. You will be given 1 credit toward your research requirements of the ASU Polytechnic Human Systems Engineering subject pool for participating in the current study.

Approximately 111 people will be participating in this study.

RISKS

There are no known risks from taking part in this study.

BENEFITS

While the main benefit of your participation will be the better understanding of the incorporation of the task of coloring and multimedia environments on your retention and transfer of the information, you could also improve your understanding of the formation of lightening.

CONFIDENTIALITY

All information obtained in this study is strictly confidential. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you. In order to maintain confidentiality of your records, Scotty D. Craig, Ph.D. will ensure no identifying information will be collected that will link the data to the individual it was collected from. All data will be kept electronically and will be deleted after a 5-year period from the date of publication as is customary with the field.

WITHDRAWAL PRIVILEGE

Participation in this study is completely voluntary. It is ok for you to say no. Even if you say yes now, you are free to say no later, and withdraw from the study at any time.

COSTS AND PAYMENTS

The researchers want your decision about participating in the study to be voluntary.

VOLUNTARY CONSENT

Any questions you have concerning the research study or your participation in the study, before or after your consent, will be answered by Scotty D. Craig, Ph.D. at Santa Catalina Hall, Ste. 150, 7001 E. Williams Field Road, Mesa, Arizona 85212. Phone: 480-727-4723

If you have questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk; you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at 480-965-6788.

Remember, your participation is voluntary. You may choose not to participate or to withdraw your consent and discontinue participation at any time without penalty

Clicking on the button below indicates your consent to participate in this research study.

01/21/018

Dear Participant:

I am a graduate student under direction of Dr. Scotty Craig, Dept. of Human Systems Engineering at Arizona State University. I am conducting a research study to examine the cognitive mechanisms underlying learning strategies like self-explanation.

I am inviting your participation, which will require you to watch learning video, read a series of texts and then answer some questions about the content. You will also be asked to perform a few standard cognitive tasks like coloring pictures that assess how well you related concepts and generate new ideas. The entire experimental session will take no more than 1 hour. You must be 18 or older to participate.

Your participation in this study is voluntary. You have the right not to answer any question, and to stop the study at any time. If you choose not to participate, there will be NO penalty. If you decide to withdraw from the study at any time, there will be NO loss of rights to which you might otherwise be entitled. Compensation is only awarded upon completion of the study.

There will be no direct benefits to you. The possible benefits of your participation in the research involve aiding in the development of effective teaching and learning methods and help researchers improve their practice. There are no foreseeable risks or discomforts to your participation.

Your responses will be confidential. Your name and address will NOT be recorded on the data. You will be assigned a case number in this study and your identity on all research records will be indicated only by that number. We will NOT collect or save any information that may associate that number with your identity. All information obtained in this study is strictly confidential. In order to maintain confidentiality of your records, computerized data files will be encrypted. The results of this research study may be used in reports, presentations, and publications, but under no circumstance will your personal information be used.

If you have any questions concerning the research study, please contact the research team at: (Jennifer.williams.2@asu.edu). If you have any questions about your rights as a participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research and Integrity Assurance at (480) 965-6788. Your participation is well appreciated.

Sincerely,

Jennifer Williams

APPENDIX I

COLORING INSTRUCTIONS

Instructions for Coloring Tasks

Passive

You have just finished watching and listening to a video on the formation of lightning. Now you will be given a set of 4 static images on the key processes from the video. Please use your memory of the processes from the video while studying the images. You will have 4 minutes to complete the next task. Quietly let the researcher know the number on your screen and that you are ready to move to the next task. The researcher will provide you with the needed materials.

Active

You have just finished watching and listening to a video on the formation of lightning. Now you will be coloring a set of 4 static images on the key processes from the video. Please use your memory of the processes from the video to color the images using the instructions and key provided by the experimenter. You will have 4 minutes to complete the next task. Quietly let the researcher know the number on your screen and that you are ready to move to the next task. The researcher will provide you with the needed materials.

Constructive

You have just finished watching and listening to a video on the formation of lightning. Now you will be coloring a set of 4 static images on the key processes from the video. Please use your memory of the process of lightning formation from the video to color the images indicating the connected concepts. You will have 4 minutes to complete the next task. Quietly let the researcher know the number on your screen and that you are ready to move to the next task. The researcher will provide you with the needed materials.

APPENDIX J

RUBRIC FOR RETENTION AND TRANSFER

Mayer & Moreno’s 19 point grading for recall:

1. Cool air moves
2. It becomes heated
3. It rises
4. Water condenses
5. The cloud extends beyond the freezing
6. Crystals form
7. Water and crystals fall
8. It produces updrafts and downdrafts
9. People feel the gusts of cool wind before the rain
10. Electrical charges build
11. Negative charges fall to the bottom of the cloud (or positive to the top)
12. A step leader travels down
13. In a step fashion
14. The leaders meet
15. At 165 feet from the ground
16. Negative charges rush down
17. They produce a light that is not very bright
18. Positive charges rush up and
19. This produces the bright light people see as a flash of lightning

Transfer questions: 12pts possible

Question 1: What could you do to decrease the intensity of lightning?

1. Warm up the cloud so no freezing takes place

2. Removing particles from the earth's surface (Mayer & Moreno, 1999)
3. Reducing the temperature between the ocean and the earth (Mayer & Moreno, 1999)
4. Placing positive particles near/to the cloud (Mayer, Bove, Bryman, Mars, Tapangco, 1996)

Question 2: Suppose you see clouds in the sky but no lightning. Why not?

5. The top of the cloud may not be above the freezing level (Mayer & Moreno, 1999)
6. No ice crystals form
7. Not enough negatively charged particles in the cloud (Mayer, Bove, Bryman, Mars, Tapangco, 1996) or positive (Mayer & Moreno, 1999)

Question 3: What does air temperature have to do with lightning?

8. The earth's surface is warm and oncoming air is cool (difference in temperature between the surface and the air) (Mayer, Bove, Bryman, Mars, Tapangco, 1996)
9. The top of the cloud is above freezing level and bottom of the cloud is below the freezing level (Mayer, Bove, Bryman, Mars, Tapangco, 1996)
10. The air must be cooler than the ground (Mayer & Moreno, 1999)

Question 4: What causes lightning?

11. A difference in electrical charge (Mayer, Bove, Bryman, Mars, Tapangco, 1996)
12. Difference in air temperature within the cloud (top and bottom) (Mayer & Moreno, 1999)