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INCREASING ASSOCIATIVE LEARNING OF ABSTRACT CONCEPTS THROUGH AUDIOVISUAL REDUNDANCY*

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ABSTRACT

In this study, the researcher developed a computer-based learning (CBL) courseware that presented the abstract concept with a concrete analogy through five different versions: 1) static graphic group; 2) static graphic with full audio group; 3) animation group; 4) animation with cued audio group, and 5) animation with full audio group. The participants were 316 college students and were divided into three ability levels based on their IQ reasoning score. Research results found that either static graphics without audio narration or animation with full audio can help students understand the abstract concepts better than either static graphics with full audio or animation alone groups. Animation with full audio has the best effect on long term retention. Students' IQ reasoning ability significantly helps them build associations between abstract and concrete knowledge more accurately and efficiently. The results of this study will contribute to the application of using multimedia CBL in teaching abstract concepts.

INTRODUCTION

With the rapid progress of computer audiovisual techniques, it has become an important concern whether the use of audio, visual, or the combination of both channels can actually facilitate the process of computer-based learning [1, 2]. Previous research found that for learning abstract concepts, static graphics provides

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more chances to build connections between the concrete and abstract domains [3]. On the other hand, the incorporation of audio narration changed the situation. With the explanation from the redundant audio, animated visualization helped students perform better than either text or static visualization [4]. In terms of improving learning, it is more important for instructional designers to be concerned with the theoretical framework for developing multimedia lessons. Among these theories, Paivio's dual coding theory [5, 6] is one of the most representative in addressing multiple-channel effects in cognition.

PERSPECTIVES AND THEORETICAL FRAMEWORK

Dual Coding Theory

In Paivio's dual coding theory [5, 6], he states that there are two memories in which stimulus information is stored, one for the visual mode and the other for the verbal mode. According to Paivio's imagery-concreteness effects [7, 8], for nonverbal imagery, the higher the concreteness of stimuli, the more likely they are to function as mediators of associative learning and memory. Verbal mediators, on the other hand, are not assumed to be functionally linked to concreteness, but may be correlated with meaningfulness for associative learning. Associative learning as defined by Paivio [7] is referred as the building of connections between one word and other related words, or visual images and other related images. The effects of meaningfulness on associative learning have been interpreted in terms of the availability of implicit associates as mediators of stimulus-response [7]. Analogy is one of the most frequently used mediators to provide the implicit association for learning abstract concepts.

For abstract concept learning, providing a concrete analogy with static graphics may provide learners more chances for self-imagination and evoke in learners a perceptual trace that helps them to clarify the interpretations [3, 7, 9-12]. The external picture from instruction helps learners visualize the concepts to be learned [12-14]. On the other hand, when animation is incorporated into analogies, animation might direct a learner's attention. However, without understanding the underlying meaning of the animation, animation might cause more confusion [15, 16]. Learners might not be able to perceive the meaning in animated presentation accurately [2, 10, 16-18], especially in the case where analogy requires learners to build connections between the base analog and the target domain [3]. As noted by Paivio [19], the superior effect of dual coding is related to the level of processing. The deeper the information is processed, the longer it will be retained in memory [20]. Consequently, visual displays, whether animated or static, facilitate learning only when their attributes are concrete and can be attended to a certain degree [21].

Meaningful learning is a generative process in which students construct relationships between visual and verbal representations of a system [2, 6, 9]. When the primary intent of the audio is to inform meaningful learning, the auditory role includes cueing or counterpointing. Cueing audio chooses a sound function to foreshadow the visual action. The counterpointing audio matches the visual and audio for meaningful comprehension [2]. Both cueing and counterpointing audio can bridge the audio and visual information and "send up" the meaning in the image. Mayer's series of research suggest that more meaningful learning is fostered when visual displays are presented with adequate narratives explaining their instructions in the given content [13, 22, 23]. Redundant audio can provide step-by-step explanations for the learner to understand the underlying meaning of the animation [4, 24] or visuals [25]. Narrative text itself contributes to the construction of a model that is a representation of the situation described by the text [26]. The human voice is an excellent instrument to call and direct the attention of learners to characters in the image [27-30]. Instructing subjects to image especially facilitated concept attainment when the to-be-learned concepts were high in imagery value [10]. Research further suggests that audio narration should be matched to the visual displayed in time and space [13, 24, 28]. When a narration states the conditions of animation (visual), the synchronous process of results should be displayed by animation [13]. The levels of complexity within the multple-channel redundant message influence the capacity of information processing. The capacity requirements are likely to increase as the fit (or semantic relatedness) between the two channels decreases [31].

Dual coding theory also supports the addictive effect of multi-channel presentations. It is often assumed that the combination of redundant channels of information will make concepts dual coded and will result in increased learning and retention [6]. Redundancy is defined as superfluous, extra, or repetitive information [25]. Multiple-channel redundancy has been studied for many years, primarily focusing on text and audio [32]. Little research has been done to investigate the effects of redundancy between audio and visual for learning abstract concepts. Nugent's research supports that increased achievement occurs with combinations of audio and images but not with audio and text [33]. Nugent concludes that the more media, the better the achievement. Other researchers propose that audio/video redundancy is harmful to memory. They argue that visuals distract viewers from the audio channel [34, 35]. Nevertheless, research about the optimum audio redundancy still provides little guidance [30] about whether the audio should mirror the visual information or be condensed to cued words for the abstract concept learning.

Ability Level

The effect of audio-visual combinations on learning is related to factors of the learner and material [33, 36-38]. Precisely the type of experiment that will be activated within the learner at any moment depends on the kind and degree of the stimuli, and how those stimuli interact with viewer's symbolic habits and abilities [6, 13, 39]. Symbolic habits include measures of cognitive style, preferences for thinking verbally or through imagery, and so on. Abilities include tests of spatial, figural, or imagery abilities. Research results found that students with high ability in mathematics are more likely to interpret and memorize visualized concepts more efficiently and accurately [40]. Additional research found that students with less experience tend to process given visualizations with uncertainty [41, 42]. A study by Barton and Dwyer reported that adding audio helped high IQ students in only one of four tests, and it had a negative effect on low IQ students [38]. However, the results are not consistent with the finding of Hsia, who states that redundancy provides an enriched learning environment, especially for students with low ability [43].

For the CBL designer, several questions are important to consider: Should I use static or animated graphics? Should I integrate the audio channel into the visual channel for a particular piece of information? To what degree should the audio be integrated in CBL? Is there any inter-individual difference? According to this review of existing research, it is clear that the results are inconsistent and there are only few instructional design guidelines available for the optimal relationship between audiovisual redundancy and ability level.

PURPOSE AND OBJECTIVES

The purpose of this experiment was to determine if various audio-visual combinations and differences in IQ levels influence learning. Five combinations of audio-visual redundancy, static graphics, static graphics with full audio, animation, animation with cued audio, and animation with full audio, were used. Students were divided into three IQ levels. Learning was defined as associative learning between abstract and concrete domains [7]. This was measured through the posttest. A delayed test was administered to measure long-term retention.

The hypotheses were stated in this way:

1. The availability of static graphics is more concrete than animation in increasing associative learning.
2. The availability of redundant audio to animation is more meaningful than redundant audio to static graphics and has additive effects on increasing associative learning and retention.
3. The IQ reasoning ability influences the associative learning and time on CBL task.

METHODOLOGY

Subjects

The sample consisted of 316 freshmen in one commercial college. The sample was built on the basis of randomly selecting seven out of twelve classes. All students in these classes enrolled in the computer literacy course that is a common requirement for all college freshmen. Most of the students in this course were novices or had little experience with programming.

Materials

CBL Program

The CBL program was designed by the researcher to teach programming concepts. Quick BASIC programming was selected as the content area for this study. This program consisted of two parts: an introduction section and a programming section. The introduction section taught the basic concepts, structures, and functions of the programming language (e.g., CLS, PRINT, LET, DIM array, READ..DATA, and FOR- NEXT loop). This section was presented in a linear sequence to make sure all subjects had experienced the same instruction and content. The programming section consisted of several programming sequences. Each sequence had about six to eight statements. For example, the following programming sequence was displayed on the screen.

```
TOTAL = 0
DIM A(5)
FOR J = 1 TO 4
     READ A(J)
     TOTAL = TOTAL + A(J)
NEXT J
PRINT "TOTAL IN THE ARRAY"; TOTAL
DATA 10, 20, 30, 40, 50
```

Throughout this article, the term audio is used to mean narration over graphics or animation, and the term visuals is used to mean the visual images of static or animated graphics that is analogous to one abstract concept. In this study, the audio and the visuals to which the abstract concept corresponded were the same. The section of programming sequence was accompanied by five different combinations of audiovisual redundancy that allowed users to attend to and elaborate on the content of teaching. For each sequence, at the top of the screen the statements were listed and highlighted line by line. At the bottom of the screen, a representative graphic was displayed either in a static graphic format or an animation format.

The five treatments:

1. The static graphic-based group used one representative graphic that was excerpted from the animation group to teach the programming as shown in Figure 1.
2. The static graphic with full audio group received programming displayed with one static graphic (the same as group one) and the redundant audio narration that step by step illustrated the meaning for each statement with analogies. For example, "Total = 0" statement was explained as "Variable Total is like a warehouse. The warehouse is stored with 0." "DIM A(5)" statement

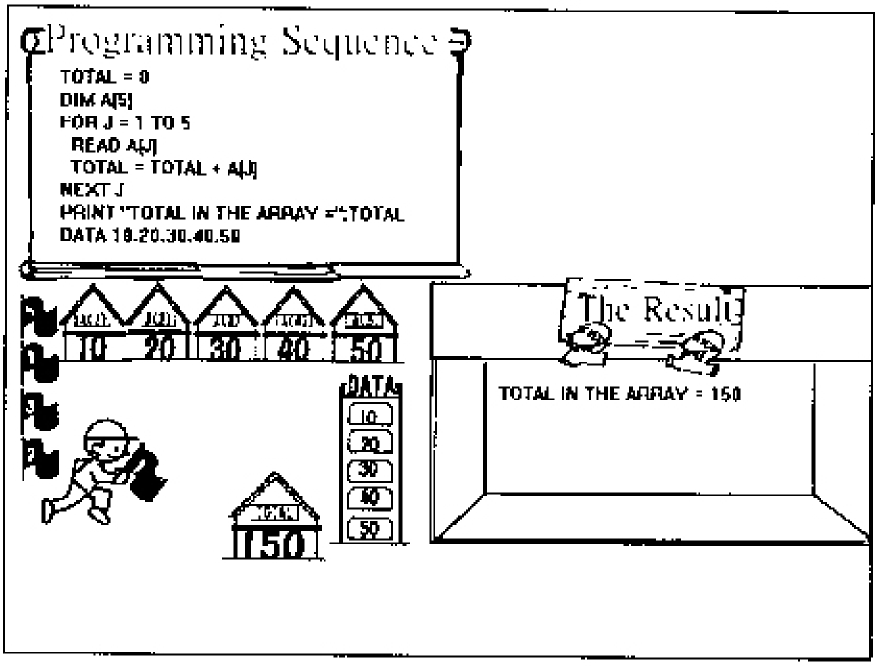

Figure 1. Visual display of static graphic excerpted from animation.

was explained as "Array A is like locating five consequent rooms in the warehouse."

3. The animation group received the programming with animation that changed the display as long as the statement was executed line by line. For example, when the statement "Total = 0" was highlighted, a warehouse was stored with the number 0. When the array was explained, it was associated with an array of warehouses. When the loop was explained, the worker ran into the warehouse as many times as the loop executed. When the READ statement was executed, the object was placed into the warehouse. Audio narration was not provided in this group.
4. The animation with cued audio group was provided both animation (the same as group three) and cued audio, such as "please pay attention to the animation provided," to draw students' attention toward the animation.
5. The animation with full audio group was provided both animation (the same as group three) and a totally redundant audio (the same as group two) narration to illustrate the meaning of the animation.

The validation and revisions of the program were made based on a series of reviews by subject matter and CBL experts. A pilot test was conducted to establish the validity and reliability of the instructional program. Macromedia Director had been chosen as the media to deliver the lesson.

Criterion Measures

Pretest, Posttest, and Retention Test

The same test was used for the pretest, posttest, and retention test. The test consisted of twenty multiple choice questions that contained four response choices per item. A pretest score was obtained prior to the administration of the study to measure students' prior knowledge. The posttest was designed to measure students' association between the abstract programming concept and the concrete analog. The retention test was administered one week later to measure students' associative learning in long-term memory. The following test item shows a typical sequence. Upon seeing such an item, subjects would be asked to decide among a choice of possible execution results.

```
FOR A = 1 TO 3
    READ (A)
    PRINT M(A) +1
NEXT A
DATA 7, 3, 5, 2, 9, 1
```

The validity of test items was attained by inviting at least three faculty members and instructional designers to review the measurement instrument. All of these experts were either familiar with the programming language or CBL. Only items receiving agreement by all reviewers were included on the test. The result of pilot testing also demonstrated that students' programming performance in the course were highly correlated to the test result ($r = 0.91$). A KR-20 test was administered to measure the internal-consistency reliability for the test (*Alpha* = 0.81).

IQ Reasoning Score

Students' ability level in reasoning were measured by one IQ test consisting of sixty items for language reasoning and sixty items for numeric reasoning. The test was developed by Lu and Ho for college students [44]. For example, in the language reasoning, students were required to find the "eye: look" relationship and identify one similar relationship from four pairs of answers: 1) ear: listen; 2) noise: taste 3) mouth: chew; and 4) head: headache. For the numeric reasoning, two numeric data (A and B) were given to compare the relationship between A and B. For example, two-thirds hours is compared to forty-five minutes. Students would be presented the following possible answers: 1) A > B; 2) B > A; 3) A = B; and 4) information inadequate, cannot be compared. The total number of language and numeric reasoning scores was counted as the independent variable of IQ reasoning ability because the purpose of this study was to compare ability level instead of viewer's symbolic habits. The reliability was 0.6 ($p < 0.01$) for the whole test. The validity was checked and confirmed ($p < 0.01$) through the correlation coefficient ($r = 0.46$) between performance and IQ score.

Time on Task

The total time each student took to review the CBL lesson was recorded from the beginning to the end of the program. This was done to determine if time on task differed significantly based on the five presentations and/or the reasoning levels of the subjects.

Procedures

At the beginning of the semester, an IQ test, a pretest, and a survey questionnaire were administered to seven classes in their classrooms. Each test was administered through the paper-pencil format. In the survey questionnaire, students' knowledge about the computer programming language, gender, and age were investigated. All subjects who indicated that they were experienced in programming language were eliminated from the study. Only students who were novices or who had little experience were retained. Students were divided into three ability groups (high, middle, and low) based on their IQ reasoning scores. Students in each IQ group were randomly assigned to one of the experimental groups.

From the time of the pretest through the retention test, subjects were instructed not to study any computer programming languages. One week later, every student in the same class went to the computer lab at the same time. In the computer lab, subjects were instructed how to operate the CBL program properly before the treatment and they were asked to complete their respective CBL lesson at their own pace. The time students spent on the CBL courseware was recorded. However, there was no time limitation. Following the completion of the lesson on the computer, the paper and pencil test was given. One week after the completion of the lesson, the delayed test was given to measure students' retention of CBL learning.

RESULTS

The independent variables of treatment and ability constitute a 5 × 3 design for the study. To investigate the effects of the two independent variables and their interaction on the three dependent variables of posttest, delayed test, and time on task, a 5 × 3 MANOVA was utilized. The pretest mean was 1.85. Pretest scores were not used as covariance because they did not demonstrate a strong relationship with the dependent variables ($r = -0.0175, p < 0.757$) and the pretest did not differ significantly between groups ($F(4, 311) = 0.47, p < 0.76$). The mean of the posttest was 10.1. Descriptive statistics, including number of subjects, mean, and

Table 1. Descriptive Statistics of Dependent Variable Compared by the Independent Variables of Treatment and Ability

	Low	Middle	High	Total
Treatment 1	*N* = 23	*N* = 17	*N* = 23	*N* = 63
Posttest	9.83 (2.15)	10.59 (2.37)	11.17 (2.33)	10.52 (2.31)
Delayed Test	8.52 (3.20)	8.59 (1.80)	8.58 (2.57)	8.56 (2.59)
Task Time	34.57 (9.40)	35.59 (7.13)	32.04 (7.79)	33.92 (8.26)
Treatment 2	*N* = 23	*N* = 20	*N* = 20	*N* = 63
Posttest	8.57 (2.98)	9.20 (2.57)	9.35 (2.37)	9.02 (2.65)
Delayed Test	7.70 (2.44)	8.35 (3.23)	9.35 (2.74)	8.43 (2.84)
Task Time	35.00 (7.18)	35.50 (7.27)	29.78 (5.29)	32.90 (6.93)
Treatment 3	*N* = 22	*N* = 21	*N* = 20	*N* = 63
Posttest	9.64 (2.17)	8.86 (2.35)	8.80 (3.17)	9.11 (2.57)
Delayed Test	8.90 (2.70)	8.62 (2.25)	8.00 (2.90)	8.51 (2.61)
Task Time	35.86 (7.64)	33.22 (7.04)	31.15 (6.60)	33.50 (7.28)
Treatment 4	*N* = 25	*N* = 14	*N* = 24	*N* = 63
Posttest	9.48 (3.42)	10.14 (2.45)	10.96 (2.63)	10.19 (2.97)
Delayed Test	8.24 (3.22)	10.15 (1.86)	10.38 (2.63)	9.47 (2.90)
Task Time	35.17 (7.46)	35.71 (8.97)	32.96 (6.28)	34.45 (7.40)
Treatment 5	*N* = 20	*N* = 21	*N* = 23	*N* = 64
Posttest	11.00 (2.15)	11.19 (2.36)	11.96 (2.38)	11.41 (2.31)
Delayed Test	9.75 (2.69)	10.05 (2.28)	10.14 (2.82)	9.98 (2.58)
Task Time	36.06 (6.56)	32.63 (6.37)	33.50 (6.33)	33.97 (6.45)
Total	*N* = 113	*N* = 93	*N* = 110	*N* = 316
Posttest	9.66 (2.72)	9.97 (2.53)	10.52 (2.79)	10.05 (2.71)
Delayed Test	8.58 (2.90)	9.09 (2.46)	9.31 (2.83)	8.99 (2.76)
Task Time	35.29 (7.65)	34.01 (7.25)	31.99 (6.56)	33.75 (7.28)

standard deviation, were grouped by the two independent variables and presented in Table 1. To justify the use of multivariate analysis instead of univariate analysis, the relationships between the three dependent variables were examined. Correlation analysis showed that the three dependent variables were significantly correlated, with correlation coefficients of .59 between posttest and delayed test, .20 between posttest and time on task, and .19 between delayed test and time on task. All relationships were significantly at the .001 level.

MANOVA showed a significant treatment effect (Wilk's lambda of .84 with $F(12, 725) = 3.99, p < .001$), a significant ability effect (Wilk's lambda of .92

with $F(6, 548) = 4.03, p < .001$), and a non-significant interaction effect between ability and treatment (Wilk's lambda of .93 with $F(24, 795) = .88, p < .64$). The significant multivariate analysis results were followed by univariate analysis on the dependent variables. Because of the big sample size and the number of hypotheses tested, the researcher conducted the analysis using the more conservative Scheffe method.

ANOVA on the three dependent variables showed significant treatment effects on the posttest score ($F(4, 276) = 8.78, p < .001$) and the delayed test score ($F(4, 276) = 4.43, p = .002$). Post-hoc comparisons between the five treatment groups found that students' performance in animation with full audio group ($M = 11.41$) and static graphics group ($M = 10.52$) was significantly better than that in graphics with full audio group ($M = 9.02$) and animation alone group ($M = 9.11$). Post-hoc comparisons on delayed test scores found only one significant difference between animation with full audio ($M = 9.98$) and graphics with full audio ($M = 8.43$) conditions.

ANOVA on the dependent variables found that the differences in posttest and time on task were responsible for the significant ability effect observed in MANOVA, but the ability effect was not significant in the delayed test. Students with difference in ability had a significant difference in their performance on the posttest [$F(2, 276) = 3.09, p = .05$]. Post-hoc comparisons indicated that students with higher reasoning ability ($M = 10.53$) performed significantly better than students with lower reasoning ability ($M = 9.66$) on the posttest. Students in different ability groups also spent different amount of time on the task ($F(2, 276) = 6.08, p = .003$). Post-hoc comparison showed the only significant difference in time on task was that students with higher IQ reasoning levels ($M = 31.99$) took significantly less time on the CBL than students with lower IQ reasoning levels ($M = 35.29$).

DISCUSSION AND CONCLUSIONS

The purpose of this study was to test the effect of a systematically designed CBL program delivered through variations of mediated channels and redundancy levels. The computer tutorial designed to teach the abstract concept using concrete analogies was quite successful. Pretest means indicated that the subjects had little prior knowledge about the subject matter. The posttest mean was above average indicating the effect of teaching.

Previous research found that when the audio narration is not provided, subjects who use a CBL program with static graphics show a greater increase in associative learning than subjects who use animated representation or text format [3]. In a succeeding study [4], the researcher found that the incorporation of audio narration changed the situation. With an explanation from the redundant audio, animated visualization helped students perform better than either text or static visualization. Based on previous findings, this research tried to integrate visual and audio effects in one experiment to determine the best combination of audiovisual redundancy.

Research results found that either static graphics without audio narration or animation with full audio are equally effective and are better than either static graphic with full audio or animation alone for associative learning. The full audio is suggested over the cued audio for animation.

Finding theoretical frameworks for developing a multimedia lesson was also an important concern in this study. Paivio's dual coding theory, as explained earlier, was used to develop the present study. Current research results support Paivio's image-concreteness effects. The higher the concreteness of stimulus items, the more likely they are to evoke images. As noted by Paivio [7], the availability of imagery is assumed to vary directly with item concreteness or image-evoking value. The static graphic helps students to focus on a unit picture that is visualized for the abstract concept [12]. Hence, students in the static graphic group are more likely to engage in the powerful organizational properties of an image system [8, 14]. Animation might direct a learner's attention, but learners might not be able to perceive the meaning or attend to the details of the display without proper guidance [2, 18, 31]. Subjects given animated presentation alone might concentrate on irrelevant visual features thus hindering association of the analogy provided [10]. Therefore, the results of this study supports the first hypothesis that static graphics is more concrete than animation in increasing associative learning.

The results of this study also find that with full auditory explanation, animated visualization helps students perform better than static graphics. Cueing audio can serve as the mediational function that arouses attention. Redundant audio has the characteristic not only to draw students' attention toward the animation, but also to provide step-by-step illustration for the learner to understand the meaning of animation [29] and to build connections between the abstract and concrete domains [24]. The current results also support Paivio's verbal meaningful effects [7]. However, when using audio effects in multimedia, many CBL designers overlook the importance of matching the aural and visual characteristics in space and time [13]. When a narration states that change of conditions (visual) without revealing the synchronous process of the results, this can cause confusion in learners and decrease the meaningfulness of the audio [4, 13, 28]. This finding further supports the second hypothesis that redundant audio to animation is more meaningful than redundant audio to static graphics and the redundancy has additive effects in increasing associative learning and long term retention.

As for the effect of reasoning ability, the research results show that students with higher IQ reasoning ability are more likely to interpret and memorize visualized concepts more efficiently and accurately. On the other hand, students with lower IQ reasoning ability tend to process given visualizations with uncertainty. Reasoning is a process to clarify the relationship of two components in one pair and to try to find a similar relationship from other pairs. This reasoning process is similar to the learning process that requires learners to identify the relationship between the base analogy and target domains and use this relationship to understand the new learning. Therefore, as expected, students with higher ability in reasoning can learn more than students with lower ability. Students' reasoning ability also helps them to understand the relationship within less time. Since the interaction effect was not significant, precisely which ability group can benefit more from the effect of audio-visual combinations cannot be answered in this study.

The nonsignificant result of the task time between treatment groups convinced the researcher that all participants experienced the CBL program within a similar length of time. In a previous study [3], the researcher found that students in the animation group took a significantly longer time to complete the CBL task, partially because the presentation speed was slow as the animation required more computer memory to process the information. With rapid progress of processing speed in computers and the increased capacity of memory, animation and audio can be displayed as fast as plain text. Therefore, it is not surprising to find that audio and animation no longer influence the time required to complete the program. This result also explains why students in the static graphics with full audio group performed worse than the static graphics alone group. The static graphic group required learners to interpret and build their own images and connections gradually. Audio narration alone, with no graphics, can serve as the mediational function that arouses the imagery [26]. When audio narration was combined with graphics in the teaching process, the learner's imaginary organization was interfered with by the audio. It is possible that without further time to reconstruct their imagines, learners are certainly confused by the self-developed image and audio-directed image. Perhaps the situation is the same for the animation group. If learners in the animated group could spend a longer time to digest the animation presented, then learners may be able to attend to the presentation accurately. This seems to support the level of processing theory which states that students will learn better when given more time to process the information [20].

In the series of experiments, the researcher has obtained several interesting findings that support that image concreteness and verbal meaningfulness can be increased by presenting different combinations of visual modes with different degrees of auditory redundancy. The results of this study will contribute to the application of using multimedia CBL in teaching abstract concepts. It would be interesting in future research to test the effects of audiovisual redundancy on different domains of knowledge and to see the effect on other dependent variables, such as problem solving and transfer of learning.

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