IMPROVING THE EFFECTIVENESS OF ORGANIC CHEMISTRY EXPERIMENTS THROUGH MULTIMEDIA TEACHING MATERIALS FOR JUNIOR HIGH SCHOOL STUDENTS

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ABSTRACT
The purpose of the study aimed to explore the effects of three different forms of the multimedia teaching materials on the achievements and attitudes of junior high school students in a chemistry laboratory context. The three forms of the multimedia teaching materials, static pictures, video, and animation, were employed to teach chemistry experiments to 54 eighth-grade students in Pingtung County, Taiwan. The research tools included the self-editing questionnaire of learning achievement, the experimental step checklist, and the learning feedback questionnaire. Descriptive statistics and ANCOVA were administered to analyze the collected data. The findings of the study indicate that the video and animation have more significant effects on promoting students' learning achievements in a chemistry laboratory context than static pictures in terms of operating equipment, technical operation, experimental procedures, and observation performance. Additionally, the students indicated that video presentation can best assist them in understanding the experiments. Finally, the findings and suggestions of this study can be useful references for multimedia designers, teachers, and school administrators.
Keywords: junior high school, multimedia teaching material, organic chemistry experiment

1. INTRODUCTION

Given the prevalence and importance of information technology in daily life, it is valuable if teachers are able to utilize technology to improve students' learning effectiveness. In recent years, elementary and high school teachers have generally agreed that information technology is beneficial for teaching, and they have begun to explore improved approaches for applying it to teaching (Ministry of Education, 2008). However, the use of multimedia in the classroom clearly has positive implications for learners. For example, the combination of images and descriptions may help students construct concrete learning experiences, and audio effects provide multi-dimensional and immersive experiences, which can enhance the effects of teaching and stimulate motivation for learning. Additionally, multimedia can serve as a preamble that organizes the conceptual framework for students and facilitates their understanding of teaching materials (Mayer & Moreno, 2003).

In the past years, auxiliary chemistry experiment teaching materials were often composed of a series of diagrams and charts, which then evolved into films with captions and explanations provided by the experiments' designers. Nowadays, the multimedia teaching materials provided by booksellers have upgraded from instructional videos to 2D and 3D animations. However, the effects of 2D and 3D animations and forms of the multimedia teaching materials integrated with different experimental content in the laboratory instruction have not yet been investigated. Thus, this study aimed to explore the effects of various forms of the multimedia teaching materials, including static pictures, videos, and animations on the students' learning performance through examining the performances of the chemistry experiment tests. The findings of the study will provide suggestions for teachers and multimedia designers in the field.

2. LITERATURE REVIEW

Mayer (2001) proposed the Generative Theory of Multimedia Learning based on the paradigmatic dual-coding theory to describe learners' information processing procedures while participating in multimedia courses (Clark & Mayer, 2008). This type of learning model reflects the following four principles: 1) dual track: humans are able to process text massages and picture information via different tracks through both visual and auditory perception; 2) limited capacity: each track has a limited information processing capacity; 3) active processing: humans can transform relevant information, organize information into consistent mental modules, and then make the learned information meaningful; and 4) transformation: these processes will input new knowledge into long-term memory. As a result, multimedia teaching should focus on assisting learners to be organized and to conduct meaningful coding as well as to make best use of information, pictures, animation, and audio effects make students more attentive and thus make received information processed and stored in long-term memory as well as link with old knowledge.

The purpose of multimedia is to provide multiple communication channels to address the differences between learners and to present teaching content through optimum modalities, including text, narration, graphics, illustrations, photographs, charts, animations, videos, music, sound effects, virtual reality, and interactive programs. Each multimedia teaching material has its own purposes and timing. If multimedia is applied well, students' learning efficiency may be enhanced. Mayer (2001) proposed a series of multimedia design principles, including multimedia, contiguity, segmentation, coherence, personalization, and individual difference. These principles state that teachers should emphasize important information and functions rather than squeezing more information into their teaching materials. Additionally, designers should make it possible to present texts and images simultaneously, to divide multimedia materials and present the desired segments, to delete repetitive and redundant information, and to find appropriate teaching materials. In doing so, learners will be able to achieve better learning effectiveness (Clark & Mayer, 2008; Mayer, Hegarty & Campbell, 2005; Mayer, Sobko & Mautohe, 2003; Inglese, Mayer & Rigotti, 2007).

Chemistry is considered both basic and applied science. When teaching chemistry, teachers should emphasize both theories and experiments; chemistry experiments play an important role in teaching and serve as an ideal tool for combining theory and practice. Therefore, chemistry experiments should focus on learning goals and developing students' laboratory skills, scientific reasoning skills, knowledge about experimental design, and comprehensive ability (Ministry of Education, 2008). Recent literature suggests that integrating multimedia into teaching can have more significant effects than traditional teaching. However, many of the studies on students' learning effectiveness tend to focus more on knowledge learning effectiveness, learning retention, and migration rather than on the influence of multimedia on laboratory skills (Arguel & Jamet, 2009; Münzer, Seufert & Brünken, 2009; McTigue, 2009; Harskamp, Mayer, & Suhre, 2007). As a result, this study aimed to explore the influence of various multimedia teaching materials on the learning of chemistry laboratory skills based on the theoretical framework of multimedia learning theory.

3. RESEARCH METHOD

3.1 Experimental design

A total of 54 eighth-grade students from a junior high school in Pingtung County in Taiwan participated in the experiment. The "chemistry experiment test" as the pre- and post-test tool was used with all students. Before the experiment treatment proceeded, the pretest was administered. Based on the students' chemistry grades in the first semester, they were randomly divided into three groups (A, B, and C) based on S-type allocation. Each group was assigned to perform a different experiment, and then the posttest was implemented.

Every group carried out two forms of the multimedia teaching materials. After the first form of the multimedia teaching materials was employed, the posttest was administered, and the students were then taught the method for performing a second experiment using the second form of the multimedia teaching materials. The independent variable was the type of multimedia teaching material used (static pictures, video, or animation); the dependent variable was the change in test scores from the pre- to post-test. Table 1 shows the experimental design of this study.

Table 1: Experimental design

Group		Pretest	The 1st Experiment	Posttest 1	The 2nd Experiment	Posttest 2
A	R	O_0	X_1	O_1	X_2	O_2
B	R	O_0	X_2	O_3	X_3	O_4
C	R	O_0	X_3	O_5	X_1	O_6

R: Random selection
O_0: pretests of groups A, B, and C; $O_{1\text{-}6}$: posttest after experimental treatment
X_1: static pictures; X_2: video; X_3: animation

3.2 Research tools

The research tools were the organic chemistry experiments, consisting of the dry distillation of chopsticks, the production of soap, self-designed chemistry experiment tests, and the self-developed learning satisfaction survey questionnaire. The multimedia teaching materials were grouped into three forms: animation, video, and static pictures. In Figure 1, it was 2D animation broadcasted by Macromedia Flash Player. Figure 2 shows the experiments conducted by demonstrators were video taped and displayed by Microsoft Windows Media Player. Figure 3, Microsoft PowerPoint was used to present static pictures, audio, and text. Audio content was extracted from the film; the descriptive text presented to students was identical in the animations and film. The subject matter in the three forms of multimedia teaching materials was identical.

The chemistry experiment tests used in the pre- and post-tests were based on the teaching contents to construct the experimental step checklist for evaluating student's performances on accuracy of experimental equipment usage, accuracy of experimental equipment operation, and the order of experimental procedures. Students would receive one point for completing each step correctly. The points were summed to produce the total score; the higher the total score, the better performance of the students' learning.

Figure 1: Images captured from the animation

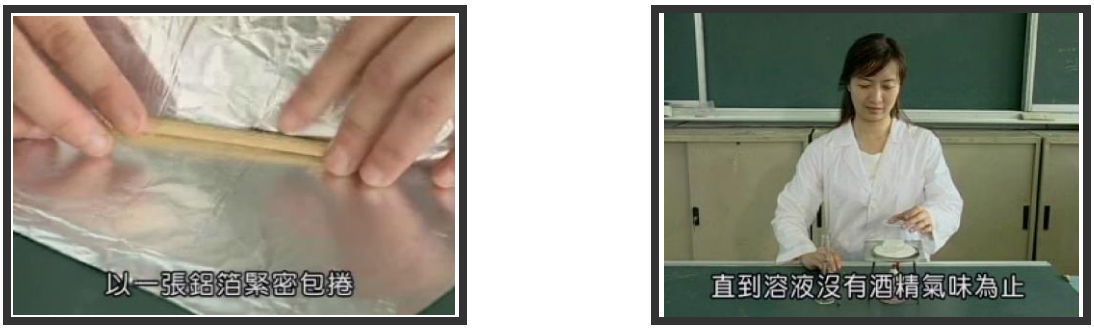

Figure 2: Images captured from the video

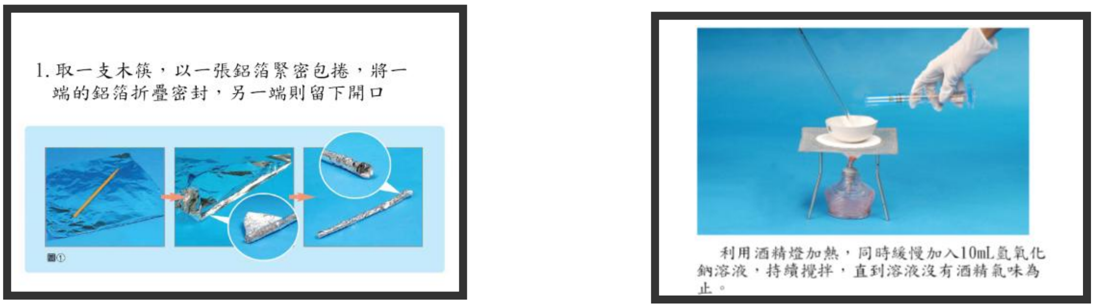

Figure 3: Images captured from the static pictures

3.3 Experimental procedures

Prior to the experiment, students were grouped and assigned randomly and notified about the test time. Meanwhile, the instructor described the purpose of the experiment and reminded students to focus on the multimedia teaching materials and not to talk to each other as well as informed students of a test after viewing the multimedia materials would be employed. To avoid interference, the computers were partitioned and equipped with headsets.

Group A, B, and C were employed with the static picture, video, and animation instruction respectively. Each process took approximately 20 minutes. The experimental procedures were:(1) in the beginning of the experiment, the instructor introduced operational methods, test methods, and importance notices to students for three minutes; (2) the presentation speed and viewing time of the multimedia teaching materials were controlled until the students fully understood the content of the materials. After all of the students finished viewing the teaching materials, they were asked to conduct the experiment and evaluated by the instructors; and (3) after each experiment, the experimental test was employed and the experiment was complete. Then, students were asked to conduct the experiment following Steps 1 to 3.

4. RESULTS AND DISCUSSION

4.1 The experiment of distillation of chopsticks

The results of the statistical analysis of covariance (ANCOVA) show that F value of homogeneity of regression coefficients was non-significant (F=1.102, p= .340> .05), which confirms the assumption of regression. Therefore, the covariance analysis could be conducted. According to Tables 1 and 2, when the influence of the pretest results were eliminated, the form of teaching materials had significant influence on the chemistry experiment tests (F=10.877, p= .000< .05). The post hoc test suggests that the learning performance of the video group (M=5.925) was better than that of the static picture group (M=5.071); the learning performance of the animation group (M=6.170) was superior to that of the static picture group (M=5.071). However, there was no significant difference between the learning performance between the video group and the animation group. Further examining the strength relationship, the ω2 of the correlation index was 37.9%, suggesting that the chemistry experiment test results were strongly correlated with the forms of the multimedia materials used.

Table 2 Covariance of chemistry grades of three groups of students

Sources of variance	*SS*	*df*	*MS*	*F*	Post hoc test	ω^2
Covariance (Score of pretest)	4.463	1	4.463	8.314	Film＞Photo Animation＞Photo	.379
Between group (Teaching methods)	11.679	2	5.839	10.877*		
Error	26.842	50	.537			

*$p < .05$.

Table 3 Adjusted mean and post hoc tests of each group

Group \ Adjusted mean	Picture (*M*=5.071)	Film (*M*=5.925)	Animation (*M*=6.170)
Picture	------------	＊	＊
Film	＊	----------------	
Animation	＊		---------------

*$p < .05$.

4.2 The experiment of soap production

The statistical result of the homogeneity of regression coefficients was non-significant (F=1.491, p= .235> .05), which confirms the assumption of regression. Therefore, the covariance analysis could be conducted. According to Tables 3 and 4, when the influence of the pretest results were eliminated, the form of the multimedia teaching material had a significant influence on the chemistry experiment test results (F=3.734, p= .031< .05). Post hoc test suggests that the learning performance of the video group (M=4.227) was superior to that of the static picture group (M=3.220); the learning performance of the animation group (M=4.170) was better than that of the static picture group (M=3.220). However, there was no significant difference between the video group and the animation group. Further examining the strength relationship, the ω2 of the correlation index was 7.8%, suggesting that the chemistry experiment test results were moderately correlated with the forms of multimedia materials used.

Table 4 Covariance of chemistry grades of three groups of students

Source of covariance	*SS*	*df*	*MS*	*F*	Post hoc comparison	ω^2
Covariance (pretest score)	.009	1	.009	.006	Film＞Picture Animation＞Picture	.078
Between group (teaching method)	12.057	2	6.028	3.734*		
Error	80.713	50	1.614			

$^{*}p<.05$

Table 5 Adjusted mean and post hoc tests of each group

Group \ Adjusted mean	Picture (*M*=3.220)	Film (*M*=4.227)	Animation (M=4.170)
Picture	------------	*	*
Film	*	----------------	
Animation	*		---------------

$^{*}p<.05$

To sum up, regardless of the experiments of dry distillation of chopsticks or soap production, the different forms of the multimedia teaching materials had significant effects on students' chemistry test scores (F=10.877, p= .000< .05, for the dry distillation of chopsticks experiment; F=3.734, p=.031<.05, for the soap production experiment). The comparison between the pretest and posttest scores suggested that the performance of the animation group and video group were significantly higher than those of the static picture group. The type of multimedia teaching tool used explained 37.9% and 7.8% of the variance in students' chemistry scores for the dry distillation of chopsticks and the soap production experiments, respectively, indicating an above-moderate correlation.

4.3 Analyses of the responses to the self-developed learning perception and satisfaction survey questionnaire

According to the literature and experts' suggestions and comments, a semi-structured learning perception and satisfaction survey questionnaire was constructed. After the experiments were terminated, the survey questionnaire was employed to the students in order to understand the students' reactions to incorporating multimedia teaching materials with experiments and their learning satisfaction. Chi-square test was used to analyze the collected data. The results of chi-square test are shown in Table 6.

Table 6: The statistical results of chi-square test on the three multimedia teaching materials

Category	Observed		Expected		adjusted residual	χ^2
	Frequency	Percentage	Frequency	Percentage		
Animation	19	35.2%	18	33.3%	1.0	14.778*
video	29	53.7%	18	33.3%	11.0	
picture	6	11.1%	18	33.3%	-12.0	
total	54		54			df＝2

$^{*}p<.05.$

Table 6 shows that the students' perception and learning satisfaction on the three multimedia teaching materials reached a significant level (df=2, χ^2=14.77, $p< .05$), indicating the frequencies of the three multimedia teaching materials were significantly chosen by the students. Among the three teaching materials, 53.7% of the students voted video and of 11.1% voted picture. In addition, Tables 7 shows the statistical results of the students' preferences for the three multimedia teaching materials (1=most preferred; 3= least preferred).

Table 7: The descriptive statistical results of the students' preferences on the three multimedia teaching materials

Category	Mean	Standard Deviation	N
animation	1.54	.50	54
video	1.54	.57	54
picture	2.93	.38	54

The statistical results show that F=95.461, $p<.05$, reached the significant level. It indicated the students' preferences for the three multimedia teaching materials were significantly different. The results of Post Hoc showed that the students prefer animation and video to picture. Finally, the reasons why the students preferred multimedia teaching materials were summarized in Table 8.

Table 8: The reasons why the students preferred multimedia teaching materials

Multimedia Teaching Material	reason	Percentage (person)
animation (19)	-easier to understand -much simple and easy to understand	31.6% (6)
	-more interesting -more livid -like cartoon	57.9% (11)
	-can attract attention more	10.5% (2)
video (29)	-is closer to reality -closer to real things -just like being in the laboratory	51.8% (15)
	-can repeatedly review	3.4% (1)
	-can watch the whole process of the experiment	3.4% (1)
	-is clearer -can be understood easily	20.7% (6)
	-can be easily operated -understood more about the experiments	20.7% (6)
picture (6)	-can be better memorized	66.7% (4)
	-picture can be remained longer	33.3% (2)

According to Table 8, over 50 % of the students suggested that video can best assist in conducting experiments because video content is much closer to the real experiments in the laboratory and it was easier to understand. Additionally, about 35.2% of the students chose animation because it was vivid, interesting, and able to attract their attention to understand the operation of experiments. Only 11.1% of the students thought that picture could help them remember and understand the content longer. To conclude, the students preferred video and animation because these two multimedia teaching materials enabled them understand the operation of experiments more. On the other hand, the static picture was too boring to arouse their learning motivation.

5. CONCLUSIONS

The results of the posttests suggested that, regardless of the experiments (the dry distillation of chopsticks or the soap production), different forms of the multimedia teaching materials have significantly different effects on students' chemistry test grades. As a result, the hypothesis of a significant difference in posttest scores between the static picture group, video group, and animation group is supported. The post hoc tests also revealed that the chemistry test grades of the video group and animation group were higher than those of the static picture group. The correlation between type of multimedia teaching material and test scores was moderate, which is consistent with the findings of Dalacosta et al. (2008), Ayres et al. (2009), and Wong et al. (2009), who suggested that multimedia teaching materials have significant effects on students' operational skills because video and animation can portray complete and coherent procedures. This finding supports the temporal, spatial, congruity, and signal principles. According to the temporal and spatial principles, learners are more likely to retain information in their working memory when texts and images are simultaneously presented. According to the coherence principle, irrelevant information should be excluded. Also, a magnifying function or arrows must be utilized to identify focal points according to the signal principle.

A single image in a video or animation does not represent all of the teaching material. Rather, multiple images are needed to portray the focal procedures and detailed measures that must be followed. The video and animation groups performed better than the static picture group in the equipment operation, accuracy of experimental procedures, and successful completion of experimental steps. Additionally, the students showed significant differences on choosing the most suitable multimedia teaching materials. Most of the students chose video and only few students chose pictures. Furthermore, the students preferred video and animation to picture. There was no difference showed between animation and video. The results of this study may provide useful references for multimedia designers, teachers, school administrators, and future studies. However, this study was limited a small research targets and research time. Thus, these factors should be taken into consideration in the future studies to make this research more complete.

6. SUGGESTIONS

The following suggestions were from the findings of the study made by the researchers for multimedia designers, teachers, school administrators, and future studies to refer to. For multimedia designers, the icon for speed control of aside should be created in order for learners to control based on their own learning needs. In addition, the principles of multimedia design should be implemented for designing the most effective teaching aided materials. Finally, since the cost of making animation was much higher than video, video can be made for assisting teaching experiments in the future. For teachers, video should be extensively used in experiment classes because it can effectively assist and enhance students' learning interest and motivation. Next, although video can effectively assist teacher and students in learning experiments, students are still encouraged to enter the laboratory to conduct experiments with hands-on practices under the best time arrangement and safety check. For school administrators, school should popularize and spread the use of multimedia teaching materials actively and the equipment and facility of multimedia should be sufficient and complete for every classroom. Finally, some other variables such as text color, font, speed of aside, voices of male and female, and students' computer literacy can be investigated in the future studies.

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