Senior High School Students' Comprehension and Interest in Science Content: Example of Participating in First-Hand Experimental Activities

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Abstract: The purpose of this study is to investigate three questions: First, it examines whether students' understanding of science increases after exposure to scientific content with animations and the provision of experience with practical scientific activities. Second, according to the Kolb Scale, an effort is made to determine which type of learning characteristics lead to higher degrees of understanding of science after engaging in practical scientific activities. Third, the study is used to investigate whether student willingness to engage in science-related work in the future is correlated with their levels of understanding of science. A total of 154 students from six senior high schools were invited to be participants. The results showed that most of the students exhibited significant improvement in their understanding of science after they were involved in actual experimental processes with animated content. The students having accommodator-type learning characteristics had higher levels of understanding of science as well as greater willingness to pursue science-related work in the future. However, the results indicated that legitimate experimental processes may help enhance student comprehension in terms of scientific content. There is no indication that they affect arousal of scientific interest and willingness to follow a science-related path as a future career.

Keywords: Scientific experiment, multi-media assisted learning, learning comprehension, learning

1. Introduction

In order to transform Taiwan's science-related courses in primary and secondary schools into exploratory and experimental curricula, the government usually contributes to equipping and funding educational units with complete sets of hardware and software. This study is part of an integrated research project comprising three sub-projects (Project I, II, III) and assists in the provision of science-related courses oriented toward exploratory approaches and experimentation in cooperation with Taiwan's National Laboratory Animal Center (NLAC). Both the NLAC and the members involved in Project II and III form a team responsible for providing science-related teaching and learning materials, such as lecture slides and photos and experimental modules. This study (Project I) is responsible for developing multi-media assisted learning materials, i.e., two-dimensional (2D) animations based on the materials provided by the NLAC and the other two sub-projects.

Prior studies have proposed that science-related course teaching materials containing concrete evidence, specifically multi-media animations or virtual objects, have significant effects on student learning [4, 5]. This purpose of this study is to assist the NLAC with evaluating the effectiveness of these materials, to confirm the readiness of the experimental modules designed by the NLAC, Project II and Project III, and to support schools with updating their content for science courses, especially in the area of experimentation. Meanwhile, this study (Project I) helps develop required 2D animations for the experimental modules. Therefore, the purpose of this study is three-fold. First, this study is intended to investigate whether animated materials are an aid to students participating in experiments as well as whether they are helpful in increasing students' learning comprehension when receiving exploratory and experimentally-oriented science content as provided by Projects II and III. Second, this study is to verify whether students with different learning characteristics obtain different levels of comprehension ability after exposure to science-related content and participation in the experiment. The students participating in this project are expected to understand scientific concepts well after they are involved in actual hand-on practical sessions that

allow them to fully experience scientific experimentation. Kolb's [2] Learning Style Inventory based on the experiential learning theory is thus considered in this study to determine the types of student learning characteristics [1, 5, 6, 7]. Kolb's experiential learning theory has been acknowledged by academics, and the Kolb's Learning Style Inventory has been widely used in various studies. Third, this study investigates whether or not participation in carefully designed experiments elevates students' interest in science-related careers as has been indicated in prior studies [8, 9], who suggest that a causal relationship exists between students' past learning experiences, such as enjoyment, performance, and satisfaction, and their future career choices.

Finally, in the process of developing animated materials, this study (Project I) provides the NLAC and the members of the other two sub-projects (Projects II and III) with concrete suggestions for amending the teaching materials and experimental modules of science-related courses. In addition, this study contributes to increasing comprehension in students learning advanced biomedical technology content, and the students' interests related to pursuing science-related occupations may also be increased after participating in the current integrated research project.

2. Reasons for Multi-Media Animation-Assisted Learning

Multi-media assisted learning has become a common trend in education due to contributions that focus on personalized acquisition, provision of hands-on sessions, and instructor assistance [4, 5, 10]. Also, animation can present a richer experience than pure textual or statistical graphs since it triggers learners' curiosity, encourages them to focus continuously on learning, and enhances motivation [11, 12, 13]. In a learning environment with extensive texts, students may have difficulty concentrating for extended periods of time. Contrarily, according to Mayer's cognitive theory of multimedia learning, if texts are combined with animations in a multi-media animation-assisted learning and teaching environment [3, 30], the process of learning and teaching gains expansion of attention spans due to exposure to differing patterns and stimuli.

In addition, multi-media assisted learning contributes to effective comprehension of content and helps students retain the objectives of the experiments [6, 11, 14, 15, 16, 17]. With the interactive features of computerization, learners can change the displays on their screens through manipulating the software interface. Prior studies have indicated that the result of continuous interaction between learners and multi-media instruction, especially animations, allows learners to acquire and retain scientific concepts through an increased understanding of scientific content. Thus, multi-media assisted learning can convey the content vividly through pictures and animations and allows students to practice computer-aided learning in daily life.

Prior studies mention that multi-media animation-assisted learning can also enhance the quality of learning [18, 19, 20]. Specifically, for teachers, the computer-aided teaching environment allows adaptable instructional flexibility by allowing insertion of additional activities that support the individual differences in students [1, 5, 6, 7]. By properly using multi-media tools for instructional design, any teaching materials can systematically or even nonlinearly display a concept in accordance with the needs of learners after being integrated with images, sound, and texts. Learner enjoyment [21, 22] and satisfaction [23, 24, 25] can then be increased in such a learning environment. Finally, a future orientation towards science can be expected in students after they are involved in a multi-media animation-assisted learning environment process [8, 9].

Overall, multi-media animation-assisted learning, which is significantly different from traditional teaching methods, increases students' learning motivation and teaching effectiveness. Animation can draw learners into the instruction and maintain their motivation to learn. Students who used an online multi-media teaching system to acquire knowledge from animated content offer more positive comments than those engaged in traditional learning environments, and these students are able to maintain high degree of satisfaction with the online multimedia teaching system interface, meet their learning needs, and experience learning effectiveness. In addition, many studies confirm that adding multi-media to instructional content helps students gain competence with content effectively and also helps them retain the content details, affording logical, effective avenues for learning and raising the personal satisfaction related to such tasks.

Currently, curriculum reform in Taiwan does not have the force of private, dedicated research units or large-scale research projects. Instead, the

reform relies on support from the Taiwanese government (i.e., the Ministry of Education) to co-ordinate planning the country's future for education, which is known as the White Paper on Education. Taiwan's future educational goal is to promote the concept of lifelong learning in academic institutions dedicated to reforming science courses. Therefore, to add micro-nano or Biomedical Technology Engineering and other related science curricula to primary and secondary educational programs allows the promotion of this concept as well as speeding up the development of informal educational materials for curricula. Informal educational materials for curricula can appear in various forms, such as texts, images, videos, and so on, and most are free for individuals to download. For instance, the National Science and Technology Museum developed a set of micro-nanotechnology animations for its websites (http://nano.nstm.gov.tw/), which welcome visitors of all ages.

3. Methodologies

This study (Project I) cooperated with the NLAC, Project II and Project III to provide science-related teaching content and experimental modules, especially in the subject of biomedical technology, along with the development of two-dimensional animated learning materials. Based on the purpose of this study and the literature review, several quasi experiments were carried out with senior high school students to participate in exploratory and experimental learning processes. The students participated in this study in a context designed as a classroom lecture setting, but they were encouraged to ask questions about any confusing scientific concepts by viewing the animations at any time, and they had hands-on sessions to get involved in the actual scientific experiments.

3.1 Research participants

The study participants comprised 154 students from six senior high schools, consisting of 32 male students (one all-male school, Group A), and 23 females (three all-female schools, Group B). The remaining two schools are co-educational senior high schools (Groups C and D). All students participating in the groups received an invitation to attend scientific lectures and conduct real experiments based on the recommendation of their science teacher. Even

though the different groups received different numbers of scientific lectures and experimental modules depending on the amount of time the science teachers had available to devote to this study, the level of difficulty for each scientific lecture and experimental module was controlled to establish the reliability of the data collection processes.

3.2 Research tools

This study measures students' learning styles according to the Kolb Learning Style Inventory [1], the most commonly-used method used in education and business. According to Kolb [2], every learner transitions through four stages of "experiential learning": Concrete experience (CE), to reflective observation (RO), to abstract conceptualization (AC), and finally to active experimentation (AE). These four stages represent categories of two different dimensions (perceptions of information and processing of information), and has been further categorized into four different types of learning styles: Converger (AE & AC), Diverger (CE & RO), Assimilator (RO & AC), and Accommodator (CE & AE).

This study evaluates students' learning performance by comparing results from tests that were distributed before and after the experiments. The tests comprised multiple-choice questions for each experimental module, where the students had to correctly respond to most of the questions to verify their comprehension. The questions appearing in the post-test were the same as those in the pre-test. In addition, the post-test included two additional nine-point Likert-type survey questions regarding: (1) the level of satisfaction with the experiment, (2) the level of similarity between the experiment and daily experience, and two open-ended questions regarding: (1) feelings and opinions about the experiment, (2) identification of the most difficult parts of the experiment, and one yes-no question, regarding attitudes toward pursuing careers in science-related fields. In addition to the animated materials designed in this study (Project I) to enhance students' understanding of science, these survey questions contribute to revising the scientific lectures and experimental modules developed by the NLAC, Projects II and III.

3.3 Research procedures

Before recruiting the research participants,

the NLAC, Project II and Project III members considered designs for the teaching materials and experimental modules, their graphic content, and the manner and timing of presenting 2D animation to the students in a pilot study. Detailed descriptions of the processes for designing the 2D animations do not appear due to limited space, but are available upon request. Then, science teachers from six high schools were invited to recommend students participating in the Scientific Exploration of Biomedical Engineering Technology Experiment through registration (May to September 2011). After receiving the registrations from high school students for participation in the study (September to December 2011), the registered students completed a learning characteristics scale and a pre-test of the experimental module to form a baseline of knowledge before scheduling participation in the scientific experiment. At the scheduled time, after absorbing the scientific lectures containing multi-media animated materials, the student participants were guided to carry out the actual scientific experiments. During the experiment, videos recorded the students' learning processes and their learning reflections were recorded via digital pens. After the experiment, the students and science teachers were invited to interview. In addition, the students responded to a post-test in a survey form containing the same pre-test questions, two nine-point Likert-type survey questions, two open-ended questions, and one yes-no question. As the registered students' responses to the open-ended questions were analyzed, suggestions for the amendments of all developed scientific lectures and experimental modules were provided to the members of the NLAC and Project II and Project III (January to April 2012). Then, the back-translation technique was adopted for the students' open-ended responses to ensure the accuracy of the Chinese to English translation. About two years later (2012-2014), all data were completely organized and were reported as this study's findings. It should be noted that due to the constrictions of available space, the qualitative data from the video recordings, reflective thoughts, and interview transcripts are not reported here, but can be provided upon request.

4. Research Results

Two parts of the research results are reported here. The first part is the analysis results of the participating students' learning outcomes as judged by the scores obtained from the pre- and post-tests, which reveal whether or not the concept of the experimental module remained unclear or vague. The second part of the analyses is the results of the students' learning characteristics and their willingness to engage in science-related occupations.

4.1 Students' learning performances

According to the students' responses to the two open-ended questions, the terminology presented and defined in the scientific lectures prior to conducting the experiments were difficult to comprehend. The 2D animated design (Table l) does assist with understanding the terminology when included in the lecture session before the experiment.

Table 1 Screen shots of 2D animation designs

Course module	Design rationales	Animation design
Magic Test Paper – Elisa	For assimilator and diverger – Different test tubes encourage students to carefully observe for self-help in forming correct judgments and organization of content.	
Amazing Book without Words – PEG	For accommodator and converger – Students prefer to find answers. After exposure to new experiences, their ability to solve technical problems or reduce risks are improved.	
Finger Map Story – N-th power of 2	For accommodator and diverger – Gene language represents an abstract concept, but appears concretely through designing interactive 2D animation with rich graphic representations.	
Little Mee's Five-Star Hotel – HEPA	For all four learning styles, the designed HEPA room showing an abstraction of air cleanliness proves it is impossible to create a concrete experience of cleanliness.	
Seeing is not Believing – Reflection	For assimilator and converger – This study aids students to rely on deducing an abstraction after a real experience.	

By providing the students with 2D animated materials along with the scientific lectures, most students' post-test scores improved (Table 2), with the exception of one group (C), many of whom displayed low interest in completing the experiments and depended on the provided 2D animations. Their low interest was obvious through observing their performance on videos taken during the entire experimental session. As a result, even though the students in Group C had difficulty concentrating on the lecture, they maintained high levels of satisfaction with the lectures and experiments, and they considered the experiments to be related to their daily experiences.

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Table 2 Scores on pre- and post-tests

Group Code (by numbers of students)	Pre-test (M,SD)	Post-test (M,SD)	t-value (p)	Results
Group A (32) – boys' schools	21.47, 2.501	23.37, 3.220	3.363 (0.002)	Improved
Group B (25) – co-educational schools	3.54, 1.285	5.33, 0.816	6.689 (0.000)	Improved
Group C (74) – co-educational schools	3.97,1.365	2.62,1.290	6.906(0.000)	Not improved
Group D (23) – three girls' schools	1.73,1.398	2.76,1.173	4.219 (0.000)	Improved

4.2 Students with different learning styles

According to Kolb [2], personal experience and scientific exploration of experimental modules should enable students to experience the four stages of learning: CE- Provide specific materials in the course lectures and instructional materials provided by the lecturer, and the lecturer's remarks should be clear and intriguing. RO- Provide a few questions to lead students to think, enable them to conduct the experiment based on past experience with conducting scientific experiments, accumulated knowledge, and finding solutions to problems. AC- Provide group discussion opportunities so that students can observe other students' thinking during the learning process. AE- Provide a sufficient length of time for each experiment, so individual thinking and implementation leads to initiatives for experimentation and observations that lead to in-depth knowledge.

Figures 1 to 4 display the scatter plots of four groups of students' learning styles. Obviously, Group A and B (CE and AE orientations) have similar accommodator-type learning styles. Both groups of students have interest in actively conducting experiments, and approximately ten students from both groups have a reflective observation learning style (RO). Notably, Table 3 shows that most Group B students (91.7%) demonstrate willingness to consider pursuing science-related careers in the future since they significantly prefer to conduct active experiments as compared to the students in Group A. The scatter plot of the learning styles of Group C's students represents a large difference compared to the other groups. Group D students have somewhat similar learning styles to those in Group A since both groups have outliers representing the abstract conceptualization and reflective observation learning style. Thus, Group D demonstrates a low percentage, in fact the lowest, willingness to pursue careers in science.
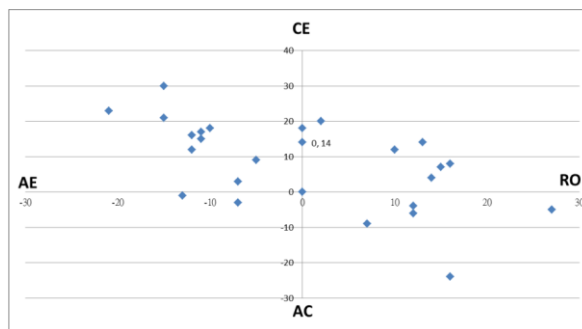

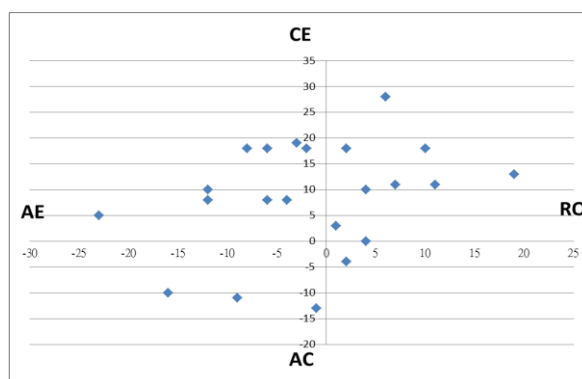**Fig. 1** Scatterplot of Group A students' learning styles (unit: score)

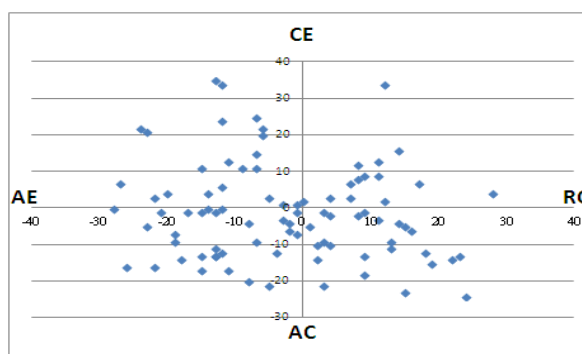**Fig. 2** Scatterplot of Group B students' learning styles (unit: score)

Fig. 3 Scatterplot of Group C students' learning styles (unit: score)
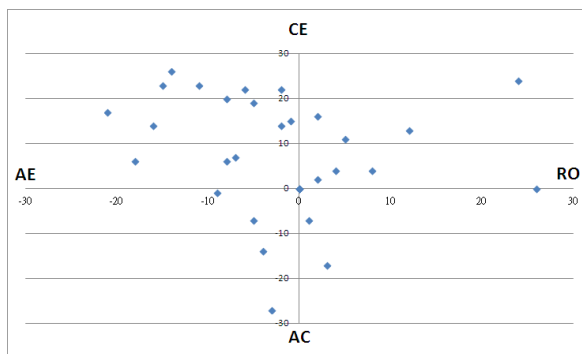

Fig. 4 Scatterplot of Group D students' learning styles (unit: score)

Table 3 Willingness to engage in scientific jobs

Group Code	Will (%)	Will not (%)*
Group A	53.3	31.3%
Group B	91.7	8.3%
Group C	9.5	67.6%
Group D	21.2	69.7%

* The total percentage does not reach 100% due to some students' lacking definitive preferences.

5. Discussion and Conclusions

This study verified the fact that the effects of multi-media animation such as 2D animated designs have a significant impact on the students' learning performance. This finding is consistent with the assumptions proposed by Mayer's cognitive theory of multimedia learning [3] suggesting that learning materials should be provided in varied ways for different types of auditory and visual learners. In this study, the students' comprehension obviously improves through exposure to the 2D animated designs provided during the lectures and during sessions for experimentation. However, there was only one group (Group C) where most students' post-test scores were lower than their pre-test scores. This was probably due to their style of learning science and resulted in their holding negative attitudes toward listening to the lectures and their low interest in completing the experiments. According to Kolb's experiential learning theory [6, 7], every student has his/her preferred learning style. This study did find that the four groups of participating students indeed had different learning styles. In addition, the types of learning styles determine the degree of understanding of science. The only group (Group C) receiving lower scores in the post-test did not have the accommodation learning style (AE-CE) as was the case for Groups A and B, nor did they have the convergence learning style (CE-RO) style as was the case for Group D. Notably, both Groups A and B indicated interest in actively conducting experiments, and approximately ten students from these groups exhibited a reflective observation (RO) learning style. Finally, this study found that most Group D students preferred to obtain concrete experiences in the learning processes, similar to Groups A and B (CE orientations), and their learning performance improved after exposure to the animated materials, but they had low willingness to engage in science-related careers. This finding implies that no correlation exists between willingness to engage in science-related careers and the degree

to which students understand science. In addition, concrete experiences can be regarded as important components when developing animated materials for scientific lectures and experimental modules.

Based on the results, different multi-media learning tools have different levels of effectiveness in contexts of science-related learning [26, 27, 28, 29]. The purpose of using multi-media learning tools is to effectively assist students in order to enhance their interest in learning and improve their learning performance. As students embrace the context of scientific experiments, they may change their minds and consider careers in science-related endeavors in the future. This study's future direction is to provide students with a totally experiential learning context, such as three-dimensional (3D) animations, virtual objects in 3D space, or developing augmented reality materials to develop deep levels of enjoyment and satisfaction from conducting experiments and to improve learning performance.

Acknowledgement

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