International Journal of Environmental & Science Education
Vol. 6, No. 1, January 2011, 39-58

An intensive ICT-integrated environmental learning strategy for enhancing student performance

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Received 20 May 2010; Accepted 21 August 2010

The purpose of this study is to design information communication technology (ICT) courses related to experimental chemistry for junior college freshmen (aged from 16 to 18), entitled "ICT-integrated environmental learning", and to assess the learning performance of these students after completing the courses. This study adopts a quasi-experimental approach to evaluate the learning of two groups of students after completing a nine-week semester syllabus. Aided by ANCOVA data, we probe the processes of the students' chemistry learning, its effectiveness and their attitudes. The result analyses verify that our ICT-integrated environmental learning has a more significant effect on the students' learning performance. Therefore, it is our goal to design an effective approach for upgrading students' cognizance and learning attitudes. The results obtained from our ICT-integrated environmental learning when compared with other chemical experimental results show the same positive and scientific perspective for academic research.

Keywords: chemistry, quasi-experimental approach, learning performance

Introduction

An intensive Information Communication Technology (ICT)-integrated environmental course for lower-level college students is urgently needed to enhance their performance of chemistry learning (Hofstein & Lunetta, 1982). Hofstein and Lunetta (2004) have suggested carrying out scientific experiments helps learning of concepts and characteristics; therefore the importance of such experimental activity should not be underestimated.

The demand to meet new standards of industrial safety, hygiene and environmental consciousness is why we focus on experiments related to chemical toxicity as a study target. Long and short-term toxicity are of great concern when dealing with problems of waste recycling. Our study incorporates chemical experiments helpful for environmental protection, designed to meet present day needs, such as recycling sources, stability, waste reduction and harmlessness to the environment. It is important to design texts and static teaching material for innovative recycling treatment.

The 21st century has seen a new approach to recycling sources, stability, waste reduction, and harmlessness to the environment by teachers and students leading to the development of new experiments of ICT chemistry texts and study material. A complete mastery of scientific knowledge, up to an advanced level, is an important aspect of learning in our well-informed liberalized global economic market. Chemical knowledge and skill transmission will be replaced

ISSN 1306-3065

http://www.ijese.com/

by the professional fluency, creativity and the ability to solve problems in this new field. Redesigning experiments to demonstrate innocuous experiments, such as flame color, halogen replacement reaction, and cathode ray tube, for our environmental protection becomes a vital focus of students' chemical learning.

An effective path to promote science and technology was discussed by West and Graham (2005) who sought to increase the interaction between students and teachers, and students and students. Science and technology curriculum should stimulate reflective thinking with the aim of letting students learn in a meaningful ICT learning environment to become engaged in science and technology to improve students' learning performance. ChanLin (2007) argued that the new technology of computer science could changes teachers' research strategies and students' learning. Several science educators (Ardac & Akaygun, 2004; Kelly, Phelpss, & Sanger, 2004) have proposed the functions of linking figures, charts and symbols into programmed ICT learning, in order to strengthen students' concepts of chemistry, and to promote the acquisition of deeper knowledge and understanding. Ardac and Akaygun (2004) maintained that computer technology could be used for cartoon spaces and symbols and interactions of molecular representations to help students understand more abstract ideas and chemical phenomena. High-tech skill development would be closely followed by the use of integrated multimedia technology including pictures, cartoons, films, sound effects, characters and pronunciations. Scientific learning is difficult for students if they are just asked to memorize and recite facts to pass examinations.

ICT chemistry experiments-- offering both declarative and procedural knowledge—could be beneficial to facilitate scientific learning. At the present time most students simply learn to memorize algorithms and lower-level content in order to pass examinations without developing a meaningful understanding of the higher-level chemical concepts and unifying principles (Nakhleh, 1993). Furthermore, much misunderstanding of chemical ideas and alternative conceptions hinders further effective learning (Coll & Treagust, 2001; Calik & Ayas, 2005). Enhancing students' understanding of chemistry concepts and process skills, rather than only teaching lower-level chemical knowledge, has become a major goal for chemistry educators (Ardac & Sezen, 2002; Nakhleh, 1993). Many have explored the implementation of some promising practices that are not commonly used in chemistry teaching, such as integrating multimedia into the learning environment (Su, 2008a, 2008b; Ardac & Akaygun, 2004; Yang & Andre, 2003) to achieve this goal (Lin, 1998; Lin, Hung, & Hung, 2002; Rodriguez & Niaz, 2002). It may be attributed to "most college students' inability to attain an organic overall conception of scientific learning which has led to conceptual myths and misconceptions" (Nurrenbern & Pickering, 1987). Our ICT experimental chemistry course is an example of an effective platform that can arouse students' interest, allowing them to absorb new scientific knowledge and foster the development of professional skills. Students' learning motivation and efficiency is largely dependent on well-prepared course designs (Sperling, Seyedmonir, Aleksic, & Meadows, 2003; Yang & Andre, 2003). Therefore, a well-designed program of ICT chemistry experiments becomes a necessity for teachers.

Purpose of the Study

The purposes of this study it to construct ICT chemistry experiment courses, to build a foundation that will be both efficient and facilitate tactical teaching for the learner, as well as increase the mutual interaction between teachers and students. At the end of our study, we evaluate the progress the students have made in terms of technological creativity and manipulative competence to solve their chemical-related problems. With the afore-mentioned research background as motivation, this study tries to evaluate the following two student objectives of learning performance:

(1) To construct a strategy for "ICT-integrated environmental learning" suitable for tenth grade students that encourages them to build and analyze their individual chemical competence.
(2) To probe into the best tactics for "ICT-integrated environmental learning" to impart to the students a positive attitude towards this chemistry learning. This study proposes two fundamental research questions and assumptions or observations:
(1) The implementation of "ICT-integrated environmental learning" as measured in two groups students' achievements has not reached up at any significant differences.
(2) The same implement of "ICT-integrated environmental learning" as indicated in two groups students' learning attitude has not reached up at any significant differences.

Theoretical Framework

Our tactic of incorporating new content into chemistry courses and creating a new environment, such as by the use of ICT programming texts (Su, 2008a; Ardac & Akaygun, 2004), integrating some science history into the courses (Lin, Hung, & Hung, 2002), and applying network technology (Keengwe, Onchwari, & Wachira, 2008). Our teachers will not only need to possess fundamental ICT skills but they need to develop sound pedagogical skills to successful integrate ICT into chemistry curriculum. This redesign of ICT-integrated environmental learning course does much to contribute to students' learning performance. It will become more important in our study of chemical teaching in future. Relevant education theories related to the formation of our teaching strategy are discussed below.

Cognitive Learning Theory

Piaget (1950) proposed a learning process by which knowledge accumulates in the learner's mind as mental structures are formed step by step. According to Piaget's theory, learning is an active process in which each learner must construct knowledge by interacting with the environment and by resolving the cognitive processes based on what the learner can observe.

In cognitive psychological theories, students are most often described as passive persons who initially acquire knowledge by knowing and continued practice (Barak & Dori, 2005); in their mature stages, the students' role in knowledge acquisition will change from passive learning to active participant. Successful learning requires gradual building up and constructing from the initial knowledge. The students choose relevant information, and teachers act as coaches or referees in the students' study process. In other words they offer their experience and appropriate teaching media. As has been pointed out by Ausubel (1968). Ausubel's major point was that the most important single factor influencing learning depends on what the learner already knows; the teachers should find the students' strengths and weaknesses, and should try to cooperate and learn with and from the students. Starting with the student's already existing knowledge, teachers should also take into consideration their backgrounds and cognitive concepts before proceeding with meaningful teaching (Mayer & Moreno, 2003).

Situated Learning Theory

Lave and Wenger (1991) made an ingenious proposition, which both constructions of knowledge and technical skills come from interactions between learners and situations. Similarly to make the inference, our understanding of meaningful knowledge comes from the interactions between the learner and society; and finally, constructive elements are of great help in transforming new knowledge for the learner. By way of active interactions in real situations, students can construct individual cognitive structures in ways corresponding to situated learning theory, proposed by Uclo, Gion, and Cowog (2005). With the effective CAI aid of 12 m/s^2 acceleration, Uclo, Gion, and Cowog launched a fashionable Ariane 5 rocket for solving various physics problems. Textbooks and learning situations can be designed to help students with active learning, to develop their competence for thinking and solving problems.

Constructivism Theory

The importance of incorporating constructivism into scientific teaching has already been recognized by most science educators with many studies carried out over the past 20 years (Trumper, 1997; Yore & Treagust, 2006). Trumper (1997), Yore and Treagust (2006) maintain that constructive knowledge is the result of students' thinking ability. Ideas are constructed from preknowledge and from their social and cultural backgrounds. Ausubel (1968) suggested that the fundamental principle of constructivist instruction was to assess what students know and then to teach then accordingly. This principle of constructivism has given rise to several interpretations ranging from information processing, interactive-constructivist, and social constructivist to radical constructivist approaches (Yore, 2001). Moreno and Valdez (2005) regards the function of a multimedia environment in the situated constructivist design, either as abundant reality or as simulation, to encourage learners to decipher knowledge on their own to grasp and control the learning process by themselves, and to facilitate the exploration and reorganization of acquired knowledge. The integration of ICT into science teaching gives us more chances to understand students' developments of complex ideas and positive attitudes (Windschitl & Andre, 1998; Joiner, Littleton, Chou, & Morahan-Martin, 2006). All fundamental improvements are related to an awareness of suitable resources, pedagogy and a critique of ICT which correlated well with collaborations environments (Dawson, Forster, & Reid, 2006). Multimedia environment is also related to our use of ICT-based chemical learning resources. The ICT resources in these chemistry classrooms include interactive CDs, electric textbooks, digital camera, data projector and laptop, personal response systems, etc. Another recent study (Frailich, Kesner, & Hofstein, 2007) shows that the building of an ICT-integrated chemistry environment is both the effective and potential study to enhance the comprehension of basic chemistry concepts, stimulating students' attitudes and interests to increase their awareness regarding the relevance of chemistry in their daily life. In our study, constructivist-based instruction was designed in accordance with the conceptual change model that engages prior knowledge (accesses and challenges students' ideas) and helps college students modify their misconceptions and develop more chemistry accurate conceptions.

Developments of Teaching Tactics

ICT developments of teaching tactics

With the rapid developments of ICT technology, scientific scholars need new learning tactics to face dynamic changes of the world. They need extensive and colorful learning programs of ICT interactions, which will eventually replace traditional classrooms teaching. This new type of learning tactic with more flexibility can help the learners to do environmental functional chemical learning, without any limit of a special space or location. Compared to the development of ICT technology, the function of the learning in traditional schools and faculty remains a lot to be improved. It loses priority with changes of learning tools, because the most effective learning can be transmitted from two-dimensions of time and space into three-dimensions of digital ICT learning. Our ICT learning activity design takes students to get involved in less time, from single to multiple technology developments. Teachers should construct the cognitive learning for effective ICT tactics. All knowledge can be learned through ICT-integrated knowledge and individual manipulation. Students can decipher new design of information actively, as opposed to negative acquisition of traditional learning, and to construct ICT situational interactions advocating functional learning and practice of intelligence (Beers et al., 2008).

In the era of information technology, the application of ICT with creative scientific knowledge will become a new approach. In accordance with this development, this study aims at building more experimental applications of ICT learning, and integrating new scientific knowledge to achieve the educational objectives for learning about chemistry. Teaching aids such as Flash Animations, combined with experimental apparatus, and multimedia technical developments including sounds and graphic arts are used in our design of the chemistry experimental process. The process can be divided into several important units where ICT experimental texts are used to enhance students' learning through visual effects, creating greater communications between teachers and students, and students and students. Our multimedia teaching tactic present three experimental programs (1) the color of flame; (2) cathode ray tubes; and (3) halogen replacement, which are related to our study of ICT-integrated environmental learning.

Development and procedure of ICT experimental texts

The development and of our ICT teaching texts can be divided into five stages, namely analysis, function, development, implementation and evaluation.

1. Analysis stage

To break free from traditional teaching texts, the analysis stage deals with what tactics can be applied and what problems can be best solved via ICT teaching.

(1) Scanning ICT teaching units. In addition to satisfying the school curriculum needs, our ICT teaching is built to include a more complex and experimental environment. There are three experimental teaching units—the color of flame (TCF), the cathode ray tube (TCRT), and the replacement of halogen (TRH); all judged suitable for our discussions.

(2) Evaluating students' abilities. Most of the students in our study have scored low on scientific achievement tests so our design of ICT-integrated experimental chemistry texts is based on both the principles of being concise and simple enough to take into consideration students' diverse abilities.

(3) Constructing classroom facilities. The science teacher needs to be able to use a range of ICT resources in this chemistry classroom. The resources include: software such as Flash Animations, Power-Point and Microsoft Word 2007; and hardware such as data projector and screen, online networks, laptop, digital camera.

(4) Responding students' participation attitude. Our investigation results show that students' characteristics include the category of active students, with low scholastic achievement and only passive learning experience.

(5) Setting up study goals. Our three study goals: (1) to learn fundamental chemical knowledge, (2) to construct basic skills of chemical experiments, (3) to fulfill embodiment of

chemical literacy, based on the outline of ICT-integrated chemistry experimental courses are set up by revisions and standards of the Ministry of Education in Taiwan.

2. Function stage

(1) Each unit of the ICT-integrated experimental text is analyzed, keywords are listed, and the key ideas for ICT teaching are explained.
(2) Animations are designed so that each procedure in the experimental unit can be set in motion, with matching colors, simple scripts, sound and music
(3) Animations are transferred into hyperlink, and Flash Animations are shown with Power Point
(4) Check animations to be sure that the size of the script, color and luminance of background are suitable or not, as well as whether the timing and clarity of animation is appropriate or not.

3. Development stage

(1) The first draft of the ICT-integrated experimental designed texts is tested. Necessary texts are deleted or added according to changes in teaching goals and learning hours
(2) After several text revisions, the ICT-integrated experimental texts are programmed into our computer

4. Implementation stage

The ICT-integrated experimental texts are completed and students' acceptance of our teaching texts obtained. We also conducted a questionnaire survey to assess students' learning achievement using our ICT-integrated experimental texts.

5. Evaluation stage

Student feedback is obtained from the questionnaire and comments after completion of the ICT-integrated experimental teaching.
(1) Learning achievement tests are given every other week after completing each teaching unit to assess students' learning achievements and differences between the experimental group and the control group.
(2) Investigations of students' learning attitudes between the experimental group and the control group -- are checked out after the bi-week achievement test.

Brief introduction of teaching texts

Experiments related to the stability of natural resources stability, reduction of harmful chemicals and innoxious chemicals are designed in ICT-integrated theory for the different units. Multimedia technology is combined with animations, static charts and descriptions of characteristics. All major units are divided to include several relevant and meaningful experimental models. These minor experimental models include the teaching of cognitive contents of chemistry text designs, teaching methods, teaching situations, course skills technology and scientific attitudes, etc. All these aspects are flexibly combined together to create new learning styles and reliable applications. Power point presentations are prepared using three groups of animated examples. Parts of our Flash Animations are converted using the Adobe Photoshop 7.01 software; see Figure 1; each animation lasts for almost 20 seconds. Students in the experimental group have five minutes after the classroom demonstrations to practice with the animation.

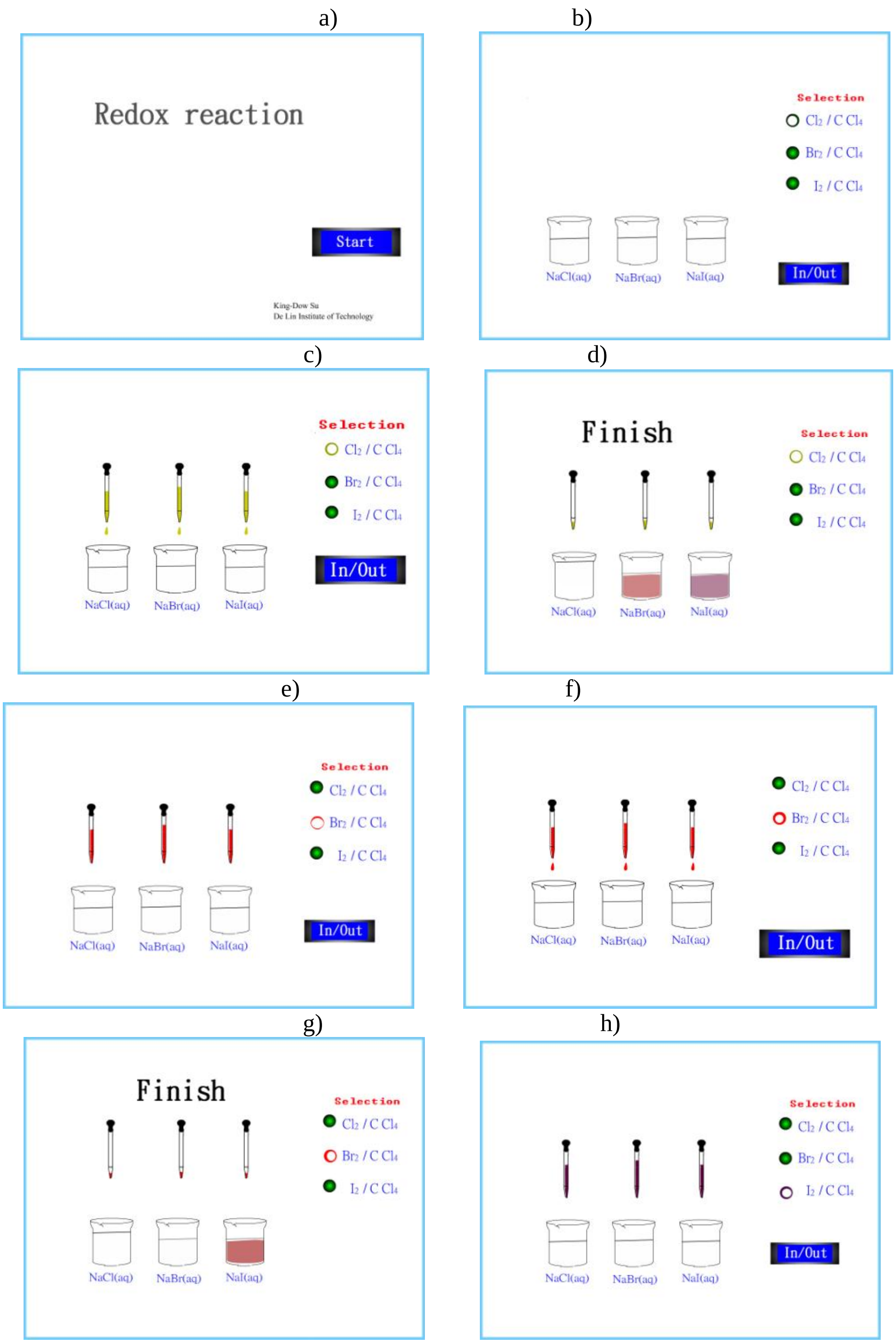

Figure 1. Replacements of the ICT-based chemical course in Adobe Photoshop 7.01 animations arranged order from (a) to (j)

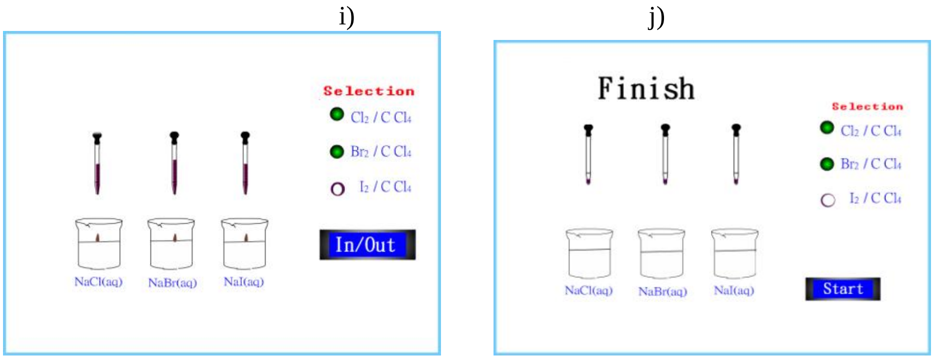

Figure 1.*Contiuned.*

Methods

Participants

For convenience of discussions, all 49 selected participants (junior college freshmen) are from the same class which is divided into 17 group/pairs with 2-3 students per group. Groups 1-9 form the experimental group (a total of 25 participants) which is taught using the ICT-integrated teaching tactics, and groups 10-17 form the control group (a total of 24 participants) who are taught with traditional teaching methods by using texts without any assistance of ICT. The characteristics of two different groups' students who completed a 27 hours in the nine-week ICT-based chemistry program courses during the academic year are discussed below.

Framework

Our research includes statistical terminologies, such as "Control variables", "Dependent variables", "Independent variables", and "Covariate variables", as our ICT-integrated environmental learning framework.

(1) Control variables: These are essential to reduce interference and obtain complete ICT experimental results. Variations in our study are minimized by employing the same instructor, the same content, the same teaching hours, and the same evaluation tools.

(2) Dependent variables: Students are required to write, discuss and hand in their experimental reports after classes. Instructors administer achievement tests to evaluate students. Another variation is to use the questionnaire to also survey learning attitudes after the instructor-administered achievement tests.

(3) Independent variables: Variations in students' personal data (enrolment, disposition toward computer use, frequency of computer application) and group divisions (i.e., experimental group and control group) of relation to instructors' teaching strategy will be in fully discussed.

(4) Covariate variables: The instructor will carry out pre-tests of students' achievement as the major covariance before each unit.

Research Approach and Procedure

In order to fulfill the goals of resource recycling, stability and reduction of harmful chemicals in our ICT-integrated chemical experimental texts, and to improve students' performance and learning attitudes, this research study presents the following major approaches and procedures:

(1) Analyze the learning goal of the target group
(2) Design appropriate ICT-integrated chemical experiments for environmental protection
(3) Design application of ICT video-aids
(4) Incorporate learning activities and teaching strategies into model ICT simulations
(5) Divide the participating students into experimental and control group for our quasi-experimental research project
(6) Evaluation of the learning efficiency of the target group by experts and participants

Methods of Applied Instruments

This study takes a quasi-experimental approach. Questionnaire tests, different criterion related to learning performance, and statistical analysis of the learning efficiency and attitudes of tenth grade students are carried out. There are four stages in our research design; namely pretesting, target group teaching, posttest and questionnaire evaluation. It is expected that all methods including pretests and posttests, experimental teaching, learning questionnaire, and statistical analysis of students' learning achievements and attitudes, should significantly help students improve problem-solving ability and promote positive efficiency.

Five aspects of students' achievement (including knowledge, understanding, application, analysis, synthesis) were tested in pretests and posttests. The draft test design was evaluated by staff members at the Joint College Entrance Examination Center in Taiwan and by 5 senior chemistry professors. The reliability of the achievement tests was analyzed by the Cronbach's <alpha> technique. Reliability was expressed in terms of the Cronbach's <alpha> coefficients to determine the internal consistency of the total questionnaire and subscales. The <alpha> coefficients obtained for TCRT (the cathode ray tube) pretest and posttest, TRH (the replacement of halogen), and TCF (the color of flame) teaching units were 0.66/0.66, 0.70/0.71, and 0.68/0.68, respectively. The same test was employed for both the pretest and posttest so as to record changes and detect differences in performance.

The questionnaire for assessing students' learning attitude contains 30 items. The five-point Likert-type scale is used (1=strongly disagree, 2=disagree, 3=neither degree nor disagree, 4=agree, and 5=strongly agree). All test items follow several revisions of the author's (Su, 2008a) draft design.

To improve content validity, we asked two science educators, two science philosophers and two educational psychologists to act as advisors and to preview the survey and revised versions. In terms of construct validity, 269 copies of pretests are taken into consideration for factor analysis. The first results of factor analysis for the KMO data (0.906) and χ^2 data (3363.094) of Bartlett spherical investigation (the degree of freedom 435) prove significant, so are deemed suitable for factor analyses. There are seven aspects considered in main component analysis. The initial Eigenvalue obtained is above 1.0 with an accumulative explanation variation of 60.759%. There are only 2 tests for the fifth aspect, one test for the sixth aspect, and another for the seventh aspect. All the results from the above 4 tests can be deleted because they are beyond the scope of our main topic. The second set of factor analysis results for the 26 remaining tests are as follows: KMO data (0.915) andχ^2 data (3028.077) for the Bartlett spherical investigation (degrees of freedom 325) prove significant, so are suitable for factor analyses. There are five aspects taken into account for our main component analysis. The initial Eigenvalue is above 1.0, with an accumulative explanation variation of 58.017%; the α value can be 0.85, 0.84, 0.81, 0.58 or 0.70 as shown by internal consistency inspection of the Cronbach's α. According to Gay's point (1992) any supposed coefficient reliability over 0.90 indicates better reliability of scale. DeVellis (1991) regards a reliability of 0.70 as the minimum acceptable reliability; therefore it is necessary to delete three tests of the fourth aspect. All statistical data, including average items if deleted, scale variation; corrected item-total correlations are indicated in Table 1. In the right column it can be seen that the reliability coefficient will change after the Cronbach's α if any item deleted. We recognize that these items are not suitable for deletion. Each item's corrected Item-Total correlation is greater than 0.440. The more correlative a coefficient becomes the higher consistency of each item among its initial relations with others. There are a total of 23 items in our questionnaire (see appendix) which can be classified into four dominated aspects:

LA1, learning attitude toward chemistry experiments
LA2, learning attitude toward experimental teaching
LA3, learning attitude toward experimental activities
LA4, learning attitude towards the instructor

All four dominated aspects will be our major study of students' learning feedback from the factor analysis. Factor loading of all items are indicated in Appendix. All mean values, standard deviations, and Cronbach's α value are indicated in Table 2. According to this table, the internal consistency of the four aspects and total scale reaches a satisfactory degree.

Data Analysis

All information acquired before and after the classes are on file and some statistical analysis are carried out using the SPSS 15.0 Windows software. The Cronbach's α value for the cathode ray

Table 1. Mean value, variance, corrected and item-total correlation (γ_{it}) for the item and Cronbach's α for each item when that item is deleted

Item	Mean	Variance	γ_{it}	Cronbach's α if Item Deleted
1	79.5353	119.921	. 601	. 916
2	79.5242	120.362	. 516	. 917
3	79.7286	119.057	. 552	. 916
4	79.5242	119.818	. 481	. 918
6	79.6208	117.617	. 599	. 915
7	79.4870	119.452	. 518	. 917
8	79.6766	117.958	. 597	. 915
9	79.5836	119.766	. 484	. 917
13	79.9182	117.613	. 579	. 916
14	79.7918	116.546	. 577	. 916
15	79.9591	115.689	. 570	. 916
16	79.6729	117.258	. 605	. 915
17	79.8067	117.045	. 575	. 916
18	80.0409	116.801	. 551	. 916
19	79.9740	118.003	. 528	. 917
20	79.7435	117.341	. 560	. 916
23	79.6208	118.020	. 575	. 916
24	79.6059	118.889	. 519	. 917
25	79.5651	117.277	. 590	. 916
26	79.5799	116.685	. 614	. 915
27	79.6766	118.638	. 564	. 916
28	79.4981	118.214	. 536	. 917
29	79.4907	119.990	. 448	. 918

Table 2. Mean (M), standard deviation (SD), and Cronbach's α

Aspect (question number)	M	SD	Cronbach's α
LA1(1,2,3,4,6,8,9,28,29)	3.77	0.64	0.85
LA2(14,23,24,25,26,27)	3.66	0.80	0.84
LA3(13,15,18,19,20)	3.37	0.83	0.81
LA4(7,16,17)	3.65	0.82	0.70
TA (the whole scale)	3.62	0.77	0.92

tube unit is .808, that for the halogen replacement unit is .817 and that for the color of flame unit is .817 as individually measured in students' posttests of learning attitude.

(1) Covariance analysis

Due to the limitations of our text models, it is required to divide groups alternatively with covariance analysis to reduce effect of the factor interference upon our study. Our emphasis is primarily on covariance analysis of both the experimental group and the control group. Thus group assumptions of coefficient homogeneity will be examined to test whether there exist any significant interactions between covariate variables (pretests) and independent variables (posttests). Our study carries out covariance analysis adjusting for the significant difference between the experimental group and the control group. Data from pretests of the experimental and control groups are used to find the covariance of the slope homogeneity, after ensuring validity of the teaching method to precede covariance analysis.

(2) Independent sample t-testing

An independent t-test is employed to examine whether there is any significant difference in students' learning attitudes between the experimental group and the control group before and after the questionnaire.

Results

The major purposes of our study were to construct ICT model texts based on educational principles for chemistry experiments at a technical school in Taiwan and to explore the students' differentiated performance in these ICT-integrated chemistry courses given specific implementation conditions and the learners' attributes.

Analysis of Students' Learning Achievement

Statistical ANCOVA analysis was carried out for students' posttest learning achievement, using students' pretest data as covariate variables, and posttest data as dependent variables, and divided groups as independent variables. Results obtained by homogeneity examination of the regression slope indicated that there was no significant different between the groups for the six learning units between independent variables and dependent variables, responding to group assumptions of covariate variable analysis in the homogeneity examination of the regression slope; thus all are available for us to precede with further covariance analysis. Results of covariance listed in Table 3 show that there is a significant difference in students' posttests achievement between the experimental teaching groups and traditional teaching groups. It is noted that the Cohen's experimental effect size (*f*), *f* value of between .385 and .594, indicates a higher effect size. The pairwise comparisons listed in Table 4 also show that posttest scores of the experimental groups are superior to those of the control groups, which confirms our assumption that the experimental teaching strategy is better than traditional teaching strategy.

Table 3. Summary of F-ratios, p-values, and effect sizes (*f*) for each learning achievement post-test of the ANOVAs

Experimental Course	Analysis of variance		
	F-ratio	p-value	*f*
TCRT[1]	9.724 **	0.003	0.494
TRH[2]	14.308 ***	0.000	0.591
TFC[3]	14.465 ***	0.000	0.594

Note: *p<0.05; **p<0.01; ***p<0.001;
[1]TCRT represents the cathode ray tube
[2]TRH represents the replacement of halogen
[3]TFC represents the color of flame

Statistical Analysis of Learning Attitudes

(1) Comparison of teaching strategies for the experimental group and the control group

This study utilizes students' pretest scores for learning attitude as the covariant and their posttest scores as the dependent variables. The p-value of the homogeneity test in three teaching units from the experimental group and the control group are all over .05 (.830, .662, and .160 for each teaching unit separately). According to our group assumptions there is no significant difference in its interactions. Thus, it is appropriate that we treat students' pretest scores of learning attitude as the covariant in the adjustment of differences in performance prior to experiments between the experimental group and the control group, done in order to get our covariant analysis.

The pretest scores of learning attitude are defined as covariant, the posttest scores as the dependent variables. All results of covariate variable analysis are listed in Table 5. There is a significant difference in students' learning attitude between the experimental group and the control group for the cathode ray tube (p=.007), the halogen replacement reaction (p=.008), and the color of flame color (p=.050) experiments. Students' learning attitude is influenced by our ICT-integrated teaching strategy. The experimental results show that all effect sizes for the cathode ray tube (*f*=.449), the halogen replacement reaction (*f*=.433), and the color of flame (*f*=.316) exceed the medium (*f*=.25).

(2) Comparative analysis of students' learning attitudes

All results for the average, standard deviations and t-test from students' pretests and posttests are listed in Table 6. It is supposed that there will be a difference in students' learning attitudes

Table 4. Adjusted post-test mean scores of experiment and control group and pairwise comparison of the students' learning for chemistry courses

Experimental Course	Experiment Group Mean	Control Group Mean	Pairwise Comparisons
TCRT[1]	60.907	49.202	*
TRH[2]	41.976	27.702	***
TFC[3]	53.690	37.448	***

Note: *p<0.05; ***p<0.001;
[1]TCRT represents the cathode ray tube
[2]TRH represents the replacement of halogen
[3]TFC represents the color of flame

shown in pretests and posttests which is dependent upon their learning via ICT-integrated teaching strategies. Analysis of the experimental design and independent t-tests show significant differences in students' learning attitudes, giving more influence for the experimental group than the control group. On average, the posttest scores were higher than that the pretest scores, showing the modules contributed a lot to students' learning.

Table 5. Summary of F-ratios, p-values, and effect sizes (*f*) for each learning attitude post-test of the ANCOVAs

Experimental	Analysis of variance		
Course	F-ratio	p-value	*f*
TCRT[1]	8.092	0.007*	0.449
TRH[2]	7.717	0.008*	0.433
TFC[3]	3.988	0.050*	0.316

Note: *p<0.05;
[1]TCRT represents the cathode ray tube
[2]TRH represents the replacement of halogen
[3]TFC represents the color of flame

Four aspects (LA1, LA2, LA3, and LA4) of students' learning attitude are defined in the questionnaire as dependent variables; student enrollment, frequency of computer use and disposition toward computer use are defined as independent variables. A one-way ANCOVA approach is taken to examine the multi-variant significance of the Wilks' Lambda parameter. All significant differences are listed in Table 7, including the F value, p value, and *f* effect sizes. In the ICT-integrated experimental units we see a significant difference in independent variable results for the halogen replacement reaction. A Scheffe's post hoc comparison reveals the results, where "very fond" is superior to "fond", "very fond" is superior to that of "really dislike", and "fond" is superior to "really dislike". Results for the experimental *f* value reach .727, indicating large effect sizes. Comparative analysis of students' attitude for the control group assumed that there should be no significant difference between pretests and posttests. All t-test results shown in Table 8 indicate that the p value of the control group (traditional teaching) is more than .05. There is no significant difference expressed in the control groups' learning attitude, which corresponding to our study results.

Table 6. Difference between experimental groups for each learning attitude in pretest and posttest, t-test, and p-value

Experimental	Pretest		Posttest			
Course	M	SD	M	SD	t	P
TCRT[1]	76.88	11.29	86.91	7.51	-3.776	0.0001***
TRH[2]	78.23	7.81	90.19	4.49	-6.771	0.0001***
TFC[3]	77.54	7.21	87.60	8.67	-4.280	0.0001***

Note: ***p<0.001;
[1]TCRT represents the cathode ray tube
[2]TRH represents the replacement of halogen
[3]TFC represents the color of flame

Discussions and Conclusion

Many ICT-integrated experiments are related to our study of chemistry. Scientific educators should incorporate chemistry experiments of environmental protections, such as electrodes and nonelectrodes, collecting oxygen (Su, 2008b), into ICT-integrated chemistry teaching. Our research questions for study reported in this paper were: Do ICT-integrated environmental learning in three chemistry units influences students' learning performances of their ICT learning achievements and attitudes? Our results attained that the majority of students' performances that they were better prepared to learn using ICT after completing these chemistry units. It will become a new effective approach suitable for helping students to learn and to reach our study target. The greatest improvements were related to consciousness of suitable ICT pedagogy, resources, and critique of ICT-integrated environmental learning which correlated well with the learning activities that college students participated in.

These results of this study support our learning theories that posit connections between verbal stimuli and visual representation to enhance chemistry learning achievement and attitude. All results from our discussions indicate that ICT-integrated environmental learning encourage college students acquire a meaningful understanding of the targeted chemistry concepts and promote a positive attitude toward chemistry learning. The ICT-integrated texts and environments help to develop more advanced-level and meaningful concepts, as well as unifying principles which can enhance the students' understanding of chemistry concepts and process skills leading to the major goal of chemistry learning.

It is our strategic goal to let students continue this ICT-integrated environmental learning and to popularize this project in Taiwan. This study focuses on setting up a safe and reliable and learning environment, which facilitates students' learning performances and increases teachers' resources. Our statistical results are consistent with those of other researchers' in relation to ICT-integrated experimental chemistry teaching strategies (Ardac & Akaygun, 2004).

It is concluded that an ICT-integrated environmental learning for chemistry teaching offers unique benefits, especially when students have to learn new complex ideas, as also noted by Ainsworth (2006) who utilized the DeFT (Design, Functions, Tasks) framework for learning with ICT representations. These results indicate that, although the benefits of using ICT-integrated environmental learning varied individually according to students' performances, instructor-guided instruction can be beneficial to most students. These positive results indicate that our teaching strategy is worth popularizing in most Taiwanese college students. ICT-integrated environmental

Table 7. Summary of F-ratios, p-values, and effect sizes (*f*) for each of the ANCOVAs

Experimental Course	Blocking Variable	Analysis of Variance	Attitude Measure LA1	LA2	LA3	LA4
TCRT[1]	Disposition toward multimedia	F-ratio	1.363	2.265	1.532	0.541
	(positive, neutral, negative)	p-value	0.276	0.127	0.237	0.589
		f	0.343	0.445	0.366	0.217
TRH[2]	Disposition toward multimedia	F-ratio	1.037	6.091	3.046	0.188
	(positive, neutral, negative)	p-value	0.371	0.008 *	0.067	0.830
		f	0.301	0.727	0.514	0.128
TFC[3]	Disposition toward multimedia	F-ratio	0.785	2.462	0.766	0.205
	(positive, neutral, negative)	p-value	0.468	0.107	0.476	0.816
		f	0.261	0.462	0.257	0.135

Note: *$p<0.05$;
[1]TCRT represents the cathode ray tube
[2]TRH represents the replacement of halogen
[3]TFC represents the color of flame

Table 8. Difference in attitude toward study of the control group before and after every teaching unit

Experimental Course	Pretest M	SD	Posttest M	SD	t	P
TCRT[1]	84.06	5.51	84.41	7.15	-0.161	0.873
TRH[2]	82.00	8.03	82.06	9.31	-0.019	0.985
TFC[3]	81.78	8.37	84.28	8.13	-0.909	0.370

Note: *$p<0.05$
[1]TCRT represents the cathode ray tube
[2]TRH represents the replacement of halogen
[3]TFC represents the color of flame

learning can play a vital role in helping college students to understand many difficult and abstract concepts and it appears to have potential benefits for integrating meaningful individual learning and group study into classroom teaching, which will in the end contribute to the sustainability of experimental development. ICT-integrated chemistry texts not only increase students' learning motivation and interest but also upgrade their performance and promoted improved their study attitudes at the same time, as well as leading to more intimate communicative interactions between teachers and students.

Nevertheless, development of multimedia experimental texts, and continuous horizontal expansion, so as to establish the simultaneous and non-simultaneous learning environments, free from the obstacles of time and space are our future study purposes. We demonstrate an experimental platform for ICT teaching that will help both students and teachers to get involved in meaningful learning.

Acknowledgement

A short but sincere thank must be given to the patronage of the National Science Council, R.O.C. in Taiwan (research project NSC 95-2511-S-237-001and NSC 98-2511-S-237-001); without their help our study can not be completed. The author also gives sincerely thanks to constructive suggestions by this article's reviewers.

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Appendix. Likert items for the attitude subscales

Sub -scale	Items	Loading Factor
LA1	1. Each unit of the chemistry experiment program matches our study project.	.569
	2. Each unit of the chemistry experiment program is very helpful with our study.	
	3. Each unit of the chemistry experiment program gives me confidence with my study.	.794
	4. Each unit of chemistry experiment program pays attention to major methods of teaching the material.	.693
	6. The teachers always encourage and show they care for students.	.478
	8. This chemistry experiment teacher pays attention to the effectiveness of our study.	.788
	9. The style of teaching is lively.	.505
	28. Chemical experiment teaching can excite the will that I pursue the chemical new knowledge.	.798
	29. The computer picture in the chemical experiment classroom that I think, can maintain my attention.	.867
		.494
LA2	14. Classmates can actively participate in the teaching activity during class.	.605
	23. Pass the chemical experiment, the study that I can be attentive and unanimous.	.818
	24. Chemical experiment teaching can promote my ability of solving a problem to the chemical examination question.	.822
	25. Chemical experiment teaching can promote my learning ability to the scientific concept.	.631
	26. Teach through chemical experiment; make me want to study other relevant chemical knowledge even more.	.548
	27. Chemical experiment teaching can promote my study interest to chemistry.	
		.655
LA3	13. Students are taught in accordance with their aptitude.	.729
	15. This type of study where classmates can help me to carry out the chemical experiment is difficult.	.708
	18. The question that classmates participate in the chemical experiment enthusiastically is discussed in the class.	.783
	19. I can work out the study plan of the chemical experiment voluntarily.	.770
	20. Teaching material that I can preview, review chemical experiment course after class before the lesson.	.559
LA4	7. This chemistry experiment teacher is encouraging and shows loving care for us.	.562
	16. Classmates all have atmosphere of reading the chemical experiment teaching material in the class.	.529
	17. Classmates like the chemical experiment teacher in the class.	
		.440

KMO= .915
Accumulative Explanation Variation(%)= 58.017
Total Cronbach α = .92

Öğrencilerin performansının arttırmak için yogun bir bilgi iletişim teknolojisi-bütünleşmiş çevre öğrenme stratejisi

Bu çalışmanın amacı genç kolej öğrencileri için (16-18 yaş) bilgi iletişim teknolojisi bütünleşmiş çevre eğitimi adlı deneysel kimya ile ilgili bilgi iletişim teknolojisi kursu tasarlamak ve öğrencilerin kursu tamamladıktan sonar performanslarının değerlendirmektir. Bu çalışma dokuz haftalık bir dönem kursunun tamamlanmasının ardından her iki grup öğrencilerin öğrenmesi değerlendirmek amacı ile yarı-deneysel yaklaşım kullanmıştır. Analiz sonuçları bizim ICT-bütünleşmiş çevre öğrenmesinin öğrencilerin öğrenme performansı üzerine anlamlı bir etki yaptığını doğruladı. Bu nedenle, amacımız, öğrencilerin idrak ve öğrenme tutumlarının arttırmak için etkin bir yaklaşım tasarlamaktır. Diğer kimyasal deneysel sonuçlarla karşılaştırıldığından bizim ICT-bütünleşmiş çevre öğrenmesinden elde ettiğimiz sonuçlar akademik çalışmalar için aynı olumlu ve bilimsel perspektifi gösterir.

Anahtar kelimeler: kimya, yarı-deneysel yaklaşım, öğrenme performansı