

行政院國家科學委員會專題研究計畫 期中進度報告

數位學習環境中學生科學概念改變之研究(2/3)

計畫類別：整合型計畫

計畫編號：NSC94-2511-S-009-002-

執行期間：94 年 08 月 01 日至 95 年 07 月 31 日

執行單位：國立交通大學教育研究所

計畫主持人：余曉清

報告類型：精簡報告

報告附件：出席國際會議研究心得報告及發表論文

處理方式：本計畫可公開查詢

中 華 民 國 95 年 6 月 3 日

行政院國家科學委員會專題研究計畫進度報告

科學概念的建構與重建數位學習研究-數位學習環境中學生科

學概念建構與改變之研究(2/3)

Research of Students' Scientific Knowledge Construction and

Conceptual Change in Digital Learning Environment (2/3)

計畫類別：☐個別型計畫 ☒整合型計畫

計畫編號：NSC 94-2511-S-009-002

執行期間：94 年 8 月 1 日至 95 年 7 月 31 日

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處理方式：☐可立即對外提供參考

(請打✓) ☐一年後可對外提供參考

☒兩年後可對外提供參考

(必要時，本會得展延發表時限)

執行單位：國立交通大學教育研究所

中華民國 95 年 6 月 3 日

Abstract

This study is to report a web learning project was developed based on the Dual Situated Learning Model (DSLML) and scientific reasoning. In addition, to explore the potential of promoting middle students' concepts construction and reconstruction involving atom through an examination of the interrelationships among the approaches of instruction (web-based experimental and conventional group) and students' level of scientific reasoning (transitional and concrete operational level) on their atomic related concepts test and scientific reasoning test scores. Results indicated that students' post-, and retention of atomic related concepts test scores were significantly affect by the instructional approach and level of scientific reasoning. Students' scientific reasoning post- and retention test scores were significantly affected by the instructional approach. In short, web-based experimental group's students outperform significantly than conventional group's students on both post- and retention of atomic related concepts test scores. Transitional group's students outperform than concrete operational group's students on both post- and retention atomic related concepts test scores. Moreover, web-based group's students outperform significantly than conventional group's students on the retention of scientific reasoning test scores. Transitional group's students outperform significantly than concrete operational level group's students on the retention of scientific reasoning test scores.

Keywords: DSLML, scientific reasoning, web-based learning, atomic achievement test, scientific reasoning test

Introduction

The characteristics of the World Wide Web (WWW) are boundless ready-to-access resources, the various visual and audio forms of information presentation, as well as the synchronous and asynchronous communication which overcomes time and space constraints of learning. These unique characteristics of the WWW possesses have led world-wide educational researchers and practitioners regard it as a potential tool for improving teaching and learning. The progress of the WWW also has captured the eyes of science educators. Except for providing an authentic wet lab experience, all learning activities are seemed possible on the Web. Accessing the Internet and incorporating the WWW into teaching activities have been considered fundamental skills of science teachers in the twenty-first century (Didion 1997).

Although Web-based learning has invoked great attention in the community of education, and the publishing of websites designed for educational purpose is flourishing in recent years, overall the quality of those websites are not in a satisfactory level. Mioduser *et al.* (2000) reviewed 436 educational websites focused on mathematics, science and technology learning and concluded that "one step ahead for the technology, two steps back for the pedagogy." In their work, a taxonomy comprising four major dimensions were developed. Examining the selected educational websites with the taxonomy, Mioduser *et al.* (2000) ascertained that traditional, hierarchical, highly structured, and directed instructional prevailed; only 28% of

the reviewed websites included inquiry-based learning; and the cognitive process the learners required were mostly lower-order information retrieval and memorizing. Although the WWW supports multiple forms of information presentation, Mioduser *et al.* (2000) found text dominated, and more than 80% of the selected websites did not have animation; more than 95% the selected websites did not include interactive image or sound. In addition, less than one third of the websites provided help functions and only 8.7% provided “ask an expert” resource.

Tuvi & Nachmias (2001), with a taxonomy modified from that of Mioduser *et al.* (2000), reviewed 93 websites focus on introducing atomic structures and resulted in similar findings: text was the absolutely major presentation of information; automatic/human and technical/content-based help were less than 18%; less than 6% had interactive image, animation and sound; non of those websites was inquiry-based; and memorizing consisted the majority of cognitive process.

The above studies point out the following critical problems of the most of the web learning program designed for science education purpose. It obviously that science teaching and learning theories are absent in the most of the science web-learning program. Second, the pedagogical consideration also is not considered in the design of the web-learning program. Third, the capability of the web and multimedia is not fully used to enhance students’ science learning. Therefore, this study attempts to employ the Dual Situated Learning Model (DSLML) and scientific reasoning to the development of a Web-based science learning program in order to facilitate students’ knowledge construction and reconstruction of atoms. DSLML is a conceptual change theory and also an instructional design guidance which is tailored to foster students’ conceptual change in scientific concepts. Details about DSLML are introduced in the later section.

Conceptual Change Theories and Dual Situated Learning Model (DSLML)

Conceptual change has been a major research area of science education in recent two decades (Duit & Treagust 2003). Research on conceptual change is spurred by the great volume of findings on students’ alternative conceptions, misconceptions or pre-instructional conceptions about scientific concepts accumulated from the studies in the past thirty years. There is a need for a theoretical foundation that can describe, predict and explain alternative conceptions, as well as incorporate the findings to enhance science classroom practice (Wandersee *et al.* 1994). The Conceptual Change Theory (CCT) brought up by Posner *et al.* (1982), while incurred some critiques (Duit 1999), is the seminal and the best known work of conceptual change theory in science education. Inspired by the work of Jean Piaget and Thomas S. Kuhn, Posner *et al.* (1982) suggested four conditions which are essential for a successful conceptual change to occur: unsatisfactory to the existing concepts, new concepts are intelligible, new concepts are plausible, and new concepts are fruitful. Science educators who follow the CCT and others who attempt to bring about conceptual change in students emphasize presenting discrepant events which create dissonances between the learner’s alternative conceptions and the scientific concepts, and further introduce the scientific concepts which are comprehensible to the learner (Limon 2001; Minstrell 2001).

Cognitive developmental psychologists approach the investigation of conceptual change via a different

route. Instead of proposing strategies which may facilitate the occurrence of conceptual change in learners, cognitive psychologists focus on searching the types of conceptual change (Carey 1985; Vosniadou & Brewer 1987), and the explanations of what make certain forms of conceptual change harder to occur than others (Chi *et al.* 1994; Carey 1985; Thagard 1992; Vosniadou & Brewer 1987).

Chi *et al.* (1994) attribute the extent of difficulty for a successful conceptual change to occur to the ontological essence of the concepts. When the alternative concept and the scientific concept belong to the same ontological category, for instance, they both belong to matter, process, or mental states, conceptual change is less difficult to occur. Otherwise, conceptual change is rather difficult to happen when it involves jumping between two ontological categories, for instance from matter to process.

Thagard (1992) views scientific concepts as structured in a hierarchical, tree-like system. In this system, concepts are linked by different kind of relations, including kind-relations, part-relations, and rule-relations. Minor conceptual change, which is common in a science class, happens when adding new concepts and relations to the hierarchical concept system. Severe conceptual change, which Thagard calls conceptual revolution, happens when reorganizing hierarchies by branch jumping and tree switching are involved. While the models of Chi *et al.* (1994) and Thagard (1992) both emphasizes, but with different explanations, the importance of the ontological essence of the conceptual structure in the process of conceptual change, Vosniadou & Brewer (1994) concerns both the ontological and epistemological presuppositions of the naïve framework theory to be either facilitate or constrain conceptual change.

In view of the different perspectives from the science education researchers and the cognitive psychologists about conceptual change, She (2001, 2002, 2003, 2004a, 2004b) integrates the strengths from the both sides to her framework and develops the Dual Situated Learning Model (DSLML). According to She (2004a 2004b), situated learning means learning is a process of conceptual change; moreover the learning process should be situated on the nature of science concepts and students' beliefs of the science concepts in order to determine what essential mental sets are needed for constructing a more scientific view of the concepts.

Dual means the learning events serve four dual functions: first, considering both the nature of science concepts and students' beliefs of science concepts; second, creating dissonance with students' pre-existing knowledge, and providing new mental set for them to achieve a more scientific view of the concept; third, arousing students' motivation and challenging their beliefs of the concepts; and fourth, challenging students' ontological and epistemological beliefs of science concepts. When the DSLML is employed in developing a science lesson, six stages are involved. These six stages are detailed in a later section.

The application of the DSLML instructional approach has evidenced effective conceptual change in middle school students in the topics of air pressure and buoyancy (She, 2002), thermal expansion (She, 2003), heat transfer (She, 2004b), dissolution and diffusion (She, 2004a), and meiosis and mitosis (Tang *et al.*, 2005). However, none of the above studies were conducted in a Web-based learning environment. In view of the call made by Mioduser *et al.* (2000) that the current state of Web-based learning is “one step ahead for the technology, two steps back for the pedagogy”, this study is the first attempt try to infuse both DSLML and scientific reasoning to the design of a web-based science learning program involving atomic related

concepts.

Scientific Reasoning

Lawson (2003) indicated that the view of development of advanced reasoning and its emphasis on alternative conceptions or misconceptions leads quite naturally to a theory of science instruction which quite happily has the potential to unite two previously competing research traditions in science education namely the Piagetian tradition with its emphasis on reasoning and hands-on discovery learning and the Ausubelian tradition with its emphasis on concept acquisition and verbal learning.

Important over the past few years a new research tradition has emerged which owes its existence in part to Piagetian theory and in part to Ausubelian theory. That research tradition, which focuses on students' alternative conceptions and misconception (Dirver, 1981; Clement, 1986; Posner, Stike, Hewson and Gertzog, 1982; Anderson and Smith, 1986) provides an opportunity to synthesize the best of the Piagetian and Ausubelian traditions into a view of the learner and the learning process which fills a gap created by these two traditions and leads directly to a theory of instruction, which if implemented should produce learners not only with adequate understanding of domain specific scientific concepts, but with truly general reasoning skills of the sort classified as formal operational by Piaget. (Lawson). Lawson has try to discuss the relationship exists between students misconceptions and reasoning ability. The rejection of the ideas during the past required the generation of alternative hypothesis and their test through hypothetico-deductive reasoning, experimentation, data collection and considerable argumentation. Open minded scientists who became aware of these alternative ideas, the available evidence, and were able to follow the lines of reasoning used to argue the cases, were generally convinced and were able to overcome prior misconceptions in favor of the more scientifically accurate conceptions. It can be hypothesized that the same thing can happen in the science classroom. For students to modify prior conceptions they must become aware of the scientific conceptions, as well as their own alternative conceptions, and they must become aware of the evidence and reasoning which bears on the validity of the alternative conceptions. In other words, they must be able logically to see how the evidence supports the scientific conceptions and contradicts the prior alternatives. Logically seeing this, however, requires the use of hypothetico-deductive reasoning. Because hypothetico-deductive reasoning is precisely that used to evaluate alternative conceptions in a logical manner, students who have failed to internalize the reasoning pattern would be expected to hold more misconceptions than their hypothetico-deductive peers. Thompson (1987) found this to be precisely the case. On a test following instruction on concepts of evolution and genetics, a sample of empirico-inductive seventh grade students revealed an average of 1.67 misconceptions per student while their hypothetico-deductive classmates held only 0.43 misconception per student. The conclusion is students who are internalized the hypothetico-deductive reasoning pattern hold fewer misconceptions because this pattern is necessary to overcome prior misconceptions.

Students frequently used scientific reasoning skills as they attempted to assess their own prior knowledge,

generate new models for scientific events, and extend their models to new situations (Keys, 1995). Scientific reasoning skills can be broadly defined as those intellectual processes used by scientists within the problem solving context of investigation (Glynn, et al., 1991). In the growth in scientific reasoning involves development in conceptual knowledge, culturally based knowledge of exploratory strategies, and knowledge of the purpose of the scientific reasoning (Tytler & Perterson, 2003). Tytler & Perterson (2003) proposed children's scientific reasoning could be appropriately characterized by the dimensions which include their approach to exploration, depth of processing, their ability to deal with competing knowledge claims, and their response to anomalous data. Hogan et al. (2000) describe the six essential components of scientific reasoning are generativity, elaboration, justification, explanation, logical coherence and synthesis. Generativity and elaboration specify the amount and type of ideas and elaborations of ideas within the topic. Justification and explanations which specify the structure of students' reasoning, meaning how their ideas are supported and explained. The logical coherence and synthesis specify the quality of the student's thinking. Key (1994) defined 11 scientific reasoning skills and further organized into four categories that correspond to the function in report writing which are reasoning skills used to assess prior models, to generate new models, to extend models, and to support of other reasoning processes. There are 3 scientific reasoning skills belong to the categories of assessing prior models: posing prediction, evaluating predictions, and explaining-justifying predictions. There are four reasoning skills belong to the category of skills used in generating new models: evaluating observations, identifying patterns and properties, drawing conclusions, and formulating models. For the category of skills used for extending models included the skills of inferring and comparing/ contrasting. For the category of Skills used for support included discussing concept meaning and identifying relevant information.

Previous Research on Students' Alternative Conceptions Involving Atoms

Garnett et al. (1995) review the previous researches on students' alternative conceptions in the particulate nature of matter, specifically point out students perceive atoms are alive. Harrison and Treagust (1996) reported that high school students view atoms as visible under a microscope or too small to see, microscopes, not sure all substances contain atoms, atoms are alive like cells can grow and divide, view atoms as balls or spheres not sure about the component inside of atoms, the texture of atoms most like a hard polystyrene sphere, not aware of electron shell or electron clouds, consistent image of atoms are protected by an outer shell. Lee et al. (1993) found similar results about the size of molecules, even after instruction, they still believe they could see molecules with Lee et al (1993) study showed that students believe that the properties of atoms were hard. In addition to the alternative conceptions involving atoms described above, we also collected the other possible alternative concepts from the experienced middle physical science teachers. Giffith & Perterson (1992) reported students believed all atom weight same, shape of atom is ball, nothing inside of the atom, something existed between atom and atom, and electrons move within the shell.

Method

The design of the DSLM lesson

The design of the DSLM lesson included six stages, each of which is described as below:

Stage 1 Examining attributes of the science concepts.

This stage provides information about which essential mental sets are needed to construct a scientific view of the concepts. The basic components of the atomic related concepts are (1). Classification of matter: identify pure substance or mixture; (2). element and compounds: identify compounds and elements, and the composition of matter; (3). atom and its components: structure of atom, the components of atom and their properties, the motion of electron and its , the electron within the atom and activity of elements, atom and chemical reaction.

Stage 2 Identifying students' misconceptions of the science concepts.

This stage involves probing the students' beliefs concerning the science concept. Students' belief of a science concept is a crucial part of determining whether conceptual change can be brought out. It is achieved by pinpointing what misconception students have. The following misconceptions identified by many previous researches and experience teachers served our basis for this stage.

Stage 3 Analyzing which mental sets students lack.

This stage aims to locate which and how many particular mental sets students lack specifically for restructuring the science concepts. An understanding of these is beneficial to design the most appropriate situated learning events, which supplement the deficiency of particular mental sets and to foster conceptual change. Comparing the results of stage 1 and stage 2 results in six mental sets about atoms the students need to construct: 1. living environment; 2. structure; 3. nutrition; 4. propagation; 5. application, and 6. classification in biology.

Stage 4 Designing dual-situated learning events.

The design of dual situated learning events is based on the results of stage 3. The design of each event needs to create dissonance with students' original beliefs of the science concept, and provide a new mental set or mental sets for them to achieve a more scientific view of the concept. Its design of creating dissonance should also arouse students' motivation as well as challenge students' beliefs of the concepts.

Series of web-based dual-situated events are designed to help students develop the mental sets they lack.

Stage 5 Instructing with dual-situated learning events.

This stage emphasizes providing students an opportunity to make prediction, provide explanation, confront dissonance, and construct a more scientific view of the concepts. During the instruction, each event allows students to confront their beliefs of science concepts, and arouse their curiosity and interest to challenge their epistemological and ontological beliefs of science concepts. Moreover, each event would also provide students a new mental set where knowledge reconstruction can occur.

Each dual-situated learning events always begin with a driving question, which targets to the misconceptions commonly found in students. The students are required to provide an answer and their reasoning to the question. Followed by the driving questions, various activities such as graphic and text illustrations, simulated animations, simulated experiments, analogies are provided. The design of these activities need to create dissonance, challenge beliefs, and help the students reconstruct the mental sets they

lack. The same driving question is asked again after the event to examine the students' conceptual change as well as their reasoning changes.

Stage 6 Instructing with challenging situated learning events

The purpose of this stage is to provide an opportunity for the students to apply the mental sets they have newly acquired to a new situation in order to ensure that a successful conceptual change to occur. The design of challenging situated learning event needs to combine all of the particular mental sets that students lack before and by now have been reconstructed through a series of dual situated learning events.

Subjects and procedures

A total of 197 eighth graders recruited from six average-achievement classes from a middle school in Taiwan participated in this study. One hundred and eight of whom received the web-based DSLM learning (hence an experimental group will be called in this article) and the remaining 89 students received conventional lecture-based instruction (hence a control group will be called). Based on the students' scientific reasoning pre-test scores, the students were further classified as transitional and concrete operational level students. A pretest of atomic related concept test on mold related concepts were administered to all students before the instruction. The independent t-test on the pretest scores showed the two groups had an equivalent initial ability ($t = 1.49, p > .05$). One week and eight weeks respectively after the instruction, a posttest and a retention test of the scientific reasoning test and atomic related concepts test were administered to both groups. Cronbach α of the atomic related concepts test was 0.76 for the pretest, 0.91 for the posttest, and 0.93 for the retention-test. Cronbach α of the scientific reasoning test was 0.78 for the pretest, 0.76 for the posttest, and 0.78 for the retention-test.

Results

Atomic Related Concepts test

Table 1 presents the descriptive statistics of the pre-, post-, and retention of the atomic related concepts test. Although the experimental group has a lower mean score than the control group, the experimental group outperforms the control group in the posttest and retention test.

Two-factor MANCOVA was conducted to examine the effects of instructional approaches and scientific reasoning levels using post-test and retention of atomic related test scores as the dependent measures, and students' pre-test scores as the covariate. Table 2 summarizes the results of the two-factor MANCOVA, instructional approaches (Wilk's $\Lambda=0.91, p=0.000$) and students' level of level of scientific reasoning (Wilk's $\Lambda=0.87, p=0.000$) have a statistically significant effect on the performance of posttest and retention test of the atomic related test. Therefore, the following main effect for the three levels of learning process was performed.

First, one-factor MANCOVA was performed to examine the effect of instructional approach factor on

both post-test and retention-test, as shown in Table 3. One-factor MANCOVA shows a significant effect for instructional approaches (Wilk's $\Lambda=0.77, p=0.000$). Then univariate F (one-factor ANCOVA) was performed to independently examine the effect of the instructional approaches on post-test and retention test. It indicated that a significant effect for instructional approaches on both post-test scores ($F=40.20, p=0.000$) and retention-test ($F=50.34, p=0.000$) was significant. Thus, the students' post-test and retention test achievements were significantly affected by the instructional approach. The post-hoc analysis for main effect suggests that the web-based instructional group performed significantly better than conventional group (web-based instruction > conventional instruction, $p_{(post)}=0.000, p_{(retention)}=0.000$) on post-test and retention-test (Table 3).

Second, the same procedures were performed for the effect of the level of scientific reasoning, as shown in Table 3. One-factor MANCOVA shows a significant effect for level of scientific reasoning (Wilk's $\Lambda=0.88, p=0.000$). Then univariate F (one-factor ANCOVA) was performed to independently examine the effect of the level of scientific reasoning on post-test and retention test. It indicated that a significant effect for the level of scientific reasoning on both post-test scores ($F=16.16, p=0.000$) and retention-test ($F=18.65, p=0.000$) was significant. Thus, the students' post-test and retention test of the atomic related concepts test were significantly affected by the level of the scientific reasoning. The post-hoc analysis for main effect suggests that the transitional level of scientific reasoning group's students performed significantly better than concrete operational group's students (transitional > concrete operational, $p_{(post)}=0.000, p_{(retention)}=0.000$) on post-test and retention-test (Table 3).

Scientific Reasoning test

Table 4 presents the descriptive statistics of the pre-, post-, and retention of the scientific reasoning test. The experimental group has a higher mean score on the pre-, post- and retention-test than the control group.

Two-factor MANCOVA was conducted to examine the effects of instructional approaches and scientific reasoning levels using post-test and retention of scientific reasoning test scores as the dependent measures, and students' pre-test scores as the covariate. Table 5 summarizes the results of the two-factor MANCOVA, instructional approaches has a statistically significant effect on the performance of posttest and retention test of the scientific reasoning test (Wilk's $\Lambda=0.93, p=0.001$). Therefore, the following main effect for the three levels of learning process was performed.

First, one-factor MANCOVA was performed to examine the effect of instructional approach factor on both

post-test and retention-test, as shown in Table 6. One-factor MANCOVA shows a significant effect for instructional approaches (Wilk's $\Lambda=0.91, p=0.001$). Then univariate F (one-factor ANCOVA) was performed to independently examine the effect of the instructional approaches on post-test and retention test. It indicated that a significant effect for instructional approaches on retention-test ($F=12.29, p=0.001$) was significant. Thus, the students' retention test achievements were significantly affected by the instructional approach. The post-hoc analysis for main effect suggests that the web-based instructional group performed significantly better than conventional group (web-based instruction > conventional instruction, $p_{(\text{retention})}=0.001$) on retention-test (Table 6).

Discussion and Conclusions

This study is to report a web learning project was developed based on the Dual Situated Learning Model (DSLMM) and scientific reasoning theories in order to promoting middle students' concepts construction and reconstruction involving atom and developing their scientific reasoning. The study examines the effectiveness of the web-based DSLMM and scientific reasoning on students' conceptual construction and reconstruction involving atomic related concepts and their scientific reasoning, as well as the comparison of students' level of scientific reasoning with students learning in a traditional lecture-based context. This study evidences that students achieve an overall successful conceptual construction and reconstruction involving atomic related concepts. Moreover, these students outperform those who receive lecture-based lessons. In addition, students with higher level of scientific reasoning (transitional) performed better than lower level of scientific reasoning (concrete operational) students on the atomic related concepts test. About the scientific reasoning scores, it indicated that students who received DSLMM with scientific reasoning web-based instruction perform better than traditional lecture-based group on the retention test.

The effectiveness of web-based courses is one of the major interests of researchers and a critical concern of educators who plan to develop or employ web-based lessons since the WWW is a new arena for delivering education. Most of the previous studies are carried at a higher education level, and their findings discord to each other. Some suggest no difference in test scores between web-based and traditional format courses, but students gain more confidence with computers in a web-based course (Leasure *et al.* 2000), others find students enroll in a web-based course perform inferior to conventional students in final exam (Wang & Newlin 2000), and still others indicate an apparent increase in satisfaction on web-based courses (Katz & Yablon 2002). None of the studies we review which are conducted at higher education level claims a superior cognitive learning outcomes in a web-based course than in a traditional format course. However, due to these literatures only have minimal description about the design of the websites, especially in their technological and pedagogical considerations; it is difficult to infer what the main reasons are causing the failure in students' cognitive learning outcome.

We grant that DSLMM and scientific reasoning are an important affective factor facilitating students

constructing atomic related concepts learning outcomes and their scientific reasoning.

In sum, the WWW possesses many unique characteristics which may serve a variety of educational purposes. The authors of this article argue that educational theories should come into play in the construction of educational websites in order to make the functions of the WWW fully and appropriately displayed for achieving educational purposes. In addition, the effectiveness of the web-based lessons should be empirically examined. This study embraces the DSLM and scientific reasoning to the construction of the atomic related learning website. DSLM, the development of which is based on theoretical perspectives as well as empirical evidences, considers influential factors concerning science learning and formulates a serial of stages to facilitate scientific conceptual construction and reconstruction in students. We have evidenced encouraging learning effectiveness in students.

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