The learning effect of modeling ability instruction

Shu-Nu CHANG

The College of Liberal and General Education, Aletheia University, TAIWAN

E-mail: shunu@ms3.url.com.tw

Received 10 Sept., 2008
Revised 16 Dec., 2008

Contents

Abstract

To achieve the goal of scientific literacy, besides conveying science and technology concepts, cultivating students' modeling ability has become important. However, in-service teachers face the difficulty that their teaching load increases while they are still bound by limited teaching hours. Teachers may know of modeling ability, life related content and hands-on activities which are all important and beneficial for science learning; however, they very often find it is hard to engage all these methods into their limited teaching hours. Therefore, the purpose of this study is to develop an efficient method of instruction based upon the frameworks of cognitive apprenticeship and modeling ability to promote students' modeling ability and scientific concept regarding battery. A topic oriented instructional design has been adopted to develop a four-lesson instruction (200 minutes in total). There were 149 non-science majors from three classes invited to participate in this study. They were randomly assigned different instructions, and students' performances were evaluated by three kinds of tests: the general modeling ability test, concept tests and context-based modeling tests. The results indicate cognitive apprenticeship and modeling ability instruction could significantly improve students' modeling ability and also enhance their learning regarding the concept of the battery. However, it is remarkable to point out that, "modeling ability instruction" and the "video lab" provided in this study play the crucial roles. The implication of this study is also discussed.

Keywords: Modeling, model, cognitive apprenticeship, concept of battery

Introduction

In the past decades, model and modeling have been recognized as an important medium of scientists' inquiry, teachers' teaching, and students' learning about the sciences. In the process of learning and teaching science, models are important representation and tools (e.g., Gilbert & Boulter, 1998a, 1998b; Grosslight, Unger, & Smith, 1991; Harrison & Treagust, 2000; Justi & Gilbert, 2002; Justi & van Driel, 2006). Scientific model and modeling processes could also make students develop higher order scientific thinking and working, such as developing meta-cognition to understand the inquiry process in science community, getting familiar with the development and construction of knowledge and individually reflecting on the understanding of scientific knowledge (Clement, 1989; Coll, France, & Taylor, 2005). It is also revealed that students can transfer the modeling ability to their science learning and inquiry, through modeling instruction (Schwarz & White, 2005), and they are able to distinguish the relationship between macro-phenomenological level and micro-phenomenological level (Ergazaki, Komis, & Zogza, 2005). Model and modeling competence is deemed an important part of scientific literacy as well (Gilbert, Boulter, & Elmer, 2000).

The goal of scientific literacy is to help individuals to live better in the current science and technology-oriented society, and to achieve the goal of scientific literacy to promote students' and citizens' learning interests, understanding and respect for sciences; in order to do so, it needs to be more emphasized on the instructional design and the evaluation of science learning (Aikenhead & Ryan, 1992; Champagne & Newell, 1992; Jenkins, 1992; Laugksch, 2000; Laugksch & Spargo, 1996). How to make students understand the scientific concepts, and meanwhile, also possess modeling ability? A good learning effect on engaging scientific concepts with daily life phenomenon and hands-on activity have been disclosed (Chang & Chiu, 2005). However, in-service teachers very often mention the difficulty of teaching with limited time for each lesson, and this is the reason why they could not add too much life related content to the scientific concepts or spend time in inducing students' learning interests and/or modeling ability via hands-on activities. Therefore, how to help teachers teach in a more efficient and fruitful way becomes increasingly important. The basic idea of this study is to develop a "modeling ability instruction" to promote students' science learning and modeling ability.

Based upon the statements above, the purpose of this study is to investigate the learning outcome of the instructional design embedded the theories in regard to "modeling" and "cognitive apprenticeship" to promote students' modeling ability and understanding of the scientific concepts about the battery. The importance of model and modeling in science education is going to be presented, and also the framework regarding modeling ability is delineated. Moreover, the effect of embedding the theory of cognitive apprenticeship in teaching from the former research is described.

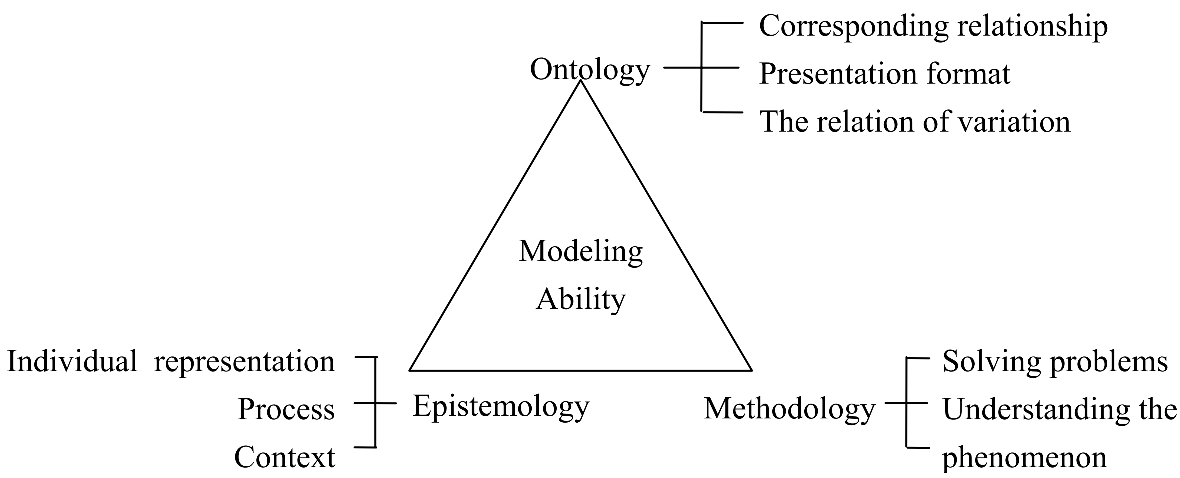
Model and modeling in science learning

It has been revealed that students can perform better when they perceive more knowledge about models (Harrison & Treagust, 2000; Hodson, 1993). Besides helping science learning, visual models are mentioned to help students' ability to create dynamic mental models (Velázquez-Marcano, Williamson, Ashkenazi, Tasker, & Williamson, 2004). In addition, modeling instruction has been revealed to correct students' misconceptions (Metcalf & Tinker, 2004). According to the advantages found from the literature, in this scienceand technology-developing century, cultivating students' modeling ability needs to be taught. Therefore, in this study, developing modeling ability instruction for promoting learners' modeling ability is a goal, and the instruction is anticipated to enhance learners' scientific concepts. While teaching the challenging topics of electricity, light, and so on, Slotta and Chi adopted ontology training before teaching scientific concepts, and the results revealed that students could learn about electric current far better after ontology training (Slotta & Chi, 2006). In this study, a similar hypothesis is developed; students could learn better about scientific concepts after modeling ability instruction. Both modeling ability framework and the theory of cognitive apprenticeship are considered in developing modeling ability instruction.

The framework of modeling ability

This study was a sub-project of a two-year project jointly funded by the National Science Council (NSC 95-2511-S-156 -001-MY2). One of the main targets of the join project is to develop a questionnaire for evaluating students' modeling ability. Three dimensions to the modeling ability include ontology (Chou, 2007), epistemology (Wu, 2007) and methodology (Chiu, 2007). The essence of these three dimensions are that individual needs to know (1) Ontology: what is the model and modeling? (2) Epistemology: how to know the model and modeling? (3) Methodology: how to manipulate the model or create models to learn concepts or solve problems? Figure 1 shows the detailed description. For ontology, the learners need to know that the model could have a corresponding relationship and present the format and relation of variation in regard to scientific concepts. In terms of epistemology, learners learn models and modeling through individual representation, the process of developing knowledge, and the specific context in which to present scientific phenomenon. Through methodology, learners can build up the modeling ability to solve problems, understand the phenomenon, and connect and develop the mental models. We could say modeling is a complex process (Halloun, 1996). A total of 46 Likert scale items were developed to evaluate students' "general" modeling ability (meaning without any specific scientific concept involved into each item) based upon the framework of modeling ability, and adapted to investigate students' improvement of modeling ability in this study. The three dimensions of modeling ability are also embedded into the instructional design of this study. The items on the questionnaire are presented by Chiu (2007), Chou (2007) and Wu (2007).

Figure 1. *The framework of modeling ability (Chiu, 2007).*



Besides the foundation regarding the general modeling ability questionnaires, mentioned above, it is also important to know whether students could apply their modeling ability in a specific context. Hence, in this study, a context-based modeling ability test was developed. Halloun points out that modeling is a complex process and it includes identifying the problem, model selection, model construction, model validation, model analysis, model deployment, model application and model re-development or re-construction (1996). In this study, these eight dimensions are considered into the design of the context-based modeling ability test, mainly focus on investigating whether students could model their own models. The detail ideas of developing this test are presented in the latter section of methods.

The learning effect on cognitive apprenticeship

The idea of apprenticeship has been taken as a kind of teaching method for a long time, and cognitive apprenticeship has been accepted as a well-structured and comprehensive teaching theory. The theory of cognitive apprenticeship was developed by Collins, Brown and Newman (1989). It represents an ideal teaching environment which hopes to guide students learning through experiencing the process of experts dealing with complex tasks. Its purpose is to promote students' self-learning and application ability. The main feature of adopting cognitive apprenticeship is to explicitly understand experts' problem solving process and to let students learn through observation. It is revealed that students could develop more learning strategies via experts' demonstration (Graeber, Neumann, & Tergan, 2005). Cognitive apprenticeship emphasizes learning in an authentic environment for achieving learners' deep understanding about concepts (Collins, Brown, & Newman, 1989). Additionally, cognitive apprenticeship provides novices the opportunity to observe what experts' doing and thinking and also makes learners obtain guidance from the experts. Cognitive apprenticeship focuses on making students actively construct their own knowledge through experts' modeling process and teaching behavior; meanwhile, it also promotes students' internal motivation via the authentic environment and collaboration experiences (Graeber et al., 2005). In sum, cognitive apprenticeship fits the environment for teaching and learning about the complex skills and concepts (Chiu, Chou, & Liu, 2002; Tilley, 2001).

In terms of the framework of cognitive apprenticeship, there are four dimensions considered in this learning environment: content, pedagogical methods, the sociology of learning, and the sequencing of learning activities. Namely, a good learning environment needs to consider these four dynamically interactive dimensions . The detailed points for each dimension are described in Table 1.

Table 1. *The characteristics for each dimension (Collins et al., 1989).*

Dimensions	Characteristics
Content	Domain knowledge Heuristic strategies Control strategies Learning strategies
Pedagogical methods	Modeling Coac hing Scaffolding and fading Articulation Reflection Exploration
Sociology of learning	Situated learning Culture of expert practice Intrinsic motivation Exploiting cooperation Exploiting competition

Sequencing of learning activities		Increasing complexity Increasing diversity Global before local skills

After cognitive apprenticeship theory was considered by Collins et al. in 1989, more recently many researchers have adopted this theoretical framework to conduct studies with good results. Based upon the significant effect on the past research results, cognitive apprenticeship theory is adopted in modeling ability instruction to teach and promote students' modeling ability and their understanding of scientific concepts.

Research purpose and research questions

According to the theoretical background depicted above, the purpose of this study is to investigate the learning outcome of modeling ability instruction based upon the theories regarding modeling ability and cognitive apprenticeship (CA). Three main research questions are investigated in this study, which are: (1) whether the **general modeling ability** could be enhanced by CA and modeling instruction; (2) whether the **learning outcome of scientific concepts** could be improved by CA and modeling instruction; (3) whether the **context-based modeling ability** could be increased by CA and modeling instruction.

Methods

According to the goal of scientific literacy, it is important to make non-science majors understand and appreciate science and technology. This study aimed for promoting non-science majors' modeling ability and understanding of scientific concepts. The concept of the battery was taught in the course, so the concepts of battery were embedded in the modeling ability instruction. The quantitative method was chosen to to disclose students' learning outcomes regarding modeling ability and scientific learning in this paper. In this section, the participants' background, instructional design, instruments developed to evaluate the students' learning outcomes and data analysis are all adopted in this study are described.

Participants

A total of 149 non-science majors were invited to participate in this study. They were composed of three different classes from three different departments in the International Trade Department (62 students), the Accounting Department (57 students) and the Applied Japanese Department (30 students). The participants were all freshmen who joined an 18-week course called the Introduction of Natural Sciences, which was a topic-oriented designed course and the goal of the course was to learn about sustainability initiated by The College of Liberal and General

Education. The battery was one of the topics in this course. Three classes were randomly assigned to receive different instructional design methods which included: (1) CA + modeling ability instruction (62 students), (2) modeling ability instruction (57 students), and (3) control group (30 students). The instructional design is depicted in detail as follows.

Instructional design

The hypothesis of this study is that students could learn scientific concepts better after modeling ability instruction. Therefore, one experimental group (the modeling ability instruction group) was taught about scientific concept of battery via a video lab after introducing the framework of modeling ability. In addition, since CA has been known as a good instruction method for developing learners' ability, all of the dimensions of CA were embedded in the modeling ability instruction in another experimental group (CA + modeling ability instruction) to see whether CA could enhance learners' learning outcomes.

Since the course chosen to use in this study was a topic-oriented designed course, the instructional design for each topic was limited to a two-week long period of 200 minutes (four lessons in total). Hence, the three invited classes all experienced the 200 minutes of instruction in this study. The other three classes were randomly assigned to receive three different instructional designs, which were: (1) CA + modeling ability instruction, (2) modeling ability instruction, and (3) control group. The basic idea for **CA instruction** was to consider the characteristics of the four dimensions presented in Table 1 to help teach the concept of the battery. Regarding the modeling phase of the pedagogical methods in the theory of CA, since there is no science lab at the university, students watched a *"video lab"* showing a female scientist conducting an experiment of constructing a volt battery in a real lab. Coaching, scaffolding articulation, reflection and fading, and exploration were all embedded into the instructional design in the CA + modeling instruction group. The design of **modeling ability instruction** was based upon the framework of the three dimensions of modeling ability containing epistemology, ontology and methodology. Learners were presented the meaning and provided examples for each dimension in class.

Above all, regarding CA + modeling ability instruction, students received CA instruction and also modeling ability instruction meanwhile. However, students in the modeling ability instruction group were taught using modeling ability instructionin addition to the video labwhich lacked the modeling phase of CA theory. In the **control group**, the instruction was only to convey the concept of the composition of the volt battery by PowerPoint without any video and modeling ability instruction. Due to ethical concerns, a compensatory instruction was designed for the control group. That is, after finishing the whole instruction and evaluation, the control group students had an opportunity to watch the video lab and also learn about modeling ability. The detailed content of the instructional design is presented in Appendix I. As mentioned, this study was one subproject of a joint project. The instructional design was validated by the three other principle investigators in this joint project before teaching occurred.

Instruments

Since the purpose of this study is to develop modeling ability instruction to promote students' modeling ability and scientific concepts of battery, three kinds of instruments were adopted to evaluate students' performance including the tests of: (1) general modeling ability, (2) concepts of battery, and (3) context-based modeling ability. In terms of general modeling ability, a Likert scale questionnaire was developed by other subprojects (Chiu, 2007; Chou, 2007; Wu, 2007). There are two sets of open-ended items developed for pre- and post-tests to evaluate participants' learning outcomes on the concept of the battery (see Appendix II as concept tests), which were developed in this study. Besides the general modeling ability questionnaires used in this study, two sets of open-ended, context-based modeling test items were created by this study as pre and post-tests, to evaluate participants' modeling ability in a specific context (see Appendix III as the context-based modeling tests). Global warming is the specific context designed for this context-based modeling test. The overall research design is presented in Table 2. To analyze the learning effect of the different instruction methods, the data collected from those instruments were analyzed further. Also, all the instruction was videotaped.

Table 2. *The overall research design of this study*

Designs / Groups	Pre-test	Instructions	Post-test
I	♦ General modeling ability questionnaire ♦ Concept test I ♦ Context-based modeling test I	CA + Modeling ability instruction	♦ General modeling ability questionnaire ♦ Concept test II ♦ Context-based modeling test II
II		Modeling ability instruction	
III		Control group	

Data analysis

According to the three kinds of instruments adopted in this study, students' data regarding pre and post-tests were all collected. General ability questionnaires included 46 Linkert scale items and five scales for each item. In each item, is one to five points from very much disagree to very much agree. Each of pre and post concept test had 10 scores in total. Regarding context-based modeling tests, students could get a full of 4 scores for each test I and II.

In this paper, only the quantitative data is presented. ANCOVA analysis (SPSS 11.0) was used to analyze students' performance of general modeling ability, concepts of battery and context-based modeling ability after three different instruction methods (CA + modeling ability instruction, modeling ability instruction, and control group). Furthermore, the Scheffe post-hoc test was conducted to understand the significance among different instructional designs after teaching.

Results

Based upon the three main research questions investigated in this study, all the learning outcomes revealed that CA + modeling ability instruction could improve students' modeling ability, in terms of general perspective or context-based. Besides, the concept test also showed the results of highly increased enhancement after CA + modeling ability instruction. However, one remarkable result disclosed that students' performance regarding general modeling ability, concept learning and context-based modeling ability were all improved significantly in the group receiving modeling ability only instruction. This discovery brings us hope of cultivating students modeling ability by a simple and efficient modeling ability instruction. The detailed outcomes are presented as follows.

The performance of general modeling ability between different instructional designs

There are three dimensions embedded in general modeling ability questionnaires, which include ontology, epistemology and methodology. Regarding the results from the three different instructional designs, it was discovered that all three groups of students had no difference in terms of these three dimensions of general modeling ability before instruction, but performances were all enhanced significantly after instruction. From the ANCOVA analysis, it was revealed a significant effect for different instructions with regard to ontology (F [2, 145] = 7.533, $p < .05$), epistemology (F [2, 145] = 16.147, $p < .05$) and methodology (F [2, 145] = 9.199, $p < .05$). The detailed result is presented in Table 3.

Moreover, a Scheffe post-hoc test indicated that students in the both groups of CA + modeling ability and modeling ability only instructions did significantly better than the control group ($p < .05$) in all three dimensions of general modeling ability. However, there were no significant differences between the CA + modeling ability and the modeling ability only instructions in all dimensions of ontology (p = .975), epistemology (p = .784) and methodology (p = .357) (Table 4).

Table 3. *The results of pre and post-tests of the general modeling ability test from different instructions.*

Three dimensions of general modeling ability	**Three different instructions**	**Mean**		**df 1**	**df 2**	**F value**	**Sig.**
		Pre-test	**Post-test**				
Ontology	CA + modeling ability	3.01 (S.D.=0.30)	3.31 (S.D.= 0.36)	2	145	7.533	0.001*
	Modeling ability	3.06 (S.D.=0.63)	3.30 (S.D.= 0.34)				
	Control	2.96 (S.D.=0.31)	3.02 (S.D.= 0.38)				
Epistemology	CA + modeling ability	3.02 (S.D.=0.27)	3.41 (S.D.= 0.40)	2	145	16.147	0.000*
	Modeling ability	2.95 (S.D.=0.33)	3.35 (S.D.= 0.42)				
	Control	2.96 (S.D.=0.38)	2.29 (S.D.= 0.68)				
Methodology	CA + modeling ability	3.22 (S.D.=0.29)	3.48 (S.D.= 0.38)	2	145	9.199	0.000*
	Modeling ability	3.11 (S.D.=0.33)	3.37 (S.D.= 0.43)				
	Control	3.14 (S.D.=0.35)	3.13 (S.D.= 0.42)				
* The mean difference is significant at the 0.05 level.							

Table 4. *The post-hoc analysis of students' performance from the post-test of general modeling ability among three different instructional groups*

Three different instructions		**Three dimensions of general modeling ability**		
		Ontology	**Epistemology**	**Methodology**
CA + modeling ability	Modeling ability	0.975	0.784	0.357
	Control	0.001*	0.000*	0.001*
Modeling ability	CA + modeling ability	0.975	0.784	0.357
	Control	0.003*	0.001*	0.028*
Control	CA + modeling ability	0.001*	0.000*	0.001*
	Modeling ability	0.003*	0.000*	0.028*
* The mean difference is significant at the 0.05 level.				

Concept test performance between different instructional designs

In terms of the concept test, it was disclosed that all three groups of students had no difference before instruction, but the performances were all highly improved after instruction with the significant differences between the groups. From the ANCOVA analysis, it showed a significant effect for different instructions for the concept test (F [2, 145] = 21.593, $p < .05$) (Table 5.) Besides, a Scheffe post-hoc test indicated students in the both groups of CA + modeling ability and modeling ability only instructions did significantly better than the control group ($p < .05$). Still, there was no significant difference between CA + modeling ability and modeling ability only instructions ($p = .314$) (Table 6).

Table 5. *Pre- and post-test results of the concept test from three groups of students*

Three different instructions	**Mean**		**df 1**	**df 2**	**F value**	**Sig.**
	Pre-test	**Post-test**				
CA + modeling ability	1.97 (S.D.= 1.36)	7.16 (S.D.= 1.89)	2	145	21.593	0.000*
Modeling ability	2.02 (S.D.= 0.88)	7.58 (S.D.= 1.12)				
Control	1.87 (S.D.= 0.57)	5.40 (S.D.= 1.10)				
* The mean difference is significant at the 0.05 level.						

Table 6. *The post-hoc analysis of students' performance on concept tests among three different instructional groups*

Three different instructions		**Sig.**
CA + modeling ability	Modeling ability	0.314
	Control	0.000*
Modeling ability	CA + modeling ability	0.314
	Control	0.000*
Control	CA + modeling ability	0.000*
	Modeling ability	0.000*
* The mean difference is significant at the 0.05 level.		

The performance of the context-based modeling ability between different instructional designs

Regarding the performance of the context-based modeling ability from the results, it was indicated that all three groups of students had no difference before instruction, but the performance was all significantly better after instruction. The ANCOVA analysis pointed out a significant effect among different instructions from the context-based modeling test (F [2, 145] = 5.383, $p < .05$) (Table 7.) Besides, a Scheffe post-hoc test displayed that those students in the both groups of CA + modeling ability and modeling ability only instructions performed significantly better than the control group ($p < .05$). Yet, no significant difference between CA + modeling ability and modeling ability only instructions ($p = .695$) (Table 8). Besides, most students still lack the context-based modeling ability after modeling ability instruction.

Table 7. *Pre- and post-test results of context-based modeling ability among three groups of students*

Three different instructions	**Mean**		**df 1**	**df 2**	**F value**	**Sig.**
	Pre-test	**Post-test**				
CA + modeling ability	0.84 (S.D.= 0.79)	1.47 (S.D.= 1.04)	2	145	5.383	0.006*
Modeling ability	0.67 (S.D.= 0.81)	1.32 (S.D.= 1.07)				
Control	0.77 (S.D.= 0.63)	0.77 (S.D.= 0.50)				
* The mean difference is significant at the 0.05 level.						

Table 8. *The post-hoc analysis of students' performance on context-based modeling test among three different instructional groups.*

Three different instructions		Sig.
CA + modeling ability	Modeling ability	0.695
	Control	0.006*
Modeling ability	CA + modeling ability	0.695
	Control	0.046*
Control	CA + modeling ability	0.006*
	Modeling ability	0.046*
* The mean difference is significant at the 0.05 level.		

Conclusions and discussions

From the results, it is revealed that non-science majors performed better after CA + modeling ability instruction and modeling ability only instruction, which both had significant difference from the control group. The good learning outcomes were based upon the evaluation regarding the concept of the battery, the general modeling ability questionnaire regarding the three dimensions of ontology, epistemology and methodology and the context-based modeling ability about global warming.

In the current science and technology-oriented society, conveying new scientific concepts and modeling competence are both the important aspects in achieving scientific literacy (Aikenhead, 1994; Gilbert et al., 2000; Halloun, 1996; Harrison & Treagust, 2000; Laugksch & Spargo, 1996). In this study, an efficient instructional design based upon CA and modeling ability was conducted and showed the good learning effect on not only students' understanding of the concepts of battery, but also the knowledge of the model and modeling. A 200 minute topic-oriented instruction could really solve the problem of limited teaching hours which teachers may meet in school. The discussions and implications of this study are delineated as follows.

Modeling ability instruction is enough?

From the results, it is interesting to discover that there was no significant difference between students' performance on concept tests, general modeling ability and context-based ability tests, in the two instructional design groups of CA + modeling ability instruction and modeling ability only instruction. On one hand, this result tells us that to increase students' modeling ability, we could focus on modeling ability instruction, and make in-service teachers feel a bit released from cultivating students' higher order thinking skills accompanying scientific concepts in limited teaching hours. Achieving good learning outcomes within short teaching hours is also revealed in Slotta and Chi's study (2006), which proved that students could understand challenging topics like electric current better with brief ontology training; and in that study, it only took around two hours in total instruction time. In this study or Slotta and Chis's study, both revealed that teaching hours is not a main focus of helping students learn better, but the instructional design is the key feature.

On the other hand, regarding the concepts of the battery were enhanced significantly in modeling ability only instruction; therefore, we need to seriously consider whether the concepts of battery conveyed in this study were simple, including the compositions and their functions of battery and not the complex scientific concepts or profound skills which need a long-term cultivation in a CA environment. This point corresponds to the idea in which Tilley indicated that CA fits the environment for teaching and learning about the complex skills and concepts (Tilley, 2001). Namely, if teachers want to improve students' learning with regards to some complex concepts like chemical reaction (Chiu et al., 2002), it is essential to embed CA is in instruction. In addition, in terms of the low score on context-based modeling ability after instruction, as science educators we ought to endeavor to cultivate students' modeling ability in specific science contexts.

The "video lab" is beneficial?

Engaging scientific concepts with life related and hands-on activity is found to be a critical factor to enhance learning interests in school education (Chang & Chiu, 2005). However, teachers very often mention the limited teaching hours in whichthey have to convey profound scientific conceptsmake them feel helpless; it often costs a lot of time in preparing experiments for students. The difficulty about embedding a hands-on activity for non-science major students to learn scientific concepts has also existed for long time, particularly at universities which are without any science related departments (not to mention letting students work in real labs). Therefore, a videotaped experiment to convey the concepts of the battery , whichalso shows the process of constructing the battery, is provided as a video lab in this study. From the results of concept tests and modeling ability tests, it reveals the good effect on students' learning. Meanwhile, the video lab not only enlightened students' modeling competence by showing the models of the battery, but it also presented the modeling process to show how expert thought constructed the battery model. The idea of the video lab fits the main feature of adopting cognitive apprenticeship through externalizing the process of experts' thinking, and by letting students learn and think by observing it (Graeber et al., 2005). The most important thing is that teachers could save a lot of preparation time by using the video lab. Again, the concepts chosen to use in the video lab need to be well considered, and the retention effect needs to be investigated in the future.

In conclusion, a 200- minute topic-oriented instruction has an effect on achieving the goal of the scientific literacy though conveying the scientific concepts and cultivating modeling ability. The critical point of the instruction design is the **modeling ability instruction**. In addition, the presence of a video lab not only demonstrates good teaching materials and decreasing teachers' teaching load, but could also represent the modeling phase of CA in the group of CA + modeling ability instruction. There is a Chinese old saying from Confucius that teaching students should be in accordance with their aptitude, and in this study, a similar ideas is also expressed that conveying concepts should be in accordance with their attributes. Although cognitive apprenticeship has been found to be a a good teaching environment, not every concept should be taught with it; for instance, in this study, non-science majors just need the modeling ability instruction and the video lab to learn the concepts of battery and also to promote their modeling ability.

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Appendix I: Instructional design

Time-line	Modeling group	Modeling + CA group	Control group
30 mins	Pre-test • General modeling ability questionnaire • Concept test I • Context-based modeling testI	Pre-test • General modeling ability questionnaire • Concept test I • Context-based modeling test I	Pre-test • General modeling ability questionnaire • Concept test I • Context-based modeling test I
40 mins	Instruction • Teaching the topic of battery by ppt. + Video lab • Model and modeling instruction • Classroom discussion • Decide the presentation topics	Instruction • Teaching the topic of battery by ppt. + Video lab (*with modeling and scaffolding of CA) • Group discussion (why the flashlight doesn't work?) (* with scaffolding, fading and reflection of CA) • Decide the presentation topics (* with exploration and reflection of CA)	Instruction • The topic of battery (ppt. only) • Classroom discussion
30 mins	Post-test • General modeling ability questionnaire • Concept test II • Context-based modeling test II	Post-test • General modeling ability questionnaire • Concept test II • Context-based modeling test II	Post-test • General modeling ability questionnaire • Concept test II • Context-based modeling test II
60 mins	• Oral presentation (10 mins/per group)	• Oral presentation (10 mins/per group) • Peer-evaluation (* with reflection of CA)	Compensatory instruction • Teaching the topic of battery by ppt. +

40 mins	• Teacher gives feedback • Delivering the award	• Students share feedback for each presentation • Delivering the award	Video lab • Students share the feedback about video and ppt. instruction

Appendix II: concept tests

Concept test I

How much do you know about the battery?

Please answer the questions below.

1. What are the basic compositions of a battery?

Ans: ____

2. If you know that copper is more active than silver, which metal should be used as a positive pole and a negative pole.

Ans:____

positive pole:______; negative pole: ______.

3. What are the categories of batteries?

Ans:____

4. Please provide two materials from your life. Which can be used as electrolyte?

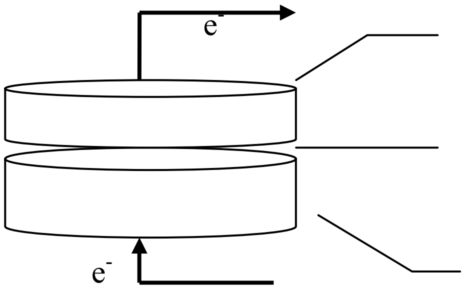
Ans: ____

Concept test II

Do you know more about the battery now?

Please fill your answers into the blanks for each question.

1. The figure below is the diagram of Volta battery. Please fill in the name of each composition (from question number 1-3) and the suitable metals for each part (copper or silver).



(1)__________ ; metal : ________

(2)__________

(3)__________ ; metal : ________

2. There are three kinds of batteries. Please describe the differences among them.

Ans: ____

3. (1) Please explain the function of the electrolyte in a battery. (2) Please provide one material from your life that can be used as electrolyte.

Ans: ____

Appendix III: context-based modeling tests

Context-based modeling test I

Following the serious problems generated by global warming, many researchers start investigating the factors that may influence the raise of global temperature. The data shown in the table below are researchers' results. Please answer the questions as follows.

A.D. / Composition	1210	1420	1670	1850	1940	2003
CO_2 (ppm)	200	255	225	260	280	290
CH_4 (ppb)	350	410	380	440	480	485
Temp. of South Pole (°C)	−6	−2	−4	−3	+0	+1

Q1. Please draw a diagram (like curve, column, pie diagrams, and so on) to represent the relationship of the three compositions above (CO_2, CH_4 and Temp. of South Pole).

Q2. According to the diagram you drew in Q1, please explain the relationship of the three compositions above (CO_2, CH_4 and Temp. of South Pole).

Q3. According to the data shown in the table above, please provide other points of view, which need to be considered more or improved while dealing with this research.

Q4. According to the relationship of the three compositions (CO_2, CH_4 and Temp. of South Pole), please provide another similar pattern of relation from your life and explain it in detail.

Context-based modeling test II

Following the serious problems generated by global warming, many researchers have started investigating the factors that may influence the raise of global temperature. According to the current results, we know that global warming is caused by green house gases. The data shown in the table below are the different industry-level countries and the gases they produced in 2005. Please answer the questions as follows.

Different gases / Industry-level	Gas A	Gas B	Gas C	Gas D	Other gases
High	45%	10%	35%	5%	5%
Middle	35%	10%	30%	5%	20%
Low	25%	10%	25%	5%	35%

Q1. Please draw a diagram (a curve, column, pie diagrams, and so on) to represent the relationship between the industry-level (high, middle and low) and four gases the three compositions (A, B, C and D).

Q2. According to the diagram you drew in Q1, please explain the relationship between the industry-level (high, middle and low) and four gases the three compositions (A, B, C and D).

Q3. According to the data shown in the table above, please provide other points of view that need to be considered or improved while dealing with this research.

Q4. According to the relationship between the industry-level (high, middle and low) and four gases the three compositions (A, B, C and D), please provide another similar pattern of the relation from your life and explain it in detail.