Enhancing Eight Grade Students’ Scientific Conceptual Change and Scientific Reasoning through a Web-based Learning Program

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ABSTRACT
This study reports the impacts of the Scientific Concept Construction and Reconstruction (SCCR) digital learning system on eighth grade students’ concept construction, conceptual change, and scientific reasoning involving the topic of “atoms”. A two-factorial experimental design was carried out to investigate the effects of the approach of instruction and students’ level of scientific reasoning on their pre-, post-, and retention-Atomic Achievement Test, Atomic Dependent Reasoning Test, and Scientific Reasoning Test. The control group (N=100) received conventional instruction whereas the experimental group (N=111) received an SCCR Web-based course. Results indicate that the experimental group significantly outperformed the conventional group on post- and retention-Atomic Achievement Test and Atomic Dependent Reasoning Test scores, and retention-Scientific Reasoning Test scores. Moreover, students with a higher level of scientific reasoning significantly performed better than students with a lower level of scientific reasoning, regardless of their scores on post- and retention-Atomic Achievement Test and Atomic Dependent Reasoning Test. This study successfully demonstrates that the experimental group students outperformed the conventional group students in the domains of concept construction, conceptual change and scientific reasoning. Moreover, students with a higher level of scientific reasoning were more able to successfully change their alternative conceptions.

Keywords
Conceptual change, scientific reasoning, Web-based learning

Introduction
The unique characteristics of the World Wide Web have led educational researchers and practitioners around the world to regard it as a potential tool for improving teaching and learning. All learning activities, except providing an authentic wet lab experience, seem possible on the Web. Accessing the internet and incorporating the World Wide Web into teaching activities are considered to be fundamental skills for science teachers in the twenty-first century (Didion, 1997).

Tuvi & Nachmias (2001), using taxonomy modified from that of Mioduser, Nachmias, Lahav, & Oren (2000), reviewed 93 Web sites that focused on introducing atomic structures. They found the following similarities: text was clearly the major means to present information; automatic/human and technical/content-based help were present in less than 18%; less than 6% had interactive images, animation or sound; none of those Web sites were inquiry-based; and memorizing was the main cognitive process.

This study clearly indicated that science teaching and learning theories are absent in most of the science Web-based learning programs, that pedagogical considerations are not sufficiently considered in the design of the Web-based learning program, and that the capability of the Web and multimedia is not fully used to enhance students’ science learning. Therefore, this study integrates both Dual Situated Learning Model (DSLM) and scientific reasoning theories to develop a Scientific Concept Construction and Reconstruction (SCCR) digital learning course to facilitate students’ science learning.

More importantly, there is still disagreement about whether Web-based learning or traditional teaching are more effective on students’ achievement and attitude. Many studies suggest no difference in test scores following Web-based and traditional courses. Although students gain more confidence with computer use in a Web-based course (Leasure, Davis, & Thievon, 2000), other studies find that students enrolled in a Web-based course perform worse in a final exam than students educated by conventional instruction (Wang & Newlin, 2000). However, others indicate an apparent increase in satisfaction on Web-based courses (Katz & Yablon, 2002). Therefore, one of the purposes of this study is to determine whether students receiving the SCCR Web-based course perform better than the conventional group in their atomic achievement scores. From the point of view of science educators, we claim that it
is very difficult to bring about conceptual change and scientific reasoning unless the instructional design is based on well-developed conceptual change theories and models. Thus, this study attempts to explore whether students who received SCCR Web-based instruction would outperform a conventionally educated group of students in their conceptual change and scientific reasoning.

Lawson & Weser (1990) did a study to measure pre- to post-instruction change among college students. They found that less skilled reasoners were initially more likely to hold a variety of nonscientific beliefs about life and were less likely to change some, though not all, of those beliefs. However, there is still a lack of study for specific well-designed instruction, including Web-based learning, comparing the performance of students with high and low levels of scientific reasoning in the area of concept construction and conceptual change. Therefore, this study intends to explore whether students with higher levels of scientific reasoning would be more likely to change their alternative conceptions than students with lower levels of scientific reasoning.

**Conceptual Change Model: Dual Situated Learning Model (DSLM)**

Conceptual change has been a major research area of science education over the past two decades (Duit & Treagust, 2003). Research on conceptual change is spurred by the great volume of findings from studies over the past thirty years on students’ alternative conceptions or pre-instructional conceptions about scientific concepts.

In view of the different perspectives of science education researchers (Brown, 1993; Clement, 1991, 1993; Posner, Strike, Hewson, & Gertzog, 1982; Steinberg & Clement, 1997) and of cognitive psychologists (Carey, 1985; Chi, Slotta, & de Leeuw, 1994; Thagard, 1992; Vosniadou & Brewer, 1987) on conceptual change, the author integrates the strengths from both sides to her theoretical construct and has developed the Dual Situated Learning Model (DSLM) (She, 2002, 2004b). The term “Situated learning” means that the design of conceptual change learning events needs to be based on the nature of science concepts and students’ beliefs of science concepts, in order to determine what essential mental sets are needed for constructing a more scientific view of the concepts. Moreover, each dual situated learning event needs to be situated on the prior dual situated learning event in order to help students connect different mental sets. The term “Dual” means that the learning events serve the following three dual functions: considering both the nature of science concepts and students’ beliefs of science concepts; creating dissonance with students’ pre-existing knowledge, and providing a new mental set for them to achieve a more scientific view of the concept; stimulating students’ motivation and challenging their beliefs of the concepts as well as challenging students’ ontological and epistemological beliefs of science concepts.

The author claims that conceptual change can not occur simply by creating cognitive conflict, but that conceptual change needs to provide students with new mental sets in addition to creating dissonance. Creating dissonance with students’ pre-existing knowledge can arouse students’ curiosity and interest, as well as challenging their epistemological and ontological beliefs about scientific concepts. Motivation is embodied in the design and the learning process of a dual situated learning event, which requires students to actively engage in the event prediction, visualize what actually happens and explain why it is different from their prediction, thereby stimulating their curiosity and interest. Providing a new mental set should be the platform upon which knowledge reconstruction can occur. Students must comprehend and believe the new mental set in order for conceptual change to happen. This can be fostered by any type of instructional activity, such as analogy, modeling, discrepant events, and inquiry activities, as long as it provides students with opportunities to visualize what actually happens in order to reconstruct new mental sets. DSLM emphasizes that students should be actively engaged in the conceptual change learning process. All of the preceding criteria should serve as the basis for developing each dual-situated learning event in order for it to be a success. Moreover, the author claims that conceptual change can not happen due only to a discrepant event; the changes need a series of events to increase the success of students’ conceptual change (She, 2002). The number of dual situated learning events required would depend on the number of mental sets that students lack for constructing a more scientific view of the concepts. More importantly, each dual situated learning event should be connected with the others and needs to build upon a prior dual situated learning event.

In order to implement this theory, the DSLM has been transformed into a six-stage learning/instructional model.

**Stage 1: Examining the attributes of the science concept.** This stage provides information about which essential mental sets are needed in order to construct a scientific view of the concept.
Stage 2: Probing students’ alternative science concept, which requires understanding the students’ beliefs concerning the science concept.

Stage 3: Analyzing which mental sets students lack for the construction of a more scientific view of the concept.

Stage 4: Designing dual situated learning events, according to the stage 3 results.

Stage 5: Instructing with dual situated learning events, giving students an opportunity to make predictions, provide explanations, confront dissonance, and construct a more scientific view of the concepts.

Stage 6: Instructing with a challenging dual situated learning event. It provides an opportunity for the students to apply the mental sets they have acquired to a new situation in order to ensure a successful conceptual change.

Application of the DSLM 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), as well as meiosis and mitosis (Tang, She, & Lee, 2005). This study attempts to use the DSLM to design an SCCR digital learning program.

**Scientific Reasoning**

Lawson (2003) indicates that the view of development of advanced reasoning and its emphasis on alternative conceptions leads quite naturally to a theory of science instruction which has the potential to unite two previously competing research traditions in science education. In that study, Lawson discussed the relationship between students’ alternative concepts and reasoning ability. Students need to be aware of their own alternative conceptions and scientific conceptions, together with the evidence and reasoning that bears on the validity of the alternative conceptions, in order to modify their alternative concepts. In other words, they must be able logically to see how the evidence supports the scientific conceptions and contradicts the prior alternatives. Park & Han (2002) assumed that deductive reasoning plays an important role in conceptual change. However, due to various unknown reasons, reasoning is not always activated and used spontaneously in students’ minds in the process of conceptual change. The conceptual change model is based on reasoning and the design of each dual situated learning event requires that students provide explanations. However, DSLM may not be efficient in activating the spontaneous use of scientific reasoning, by students, to cope with conceptual change. Thus this study combines both scientific reasoning and DSLM theories in designing the SCCR digital learning program.

Lawson & Worsnop (1992) again found that the more skilled reasoners in a sample of high school students were less likely to hold pre-instruction misconceptions regarding evolution and special creation. Lawson & Weser (1990) did a further study to measure pre- to post-instruction change among college students and found that less skilled reasoners were initially more likely to hold a variety of nonscientific beliefs about life and were less likely to change some, though not all, of those beliefs. Therefore, one of the purposes of this study is to explore whether students with a higher level of scientific reasoning would be more likely to change their alternative conceptions and hold more correct scientific conceptions.

**Previous Research on Students’ Alternative Conceptions Involving Atoms**

Garnett, Garnett, & Hachling (1995) review previous studies on students’ alternative conceptions for the particulate nature of matter, and specifically point out that some students consider atoms to be alive. Harrison & Treagust (1996) report that high school students view atoms as either visible under a microscope or too small to be seen at all, are not sure whether all substances contain atoms, consider that atoms are alive like cells and can grow and divide, view atoms as balls or spheres but are not sure about the components inside atoms, view the texture of atoms as being most like a hard polystyrene sphere, are not aware of the electron shell or electron clouds, and have a consistent image of atoms as being protected by an outer shell. Lee, Eichinger, Anderson, Berkheimer, & Blakeslee (1993) find similar results about the size of molecules, so that even after instruction, students still believe they can see molecules with a microscope. Lee et al. (1993) show that students believe that atoms are hard. Griffiths & Peterson (1992) report that students tend to believe that all atoms weigh the same, atoms are ball-shaped, there is nothing inside atoms, something exists between atoms, and electrons move within the shell.
Harrison & Treagust (2001) further reported that high school students perceive that there is a large distance between electrons and nucleus and that an atom is mostly space with the majority of its mass in the nucleus. As well, high school students are not able to differentiate between electron shells and electron clouds. Taber (2001) reported that students often have little difficulty in explaining how size increases down the periodic table, as more electron shells are added. The design of the atomic related Web-based learning events in this study considers some alternative conceptions described above to be one of the major sources.

**Purpose**

This study reports the development of the Scientific Concept Construction and Reconstruction (SCCR) digital learning system that was developed based on the theories of the Dual Situated Learning Model (DSLM) and scientific reasoning, and further examines its impact on eighth grade students’ concept construction, conceptual change and scientific reasoning involving the concept of atoms. A two-factorial experimental design was carried out to investigate the effects of the approaches of instruction and the students’ levels of scientific reasoning on their pre-, post-, and retention-Atomic Achievement Test (AAT), Atomic Dependent Reasoning Test (ADRT), and scientific reasoning Test (SRT). The control group (N=100) received conventional instruction, whereas the experimental group (N=111) received the SCCR digital learning course. Students were classified into high and low levels of scientific reasoning ability according to their Scientific Reasoning Test (SRT) scores.

Three goals serve as the guideline for examining the impact of the SCCR. The first is to document that students receiving an SCCR Web-based course perform better than conventional group in their atomic conceptual understanding achievement. The second is to demonstrate that SCCR Web-based instruction can be more effective than conventional instruction in facilitating the experimental group students’ conceptual change as well as scientific reasoning in the “atoms” unit. The third is to confirm that students with higher levels of scientific reasoning ability would be more able to overcome their alternative conceptions than the students with lower levels of scientific reasoning.
Development of SCCR Digital Learning Project

The SCCR project was developed based upon the theories of DSLM and scientific reasoning as the foundation for developing the Web-based learning content. The current SCCR digital learning project includes several units: the electricity unit and buoyancy unit in physics, the atom unit and the combustion unit in chemistry, and the genetics unit in biology. All of the units have been implemented in several middle schools’ science classes and received similar encouraging results. This paper reports an impact of SCCR on students’ learning from one the units in chemistry: atom.

SCCR Digital Learning System Software and Operating Requirement

The SCCR platform was FreeBSD running with an Apache WWW server. The core of the SCCR system was programmed in PHP and Java Applet and JavaScript and it worked with MySQL to efficiently handle extremely large data sets and analytical programs. By using PHP, we can receive user input and process it on the server side, and then dynamically generate the next new pages. We also used the free software Simple Machine Forum (SMF) which is programmed in PHP to build up a discussion forum. To synchronize the data between SCCR and SMF, we rewrote some codes in SMF.

For the authoring interface, there were three main pages (Normal, Advance and Special) and ten different kinds of functional pages (eg. junction, comparisons, correct answer, keyword to multipath, etc.), depending on the nature of the science concept involved and students’ learning progress (Figure 1).

![Figure 2. Students answer and reasoning before and after the web-based dual situated learning events](image)

Characteristics of the SCCR:

Facilitate students’ conceptual change and scientific reasoning

In order to facilitate students’ conceptual change and scientific reasoning, the design of each Web-based dual situated learning event requires students to provide an answer to the driving question, along with their reasons, before proceeding with various activities. In addition to writing down their reasons, students were required to choose the best reasons for what they had written down. The system generated an appropriate HTML page for each
individual student according to the answers and reasons selected before each event. The same driving question was asked again after the event to examine the students’ conceptual change and their reasoning changes. In order to activate students’ use of scientific reasoning, we specifically restructured the process. Students could view their answers and their written reasons before and after events. They could also view the correct answers. We then requested that students justify why they changed or stayed with their original thoughts after the learning events. This process was purposely intended to direct students’ minds to spontaneously become involved in the process of scientific reasoning and conceptual change (figure 2).

Facilitate individualized science learning

A Web-based learning system must not only allow students to navigate between different pages but must also help students better achieve their learning goals. It is also necessary to provide more sophisticated mechanisms that modify the navigation alternatives by a procedure for individual student adaptation. Adaptive learning can offer flexible solutions that dynamically adapt content to fit individual real-time learning needs. Very often, students hold different alternative conceptions or different reasoning patterns. Adaptive learning is therefore included in the design of SCCR to provide students with different learning paths to maximize their science learning.

Adaptive learning to individual student needs is implemented by presenting students with different HTML pages, depending on their prior alternative concepts and their previous reasoning results. The adaptive linking is used to modify the link structure depending on the state of students’ conceptions and reasoning. This leads to the development of an individual course, with a dynamically changing link structure, depending on each individual student’s progress.

Different learning events are provided depending on what alternative concepts and reasoning patterns the students already possesses. Some of the units of SCCR are specifically designed to provide students with different learning events according to the choices of answers and reasons they made regarding either accuracy of concepts and reasoning, and thus further determine which learning pathway the students need to work on.

Design of SCCR content: Unit for Atoms

The design of the Web-based program for the unit on atoms specifically focuses on those students’ alternative concepts of atoms, as found in previous studies (Griffiths & Peterson, 1992; Harrison & Treagust, 1996; Lee et al., 1993). It is clear that students’ alternative concepts of atoms are due to the invisible molecular and dynamic nature of
atoms, so students have difficulty constructing concepts related to atoms. Therefore, the design of this unit on atoms provides students with 2D- and 3D-models to help them develop more scientific views of atomic structure. For instance, students can interact with one of the models. They can then visualize the motion of, and number of electrons in, each shell, or the number of protons and neutrons at the nucleus of the atom (Figure 3). As another example, with the model of chemical reaction, students can see how atoms react with other atoms at the microscopic level.

The design of the unit on atoms is based upon the six stages of DSLM described above. The mental sets which students lacked were categorized into four topics to further develop the following series of four dual situated learning events:

1. Elements and compounds: identify the difference between compounds and elements, and understand how compounds can be separated into elements through chemical means.
2. Atomic structure: concerning the components of atoms and their properties as well as the motion of electrons.
3. Arrangement of electrons and chemical reactivity of elements: understand that the arrangement of electrons in a noble gas is stable because there are eight electrons on the outer shell, and the alkali metals such as sodium and potassium have greater chemical reactivity because there is only one electron at the outer shell of the atom.
4. Atomic and chemical reactions: the nature and number of electron transfers occurring when two different atoms react with each other to form a compound, as well as the relationship between the donating/receiving electrons and the electron arrangement of atoms during a chemical reaction.

Subjects and Procedures

A total of 211 eighth graders participated in this study, recruited from six average-achievement classes of a middle school in Taiwan. One hundred and eleven of the participants received the Web-based DSLM learning (the experimental group) in three classes and the remaining 100 students received conventional lecture-based instruction (the control group) in the other three classes. Based on the students’ scientific reasoning pre-test scores (pre-SRT), the students were further classified as transitional (higher level of scientific reasoning) (N=69) and concrete operational level (lower level of scientific reasoning) (N=142) students. A pretest for AAT was administered to all students before the instruction. The independent t-test on the pretest scores of atomic related concepts showed that the two groups had an equivalent initial ability (t = 1.5, p = .12). All of the students received the AAT, ADRT, and SRT before instruction, after instruction and eight weeks after the instruction.

The mandated class periods for physical science are four class periods per week. The school schedule allocated approximately 12 class periods on the atom unit which included two class periods for laboratory activities. There were a total of ten class periods over four weeks for learning the atom unit, with each class period lasting about 45 minutes. Our study took place over two class periods in the first week of the four-weeks learning of the atom unit, then three class periods in the second week and third week, and two class periods in the fourth week. Both groups of students did the same experiments in their respective laboratory periods.

Students who received the SCCR Web-based learning program learned and interacted with the Web courses individually, so they learned at their own pace. Teachers served as facilitators to provide help if students requested it and the researcher also served as an assistant to help with any problems that arose from using the Web course.

For the conventional group, teachers mainly gave lectures and used the textbook as the primary major method of instruction. Students were mainly passive when receiving knowledge from the teacher and the textbook. The teachers also arranged discussions and did the same experiments in the laboratory for students.

Instruments

Atomic Achievement Test (AAT)

The AAT is a multiple choice diagnostic instrument developed for this study to measure students’ concepts of atom-related concepts before, directly after, and three months after receiving the atom unit of the SCCR digital learning program (Appendix 2). The content validity was established by a panel of eight evaluators, ensuring that the items
were properly constructed and relevant to the atom unit Web-based learning materials we developed. The questions requiring students to use their deeper information processing ability are mainly concerned with the analysis and synthesis. There are nine items for topic 1 and the other three topics each have eight items, for a total of 33 items. Students receive one point for each question they answered correctly, so the highest score is 33. The Cronbach $\alpha$ of the Atomic Achievement Test (AAT) was 0.74 for the pretest, 0.90 for the posttest, and 0.93 for the retention-test.

**Atomic Dependent Reasoning Test (ADRT)**

The ADRT is a two-tier multiple choice diagnostic instrument that was developed for this study to measure the degree of students’ conceptual change involving atom-related concepts before, directly after, and three months after receiving the atom unit of the SCCR digital learning program (Appendix 3). The ADRT requires students to use scientific reasoning to reason and process atom-related concepts in order to answer both tiers correctly. The content validity was established by the same panel of eight evaluators, ensuring that the items were properly constructed and relevant to the atom unit Web-based learning materials we developed. There are eight items for each topic, and each item contains two tiers, with the first tier to check whether students have scientific concepts/or alternative concepts, and the second tier to require students to use scientific reasoning on atom-related concepts. There are 32 items and each item has two tiers. Students need to answer both tiers correctly in order to receive one point, so the highest score is 32. The Cronbach $\alpha$ of ADRT was 0.88 for the pretest, 0.95 for the posttest, and 0.95 for the retention-test.

**Scientific Reasoning Test (SRT)**

The SRT is a two-tier multiple-choice diagnostic instrument that was developed to measure students’ scientific reasoning before, directly after, and three months after receiving the atom unit of the SCCR digital learning program (Appendix 1). The SRT was originally developed by Lawson in 1978 and was modified in 2003. It measures students’ conservation, proportional thinking, identification and control of variables, probabilistic thinking, correlative thinking and hypothetic–deductive ability. There are 12 items, and each item contains two tiers—the first tier for choosing the answer, and second tier for using the thinking ability mentioned above. Students need to answer both tiers correctly in order to receive one point, so the highest score is 12. The Cronbach $\alpha$ of the Scientific Reasoning Test (SRT) was 0.78 which is close to Lawson’s result for the Cronbach $\alpha$.

**Results**

**Atomic Achievement Test (AAT)**

Two-factor MANCOVA was conducted to examine the effects of instructional approaches and scientific reasoning levels using post- and retention-AAT scores as the dependent measures, and students’ pre-AAT scores as the covariate. Table 1 summarizes the results of the two-factor MANCOVA: specifically, instructional approaches (Wilk’s $\Lambda=0.91$, $p=0.000$) and students’ level of scientific reasoning (Wilk’s $\Lambda=0.95$, $p=0.007$) both have statistically significant effect on the performance of post- and retention-AAT. There is no interaction found between instructional approaches and students’ level of scientific reasoning. In short, both the instructional approaches and the level of scientific reasoning have significant impact on students’ performance of atomic achievement.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Wilk’s $\Lambda$</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Multivariate F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test scores</td>
<td>0.79</td>
<td>2</td>
<td>201</td>
<td>26.56 ***</td>
</tr>
<tr>
<td>Group memberships</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructional approaches</td>
<td>0.91</td>
<td>2</td>
<td>201</td>
<td>9.71 ***</td>
</tr>
<tr>
<td>Levels of Scientific Reasoning</td>
<td>0.95</td>
<td>2</td>
<td>201</td>
<td>5.04 *</td>
</tr>
</tbody>
</table>

Note. **$p<0.0001$, *$p<0.001$, *$p<0.01$**

Therefore, the following main effect for the instructional mode and level of scientific reasoning 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 2. One-factor MANCOVA shows a significant effect for instructional approaches (Wilk’s Λ=0.85, p= 0.000). Then univariate F (one-factor ANCOVA) was performed to independently examine the effect of the instructional approaches on post- and retention-AAT. This indicated that the effects for instructional approaches on both post-AAT (F=12.87, p= 0.000) and retention-AAT (F=38.77, p=0.000) were significant. Thus, the students’ post- and retention-AAT were significantly affected by the instructional approach. The post-hoc analysis for the main effect suggests that the Web-based instructional group performed significantly better than the conventional group (Web-based instruction> conventional instruction, p (post)=0.000, p (retention) =0.000) on post- and retention-AAT. In summary, the Web-based group outperformed the conventional group on both post- and retention-performance of atomic achievement.

### Table 2. MANCOVA and ANCOVA of Instructional Approaches and 2-Levels of Scientific Reasoning of Post- and Retention- of Atomic Achievement Test (AAT) Scores

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Wilk’s Λ</th>
<th>Univariate F Post-test</th>
<th>Univariate F Retention-test</th>
<th>Post-hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Approaches</td>
<td>0.85***</td>
<td>12.87***</td>
<td>38.77***</td>
<td>Post: Web-based instruction &gt; Conventional instruction (0.000) Retention: Web-based instruction &gt; Conventional instruction (0.000)</td>
</tr>
<tr>
<td>Levels of Scientific Reasoning</td>
<td>0.92***</td>
<td>6.15*</td>
<td>16.71***</td>
<td>Post: Transitional &gt; Concrete (0.014) Retention: Transitional &gt; Concrete (0.000)</td>
</tr>
</tbody>
</table>

***p<0.0001, **p<0.001, *p<0.01

Second, the same procedures were performed for the effect of the level of scientific reasoning, as shown in Table 2. One-factor MANCOVA shows a significant effect for the level of scientific reasoning (Wilk’s Λ=0.92, p= 0.000). Then univariate F (one-factor ANCOVA) was performed to independently examine the effect of the level of scientific reasoning on post- and retention-AAT. This indicated that there was a significant effect for the level of scientific reasoning on the post-AAT (F=6.15, p=0.014) and retention-AAT (F=16.71, p=0.000). Thus, the students’ post and retention test of the AAT was significantly affected by the level of the scientific reasoning. The post-hoc analysis for the main effect suggests that the transition level of students in the scientific reasoning group performed significantly better than the students in the concrete operational group (transitional >concrete operational, p (post) =0.014; transitional >concrete operational, p (retention) =0.000) on both post- and retention-AAT. In short, students with higher levels of scientific reasoning (transitional) performed better than those with lower levels of scientific reasoning (concrete operational) on their post- and retention-performance of atomic achievement.

### Atomic Dependent Reasoning Test (ADRT)

Two-factor MANCOVA was conducted to examine the effects of instructional approaches and scientific reasoning levels using post- and retention-ADRT scores as the dependent measures, and students’ pre-ADRT scores as the covariate. Table 3 summarizes the results of the two-factor MANCOVA: specifically, instructional approaches (Wilk’s Λ=0.75, p= 0.000) and students’ levels of scientific reasoning (Wilk’s Λ=0.92, p= 0.000) both have statistically significant effect on the performance of post- and retention-ADRT. There is no interaction between instructional approaches and students’ level of scientific reasoning. In short, both instructional approaches and level of scientific reasoning have significant impact on students’ conceptual change. Therefore, the following main effects for the instructional approaches and level of scientific reasoning were performed separately.

### Table 3. Multivariate Analysis of Covariance (MANCOVA) of Post- and Retention- of Atomic Dependent Reasoning Test (ADRT) Scores

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Wilk’s Λ</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Multivariate F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariates</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pre-test scores</td>
<td>0.84</td>
<td>2</td>
<td>199</td>
<td>19.09 ***</td>
</tr>
<tr>
<td>Group memberships</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructional approaches</td>
<td>0.75</td>
<td>2</td>
<td>199</td>
<td>33.92 ***</td>
</tr>
<tr>
<td>Levels of Scientific Reasoning</td>
<td>0.92</td>
<td>2</td>
<td>199</td>
<td>8.37 ***</td>
</tr>
</tbody>
</table>

Note. ***p<0.0001, **p<0.001, *p<0.01
First, one-factor MANCOVA was performed to examine the effect of instructional approach factor on both post- and retention-ADRT. One-factor MANCOVA shows a significant effect for instructional approaches (Wilk’s Λ=0.70, \( p=0.000 \)). Then univariate F (one-factor ANCOVA) was performed to independently examine the effect of the instructional approaches on post- and retention-ADRT. It indicated that the effects for instructional approaches on both post-ADRT (F=82.06, \( p=0.000 \)) and retention-ADRT (F=47.68, \( p=0.000 \)) were significant. Thus, the students’ post- and retention-ADRT were significantly affected by the instructional approach. The post-hoc analysis for the main effect suggests that the Web-based instructional group performed significantly better than the conventional group (Web-based instruction>conventional instruction, \( p_{(post)}=0.000, p_{(retention)}=0.000 \)) on both the post-test and the retention-test. This shows that the Web-based group outperformed the conventional group on the post- and retention-performance of conceptual change.

Second, the same procedures were performed for the effect of the level of scientific reasoning. One-factor MANCOVA shows a significant effect for the level of scientific reasoning (Wilk’s Λ=0.89, \( p=0.000 \)). Then univariate F (one-factor ANCOVA) was performed to independently examine the effect of the level of scientific reasoning on post- and retention-ADRT. It indicated that there was a significant effect for the level of scientific reasoning on both post-ADRT scores (F=22.78, \( p=0.000 \)) and retention-ADRT (F=13.32, \( p=0.000 \)). Thus, the students’ post- and retention-ADRT were significantly affected by the level of the scientific reasoning. The post-hoc analysis for the main effect suggests that the transitional level of students in the scientific reasoning group performed significantly better than the students in the concrete operational group (transitional >concrete operational, \( p_{(post)}=0.000, p_{(retention)}=0.000 \)) on post- and retention-ADRT. This indicated that students with higher levels of scientific reasoning outperformed the conventional group on their post- and retention-performance of conceptual change.

### Scientific Reasoning Test (SRT)

Two-factor MANCOVA was conducted to examine the effects of instructional approaches and scientific reasoning levels using post- and retention-SRT scores as the dependent measures, and students’ pre-SRT scores as the covariate. Table 4 summarizes the results of the two-factor MANCOVA, showing that only instructional approach has a statistically significant effect on the performance of post- and retention-SRT (Wilk’s Λ=0.95, \( p=0.006 \)). There is no interaction between instructional approach and students’ level of scientific reasoning. In short, only instructional approach has a significant impact on students’ scientific reasoning performance. Therefore, the following main effect for the instructional approaches was performed.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Wilk’s Λ</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Multivariate F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test scores</td>
<td>0.79</td>
<td>2</td>
<td>205</td>
<td>27.90 ***</td>
</tr>
<tr>
<td>Group memberships</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructional approaches</td>
<td>0.95</td>
<td>2</td>
<td>205</td>
<td>5.29 *</td>
</tr>
<tr>
<td>Levels of Scientific Reasoning</td>
<td>0.99</td>
<td>2</td>
<td>205</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Note. ***p<0.0001, **p<0.001, *p<0.01

One-factor MANCOVA was performed to examine the effect of instructional approach factor on both post- and retention-SRT. One-factor MANCOVA shows a significant effect for instructional approaches (Wilk’s Λ=0.92, \( p=0.000 \)). Then univariate F (one-factor ANCOVA) was performed to independently examine the effect of the instructional approaches on post- and retention-SRT. It indicates that the effect for instructional approaches on retention-SRT (F=16.06, \( p=0.000 \)) was significant. The post-hoc analysis for the main effect suggests that the Web-based instructional group performed significantly better than the conventional group (Web-based instruction>conventional instruction, \( p_{(retention)}=0.000 \)) on retention-SRT. In short, the Web-based group outperformed the conventional group in the retention-performance of scientific reasoning performance.
Discussion and Conclusions

This study reports a Web-based learning project that was developed based on the Dual Situated Learning Model (DSLM) and scientific reasoning theories in order to promote middle school students’ conceptual change and scientific reasoning ability. This study is a major step from previous Web-based instructional learning programs, as it brings well-developed science learning and pedagogy theories and models into an SCCR Web-based learning program. In addition, personal adaptivity is implemented into the design of SCCR to provide individual students with different HTML pages, depending on each student’s prior alternative conceptions and scientific reasoning results. Moreover, SCCR also develops many unique functions (eg. junction, comparisons, correct answers, keyword to multipath, etc.) for teachers to develop the Web-based learning content to make learning more efficient.

The results of this study show that the students who received a SCCR Web-based learning course significantly outperformed the conventional group of students in both post- and retention-AAT. Many studies suggest that there is no difference in test scores between Web-based and traditional format courses, although students may gain more confidence with computers in a Web-based course (Leasure et al., 2000); other studies find that students in a Web-based course actually perform worse than conventional students in final exams (Wang & Newlin, 2000); and still others indicate an apparent increase in satisfaction from Web-based courses (Katz & Yablon, 2002). The result of AAT adds a positive documentation to the current research that students who receive a Web-based learning course can perform better than a conventional group’s students in their atomic concept construction, especially when the Web-based learning course is effectively designed.

With the ADRT, it shows that students who received SCCR Web-based learning significantly outperformed the conventional group of students in both post- and retention-ADRT. This study definitely demonstrates that combining both the DSLM conceptual change model and scientific reasoning into a Web-based learning program does facilitate the experimental group of students’ conceptual changes involving atomic concepts. Our study demonstrated that students’ conceptual change can be facilitated through a well-designed conceptual change model and scientific reasoning theories.

With the SRT, students who received Web-based learning statistically significant outperform the conventional group of students on retention-SRT. It is possible that since there were only ten class periods over four weeks of instruction, this length of time might be too short to make a very large difference between the two groups in their immediate test. However, it supports the contention that students’ performance of scientific reasoning can be retained after eight weeks of learning from a well designed learning program.

The possible explanation of AAT and ADRT not showing any interaction between the instructional approaches and level of scientific reasoning is that students with a higher level of scientific reasoning perform better on the concept test and conceptual change test than students with a lower level of scientific reasoning no matter which types of instruction they received. It is especially noteworthy that students who had a higher level of scientific reasoning (transitional) performed significantly better than those with a lower level of scientific reasoning (concrete operational) on both post- and retention-AAT. This implies that students with higher levels of scientific reasoning would outperform those with lower levels of scientific reasoning on their atomic concepts construction. Moreover, students with a higher level of scientific reasoning (transitional) performed significantly better than students with a lower level (concrete operational) on both post- and retention-ADRT. Lawson & Weser (1990) conducted a study to measure pre- to post-instruction change among college students. They found that less skilled reasoners were initially more likely to hold a variety of nonscientific beliefs about life and were less likely to change some. This supports our findings. Our result confirms the findings of Lawson & Weser (1990), and further demonstrates that students with higher levels of scientific reasoning ability are more able to overcome their alternative conceptions and make the conceptual change more effectively.

To summarize, this study clearly demonstrates that uniting DSLM and the scientific reasoning theory in a Web-based learning environment promotes the experimental group of students’ atomic concept construction as well as their conceptual change more efficiently when compared with the group of conventionally-instructed students. This indeed provides evidence that using well developed theories and models of conceptual change and scientific reasoning as the basis for developing Web-based instructional materials and learning environment makes a significant difference. In addition, this study further contributes to the field of study by demonstrating that students
with higher levels of scientific reasoning would be more likely to evidence conceptual change and construct more correct scientific conceptions as compared to students with lower levels of scientific reasoning.

The implications are provided by the present study in the following:
1) It is highly suggested that Web-based learning can be successful if the design of the Web-based course is based on a specific learning or pedagogy theory.
2) Students’ successful learning or conceptual change is possible if the design of Web-based learning is based on well-developed learning or pedagogy theories.
3) More empirical studies are needed to confirm the results that students with higher levels of scientific reasoning are more likely to change their alternative conceptions, as well as confirming that specific learning or pedagogy theory-based Web learning can effectively promote science learning.

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References


