Development and Evaluation of SCCR Digital Learning System for improving scientific conceptual change and scientific reasoning

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ABSTRACT

This study is to report the development and evaluation of an adaptive digital learning project – SCCR (Scientific Concept Construction and Reconstruction) which was constructed based on the theories of Dual Situated Learning Model (DSLM) and scientific reasoning. An experimental research design including the Combustion Achievement Test (CAT), Scientific Reasoning Test (SRT) and Combustion Dependent Reasoning Test (CDRT) were applied for both web-based experimental and conventional groups' students before, after, and after sixth week of the research as pre-, post- and retention-test. Results indicated experimental group's students outperform significantly than conventional group's students on both post- and retention- of CAT and CDRT scores. The successful rate of conceptual change ranged from 70 % to 100% for experimental group students for most web-based dual situated learning events. All of these results support students' conceptual change and can be promoted as well as their scientific reasoning ability through SCCR digital learning program.

Significance of the study

Many studies have suggested that there is relationship exist between students' misconceptions and reasoning ability.[4,5,8] They found similar results of students with better scientific reasoning skills would hold less misconceptions and more easily to change their misconceptions. It somehow indicates the potential of linking scientific reasoning with conceptual change.

The author has developed a conceptual change model-Dual Situated Learning Model and has evidenced effective conceptual change in middle school students in the topics of air pressure and buoyancy, thermal expansion, heat transfer, dissolution and diffusion, and meiosis and mitosis [10,11,12,13,14]. "Situated learning" means that the process of conceptual change 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 that this model has two functions in many of its facets. First, conceptual change should be built upon both the nature of science concepts and students' beliefs of science concepts. Second, the conceptual change process should create dissonance with students' pre-existing knowledge, and provide new mental set for them to achieve a more scientific view of the concept, which can be either a revision of the old model or the construction of a new one. Third, the process of creating dissonance needs to both arouse students' motivation and challenge their beliefs of the concepts. Fourth, the process of conceptual change needs to challenge students' ontological and epistemological beliefs of science concepts [10,12,13]. The Dual Situated Learning Model is comprised of the following six major stages that aim to help students restructure their science concepts: (1) Stage 1: Examining the attributes of the science concept. (2) Stage 2: Probing students' misconceptions of the science concept. (3) Stage 3: Analyzing which mental sets the students lack. (4) Stage 4: Designing dual situated learning events. (5). Stage 5: Instructing with dual situated learning events. (6) Stage 6: Instructing with a challenging situated learning event [10,12,13].

The author feels a great potential to enhance students' conceptual change as well as scientific reasoning ability through uniting both scientific reasoning and conceptual change. Though the conceptual change model has existed the ideas of reasoning and the design of each dual situated learning event has requested students to provide explanation, however, it has not examined whether DSLM has any impact on students' scientific reasoning ability yet. According to Park & Han's study [9], indicated that students reasoning is not always activated and used in students' minds in the process of conceptual change, so it may not be efficient for fostering students using scientific reasoning skill. Thus this study is purposely using the DSLM [10, 11, 12, 13, 14] as the basis with stronger scientific reasoning emphasis for developing this web based learning Project.

Tuvi & Nachmias [15], with a taxonomy modified from that of Mioduser et al. [7], 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. These studies indicate the employing of science education learning and pedagogy theory as the bases for developing science web-learning program is really important.

It is because author also believes if students can involve within individualized digital learning environment would be more possible to increase the effectiveness of conceptual change as well as scientific reasoning ability. Therefore, this study attempts to employ the Dual Situated Learning Model (DSLM) and scientific reasoning to the development of a Web-based science learning program in order to facilitate students' knowledge construction and reconstruction of atoms. It is specifically examines whether it can facilitate students' conceptual change as well as scientific reasoning ability.

Veermans et al. [16] have studied the effect of adaptive feedback in comparing pre-defined feedback. The adaptive feedback in comparing pre-defined feedback. The adaptive feedback is designed on the basis of hypotheses and activities made during inquiry process by each learner, whereas, the pre-defined feedback is the same theoretical answer to each student. Result shows that there are no differences in defining the concepts of physics and recalling equation, however, the experimental group improved significantly more in understanding the processes and applying the knowledge in new situations. This indicated that the adaptive learning would promote students deeper leanring.

The DSLM has applied into the classroom for several topics and evidenced successfully fostering students' conceptual change within classroom setting. The limitation of employing DSLM at classroom is not able to provide different students with adaptive learning according to their hold of misconceptions and scientific reasoning patterns. It seems that adaptive web learning very promising for overcoming this limitation. Therefore, we move one step beyond the classroom instruction to the adaptive web-learning approach. It is hoping that SCCR would maximize the efficiency and effectiveness of students' conceptual change and scientific reasoning.

Purpose

This study is to report an adaptive digital learning project – SCCR (Scientific Concept Construction and Reconstruction) was developed based on the theories of Dual Situated Learning Model (DSLM) and scientific reasoning. In addition, to investigate the effects of a SCCR related to "combustion" topic on sixth grade students conceptual change and scientific reasoning. An experimental research design including the Combustion Achievement Test (CAT), Scientific Reasoning Test (SRT) and Combustion Dependent Reasoning Test (CDRT) were applied for both web-based experimental and conventional groups' students before, after, and after sixth week of the research as pre-, post- and retention-test. Moreover, experimental group students' learning of the web-based dual situated learning events (DSLE) were analyzed and yielded the level of scientific reasoning and successful rate of conceptual change to examine the effects of SCCR.

Development of SCCR Digital Learning System

The SCCR project was developed based upon the theories of DSLM and scientific reasoning as the major basis for developing the web-learning content. The Current SCCR digital learning project included several units which are electricity unit and buoyancy unit in physics, combustion unit and combustion unit in chemistry, and genetics unit in biology. This paper reports the impact of students' learning from the combustion unit. The SCCR platform was the FreeBSD running with an Apache WWW server. The core of the SCCR system is programmed in PHP and Java Applet and JavaScript and works with MySQL to handle extremely large data sets and analytical programs efficiently. By using PHP, we can receive users' input and process it on the server side, then dynamically generate the next new pages. We also use 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 rewrite some codes in SMF.

There are two major characteristics of the SCCR is to facilitate students' conceptual change and scientific reasoning and provide dynamic generation of adaptive web-learning content. In order to facilitate students' conceptual change and scientific reasoning, therefore, the design of each dual situated learning event would require students to provide an answer and their reasoning to the driving question before various activities. The same driving question

is asked again after the event to examine the students' conceptual change as well as their reasoning changes. In order to activate students using scientific reasoning, therefore, we specifically restructure the process to let students viewing both of their answers and reasoning before and after events as well as the correct answers, and further requested students to reason why they change or stay with their original thoughts after learning the events.

In order to provide students with different learning task depending their different misconceptions and different reasoning patterns, therefore, the adaptive learning approach were used for SCCR. More specifically, some of the units of SCCR would provide different learning events according to the response they made of regarding either accuracy of concepts or reasoning and further determine which learning pathway they need to learn. Adaptivity is implemented by presenting students with different HTML pages depending on their prior misconceptions and their previous reasoning results. The adaptive linking is used to actually modify the link structure depending on the students' knowledge state. It leads to the development of a new course text, with a dynamically changing link structure, depending on each individual student's progress.

Subjects and procedures

A total of 62 sixth graders (11 years old average) recruited from two average-achievement classes from a middle school participated in this study. These students have not learned combustion before. The classroom teaching style is mainly expository teaching. One of class students received SCCR digital learning Program "combustion" unit, and the other class group students received conventional instruction of "combustion" unit. A pretest of combustion Dependent Reasoning Test (CART), scientific reasoning Test (SRT), and combustion Academic Achievement Test (ACAT) were administered to all students before the instruction. One week and sixth weeks respectively after the instruction, a posttest and a retention test of the Combustion Dependent Reasoning Test (CART), Scientific Reasoning Test (SRT), and Combustion Achievement Test (CAT) were administered to both groups. Cronbach α of the AAT, ADRT, and SRT was 0.90, 0.78, 0.88 for the pretest, 0.71,0.61, 0.76 for the posttest, and 0.89,0.92, 0.94 for the retention-test. In addition, experimental group students learning of a series of web-based learning events at "combustion" unit were further analyzed and yield both of the scientific conceptual change and scientific reasoning results. For the complexity of scientific reasoning, there are four levels of scientific reasoning modified from Hogans' study [12] were used in this study which are Generativity (G), Elaboration (EL), Justification (J), and Explanation (Ex). For quantity of conceptual change, there are several categories were measure in the following: Progress (PG), Maintain-correct (MTC), Maintain-partial correct (MTPC), Maintain-incorrect (MTIC), and Retrogress (RTG).

Findings and Conclusions

This study is to report an adaptive web learning project was developed based on the Dual Situated Learning Model (DSLM) and scientific reasoning theories in order to promoting middle students' conceptual change involving combustion and their scientific reasoning. Our study makes a big step from previous web-based instructional learning program, it brought the well developed theories and models of science education learning and pedagogy into web learning program which has evidenced effective models at traditional classroom [10, 11, 12, 13]. In addition, our SCCR also employed ideas from adaptivity web learning into our design of learning and our SSCR system also develop many unique functions such as junction, comparisons, correct answer, keyword to multiple path, frequency of correct answer to multiple path for teachers to develop the web-learning content depending on the topics characteristics which make learning more efficient.

The one-factor MANCOVA indicated that instructional approach has a significant effect on students' performance of post- and retention-test of CAT and CDRT. Post hoc analysis further suggests that web-based instructional group performed significantly better than conventional group on both post- and retention-test of CAT and CDRT. However, it shows that instructional approach does not have a significant effect on students' performance of post- and retention-test of SRT. In short, web-based instructional group did not perform significantly better than conventional group on the performance of post- and retention-SRT. However, it shows that experimental group students made significant progress from pre- to post-SRT. The possible explanation is that SRT specifically focusing on measuring students' conservation, proportional thinking, identification and control of variables, probabilistic thinking, correlative thinking and hypothetic–deductive ability. Our design of SCCR "combustion" unit purposely focusing on more broad ability of scientific reasoning which emphasize on the ability of formulate plans; analyze elements; evaluate alternative ideas; determine the consequence and hypothesis; identifying variables; make inference; make clarification; make justification; make conclusion based upon observation, experiment, and previous inference; process rules and general principles; judge the credibility of a source;

distinguish between fact, opinion and reason judgment; weigh evidence and assess data; decide between competing theories. The possible explanation is that the SCCR web learning is only last for five weeks and not long enough to make difference between experimental and conventional group within such sort period. However, the five week is enough for experimental group to make significant progress of SRT from pre to post. The design of CART contains more broad view of the scientific reasoning which explains why instructional approach has a significant effect on students' performance of post- and retention-CDRT, and moreover, why would experimental group outperform than conventional group at both post and retention-CDRT.

The web learning events results indicated that students use of level of scientific reasoning move from Generativity (G) to Elaboration (EL) after learning from the program, and the use of Justification (J) also appeared more often after learning. It supports the result of students' scores of SRT made progress from pre- to post-, and CART made progress from pre-to post-test and then from post- to retention-test. Moreover, it further shows that students use of scientific reasoning mainly are at PG and MTC categories across most of all of the web-based learning events. The average percentage for the categories of PG, MTC, and RTG across all the events is about 31.3%, 54.3%, and 14.4%. These results evidence the effectiveness of specifically designed each dual situated learning event with scientific reasoning. It also somehow demonstrated that students' scientific reasoning ability can be trained within very short period as long as the design of learning events are well and carefully addressed the ability.

The quantity of conceptual change shows that the successful rate of conceptual change is ranged from 75% to 98% for most of the web-based leaning events, except four events ranged around 50% to 60%. It supports the result of students' scores of CART and CAT make significant progress from pre- to post- and then from post- to retention-test. It somehow demonstrated that well designed DSLM and scientific reasoning indeed promote students conceptual change.

Many studies 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 [6], others find students enroll in a web-based course perform inferior to conventional students in final exam [17], and still others indicate an apparent increase in satisfaction on web-based courses [3]. One of the study suggested that computer assisted materials (CAIM) did not change students misconception related to photosynthesis, however, they change students' comprehension and application levels of cognitive domain and attitudes [1]. The author argues the reasons why their study can not be effectively change students misconception it is because their CAIM did not develop with effective conceptual change model, thus, it is reasonable that students misconception can not be changed. The results of this study is quite encouraging that students conceptual change can be promoted as well as their scientific reasoning ability after learning of well designed and theory based SCCR adaptive digital learning program. Our study again demonstrated that the possibility of web-based learning program can efficient for students' conceptual change and scientific reasoning once they can construct based upon a well development conceptual change theories or models as author proposed and argued.

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