Facilitating students' Scientific Inquiry through knowledge building

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Abstract: The present study investigated the effect of knowledge building on students' scientific inquiry in a computer-supported collaborative knowledge building environment. Participants were 52 college students. Data mainly came from a survey concerning the nature of science and online discussion. The findings showed better discussion quality and more effective scientific inquiry activities toward the end of the course, as well as a positive correlation between students' understanding of the nature of science and online discussion activities.

Introduction

Science educators and institutes of science education have been focusing on the cultivation of scientific literacy (AAAS, 1993; National Research Council [NRC], 1996). Particularly in many studies related to the nature of science (NOS), a specific concern focuses on students' views of scientific theories as a main aspect of NOS. Helping students achieve deeper understanding of NOS, however, is a challenging task. According to Chuy et al.'s (2010) study, the reason why many students cannot achieve a more sophisticated understanding of the nature of science is because they do not pay attention to the role played by scientific theories in science education (Chuy, Scardamalia, Bereiter, Prinsen, Resendes, Messina, et. al, 2010). Scientific theories are often viewed as a product of science, rather than examined from a process perspective. Knowing how theories were being produced and improved, however, is critical in helping students to reflect on the value of scientific theories and understand the nature of knowledge. Therefore, the present study tried to introduce more innovative pedagogy into traditional classroom teaching, making students shift from passive learning to more autonomous learning. This study employed a deep constructivist approach, the knowledge building pedagogy, to let students play the role of scientists and collectively engaged in scientific inquiry online. It was hoped that they would experience the process of how theories were being constructed.

Literature review

The nature of science and science learning

Although the definitions of "nature of scientific theory" differed among philosophers, historians, sociologists and psychologists, most people recognize that the nature of scientific theory is multi-faceted (Wen, Kuo, Tsai & Chang, 2010). Palmquist and Finley (1997) developed a questionnaire regarding nature of scientific theory. The questionnaire was developed according to philosophers' (e.g. Feyerabend, Kuhn, or Toulmin) understanding of the nature of science. In general, there are two views--traditional view and contemporary view--toward nature of scientific theory. In terms of the traditional view, people tend to believe theories are based on observation directly and the improvements of theories are because of the improvements of observations and experiments. In contrast, the contemporary view of the nature of scientific theory tends to believe that observation itself is theory-laden and theories could be influenced by social factors. One important aspect of NOS is that theory could be improved or replaced by a better theory. In other words, theories are temporarily best explanations for a phenomenon. Researches point out that when students hold a more flexible and contemporary views toward the nature of science, they can learn science in more diverse ways, showing less anxiety and reaching a better understanding of scientific issues (Chuy et. al, 2010; Deng, Chen, Tsai, & Chai, 2011; Songer & Linn, 1991; Tsai, 1998; Wen, 2010). In order to create an environment for students to explore how scientists conducted scientific inquiry, knowledge building pedagogy was applied to engage students into this process.

Knowledge building pedagogy

Knowledge building is a principle-based pedagogy. It gives no specific ways for teaching or designing a course, but encourages teachers to teach according to 12 knowledge building principles. Some examples of these principles include "Real ideas, Authentic problems", "improvable ideas" and "epistemic agency" (Scardamalia, 2002). Overall, it expects students to learn from direct problem-solving using authentic problems that have a bearing on students' real life experiences. In the process of knowledge building, it is important to make students construct their own understanding/knowledge through collaboration and keep revising their ideas for knowledge advances.

In this research, knowledge building was employed to make students co-create scientific theories. The purpose of this research was to understand how students would develop a better idea (theory) when they co-created their theory in a computer supported collaborative knowledge building environment called Knowledge Forum.

Method

Participants were 52 teacher-education students (with 39 freshmen and 13 sophomores) who took a course titled "Introduction to Natural Sciences" for a semester of 18 weeks. Data were gathered from (1) a survey using open-ended questions, (2) students' online discussion, and (3) their online interaction records. The pre-post survey data was collected in the first and last week of the semester. The other two forms of data were gathered throughout the course. The first two sets of data were analyzed with coding schemes developed or revised by the first researcher. The third set of data was analyzed with quantitative methods.

For the first questionnaire, there were five open-ended questions including "what is a scientific theory?", "where do theories came from?" or "can theories being evaluated?" etc., which were asked in the beginning and the end of the semester. All the questions' answers have been globally evaluated to attribute the scoring points from 1 to 5 based on the coding scheme that has five evaluative aspects:(1) theory-laden: whether theories came from only the observation of the facts; were the results by experiments in the laboratory; or were influenced by previous theories; (2) the role of social negotiation on science: whether theories were mainly produced by 'scientist' and were not influenced by social factors or other factors; or theories could be influenced by current technique and scientific community; (3)value of theory: whether theories could be compared or judged; (4) inventive and creative nature of science: whether theories are descriptions of phenomenon without the interpretation of human, or they contain the interpretation by humans; and (5) the evolving and tentative nature of science: whether theories could be refined and revised by better theories. The inter-rater reliability of this coding scheme was .72. ($r = .722$, $p<.001$)

The notes contributed on the Knowledge Forum were also collected and categorized based on a coding scheme concerning scientific concepts in 6 different levels which was revised based on Zhang et al. (2007) coding scheme. The scheme has six levels from a less sophisticated level of concept to a more sophisticated one, including: (1) non-scientific concept, (2) pre-scientific concept, (3) hybrid concept, (4) basically scientific concept, (5) scientific concept, and (6) theory construction. The inter-rater reliability of this coding scheme was .76. ($r = .757$, $p<.001$). This analysis was to see the quality of students' online discussion. In order to understand the relationship between the results regarding students' views of the nature of science and the amount of activities online, the researchers also performed Chi-square statistics to exanimate the association between the factors mentioned above.

Result

Change of students' view of the nature of science

It was found that there was a significant change of students' view of the nature of science after engaging in sustained idea improvement in order to address the problems emerged during online scientific inquiry. In particular, it was found that in the beginning of the semester, students tended to hold a traditional (more positivist) view. For example, they believed that theories were discovered and were not influenced by previous theories and social values. However, after engaging in knowledge building activities for a semester, they started to demonstrate a more constructivist view. They were more likely to describe theory as an invention and believe that social negotiation plays an important role in influencing the development of a theory. Table 1 shows the pre-post change in terms of the five dimensions of the nature of science and Table 2 shows coding examples.

Table1. Students' change of view of the nature of science after engaging in knowledge building for a semester (N=52)

Category	Pre-test		Post-test		t-value	Cohen's *d*
	M	SD	M	SD		
Theory-laden	3.21	1.47	4.35	1.08	-5.12***	-.88
The role of social negotiation on science	2.79	1.47	4.04	1.22	-5.49***	-.93
Value of theory	3.10	1.56	3.94	1.51	-3.05*	-.55
Inventive & creative nature of science	2.87	1.58	3.85	1.18	-3.58**	-.70
Then evolving and tentative nature of science	3.08	1.57	4.21	1.23	-4.35***	-.80

* $p<.05$ ** $p<.01$

Table 2. Examples of each category

Category		Example
The theory-laden exploration of science	Theory independent	The law of nature exists objectively. What science does is to find out these laws. (S8)
	Theory laden	Scientific theory is just like a cube. After piling up and influencing each other, new theory will arise(S15).
The role of social negotiation on science	Non-social negotiation	Theory was observed and explained by scientists after they found out things or phenomenon. (S48)
	Social negotiation	Theory was developed by scientists discussing or working together.(S43)
The value of theory	No judgment	Theories could be explained through different sides. So there's no absolute good or bad. (S30)
	With judgment	There are good and bad theories. Usually good theory contains better explanatory ability. Worse theories are not suitable for facts.(S5)
The invented and creative reality of science	Discover	Actually a lot of phenomenon exist in daily life. The difference is if there's anyone discover it and lead to a valid theory. (S35)
	Invent	Scientific theory was created by scientist's own thought. It may suit the fact, which means his/ her logic is precise. It may be wrong, too. Which means the theory could be revised. So I think theories tend to be a "invention".(S31)
The changing and tentative features of science	Could not be changed	I think this world is a perfect and precise machine. It is working in a fixed mode. (S23)
	Changeable	Every theory can be revised. When the explanatory ability of the theory stronger, means the theory is more reasonable. (S20)

Relationships between students' online activities and their inquiry processes

Table 3 shows the pre-post change of students' online inquiry activities. Overall, in early stage, students tend to discuss more about hybrid scientific concepts. In the later stage (second-half semester), students' discussion quality improved with more discussion about scientific concepts and theory construction. In addition, in order to know whether the change could be associated with online inquiry activities, chi-square results were computed (as shown in table 4) which explored the relationship between (1) students' change of views of the nature of science, (2) the quality of their online inquiry activities, and (3) the amount of online activities in Knowledge Forum. Results showed that there are associations ($X^{2=}$4.93, p<.05; $X^{2=}$33.66, p<.001). When students contributed more in the Knowledge Forum, they also showed a more contemporary view of the nature of science and better quality of scientific inquiry online.

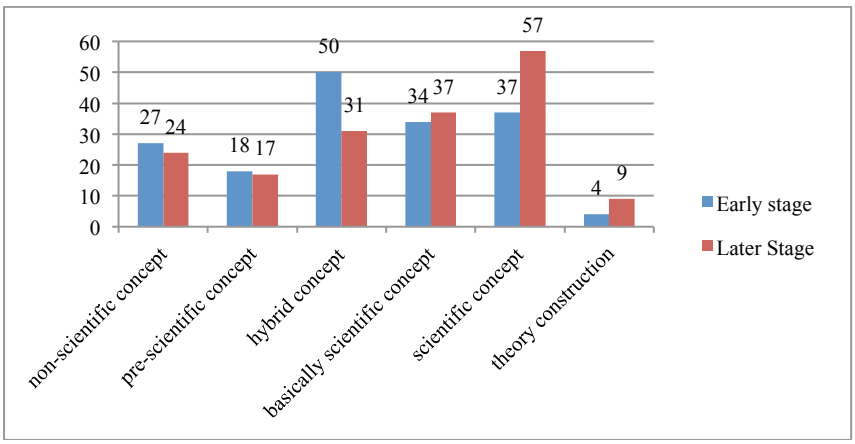

Figure 1. The number of students' notes into 6 levels of scientific concept

Table 4. Cross table of student' view change, inquiry level and amount of online activities

	Pre-post change		*Students' level of scientific concept*	
The sum of online activities	Lower change	Higher change	Lower level	Higher level
Low amount of activities	58	46	35	5
High amount of activities	42	62	17	43

Conclusion

In summary, results indicated that students showed positive change toward the nature of science after engaging in knowledge building for a semester. The content of students' discussion and scientific inquiry activities also become more substantial towards the later phase of the semester. The three forms of changes seem to occur in tandem, indicating that they may be associated. Further studies are needed to examine whether there are causal relationships among the nature of science, scientific inquiry and online discussion activities. The details and the processes of students' online inquiry will also be reviewed.

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