

Fostering change of views of the nature of scientific theories in a CACL environment

Pei-Jung, Li^{a*}, Huang-Yao, Hong^a

^a*Department of Education, National Chengchi University, Taiwan*

*101152005@nccu.edu.tw

Abstract: This study investigated whether engaging students in knowledge-building help them develop more informed views regarding the nature of scientific theories. Findings indicated that students' views of the nature of scientific theories became more constructivist-oriented toward the end of the semester. A relationship was also observed between students' online activities and their changed views about the nature of scientific theories.

Keywords: Knowledge building pedagogy, Computer supported collaborative learning, Nature of scientific theory.

1. Introduction

Recent educational research shows that promoting students' understanding of the nature of science can help them understand science more deeply (Songer & Linn, 1991; Tsai, 1998; Lee, 2002). However, research in the investigation of students' perspectives of the nature of science showed that many students, even teachers, still see science as absolutely objective and definite; as such, they believe learning science is equivalent to memorizing a bunch of scientific facts. The teaching of science also emphasizes rote-learning rather than deep understanding. Consequently, students often do not know how to apply what they learned and eventually lost their interest in, and motivation to learn, science. Researchers need to investigate how to create a learning environment that can better encourage students to learn in a more autonomous and self-directed manner, and to guide them to construct their knowledge through learning-by-participating in various educational and cultural activities, rather than just highlighting knowledge telling and acquiring. To this end, this study adopted an instructional approach called 'knowledge building'. Knowledge building theory and pedagogy was originally proposed by Carl Bereiter and Marlene Scardamalia (2006), and it is manifested by twelve knowledge building principles that highlight intentional, self-directed learning and are different from conventional instructional approaches in Taiwan that emphasize knowledge-telling. For example, the principle of "real ideas and authentic problems" argue for the importance of using real-life related problems to engage students in working with their own ideas as a start of self-paced learning; and this is different from the kind of learning usually involved learning based on textbook knowledge. Other principles are such as improvable ideas; constructive uses of authoritative source, and epistemic agency (see Scardamalia, 2002, for details). Building on these principles, this study employed a knowledge building environment called Knowledge Forum, as an online forum for open-ended discussion and inquiry, where students could bring up issues or inquire topics they were interested in and responded to other peers with their own experiences or knowledge they learned in the past. The instructional goal is to guide students to work through a process similar to how scientists work with ideas by means of exploring a better explanation for an observed natural phenomenon. It is posited that engaging student in knowledge building process can help them develop a more informed and constructivist-oriented views of the nature of scientific theories.

2. Method

Participants were fifty-two college students in Taiwan who took a course titled "Introduction of Natural Sciences". The duration of the course was eighteen weeks. At the beginning of the semester, the participants brought up issues they were interested in inquiry in the discussion forum and then they used

the design features in the forum to conduct their inquiry (e.g., using scaffolds such as “I need to understand...”, “My theory...”, “This theory cannot explain...”, “New information...”, “A better theory...”, and “Putting our knowledge together...”), and to advance their knowledge in the community. Figure 1 shows a snapshot of students’ online discussion.

The data collected in this study included participants’ activities in the discussion forum and a survey. The survey was administered at the beginning and the end of the semester and used five open-ended questions as following: 1) What is scientific theory? 2) Are there good and bad theories? Why? 3) Where does a scientific theory come from? 4) Are scientific theories invented or discovered? Why? 5) Why do we need scientific theory? The survey was administered to assess participants’ views of the nature of scientific theories.

For the purpose of analysis, the pre and post survey was examined using a coding scheme emerged from a process of reading and re-reading the raw data. Five coding themes emerged were as follows: theory-independent vs. theory-dependent, single research method vs. diverse research methods, non value-laden vs. value-laden, discovery vs. invention, and permanent vs. temporary. Theory-independent means that students consider theories as objective presentation of a phenomenon without personal interpretation or inference; vice versa, theory dependent means that students think theories can be influenced by social factors, previous theories, and prior research results, and can further influence other research/theory. The second “single research method vs. diverse research methods” category assesses whether students consider that the generation of a theory involves repetitive validation using a or mixed single research methods. The third category of “non value-laden vs. value-laden” assess whether students think that theory could be judged as good or bad according to some specific standards. The fourth “discovery vs. invention” category assesses whether students consider theory as resulted from imagination and interpretation. The last category of “permanent vs. temporary” assesses whether students think that theory could be changed or replaced by better theory. The pre and post surveys were then further rated with a five-point Likert scale for each code. Take “permanent and temporary” as example, point one indicated that the participant tended to see scientific theory as infinite existence and unchangeable, whereas point five referred to a perspective that sees a scientific theory as replaceable by a better theory. The results of coding were statistically examined with t-test to see if there were any changes in the views of the nature of scientific theories over time.

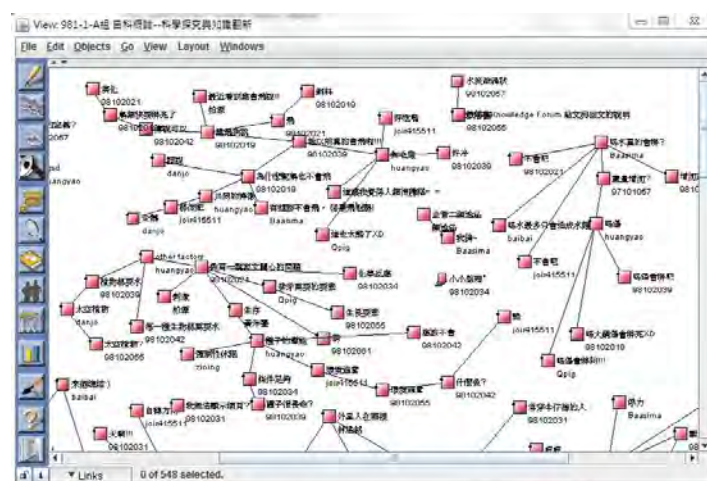


Figure 1. An example of the discussion activities in Knowledge Forum

Further, participants’ activities in the forum was analyzed by a tool called Analytic Toolkit (ATK) that was built-in in the forum for a purpose of obtaining quantitative data regarding online activities (e.g., their interaction). The content of online inquiry and discussion was content-analyzed using a coding scheme modified based on Zhang’s (2007) coding categorization of scientific concepts. There are six levels ranging from less-developed to well-developed scientific concepts. They are non-scientific concept, pre-scientific concept, hybrid concept, basically-scientific concept, scientific concept, and theory construction. Take non-scientific level for example, students’ note content is such as: “I don’t really remember... but this is a good way. So I’ll dry it (my jeans) inside out from now on!” or “It’s (plastic bags) not good to eat! Does this represent the feelings of germs? Though I think it’s kinda cute.”

Such content contains information (e.g., social chat) that is not very useful for or relevant to the development of scientific concepts. To elaborate further, pre-scientific concept (and hybrid concept) mean that students try to address questions mainly based on their personal experiences. Basically-scientific concept or scientific concept means that students can use constructive or proven scientific concepts to address questions. A key difference between these two categories is if students can provide better explanations. The highest level of theory construction means that students can further propose higher-level assumptions to develop a topic or to refute/challenge previous scientific concepts with higher level thinking and understanding.

In addition, the analysis of online activities in the forum was conducted with “week” as the unit of analysis, focusing on a given topic and its corresponding discussion. The entire semester was divided into two periods with mid-term (week 9) as the cutoff point to observe changes from the first half to the latter half of the semester. To understand the relationship between online forum activities and participants’ changes in their views of the nature of scientific theory, participants’ online activities were categorized based on the following characteristics: contribution activity, reading activity, improvement activity, and collaborative activity (see Table 1). Then, correlation analysis and a pair-sample t-test were conducted to observe whether there was a relationship between the number of each coding category and activities in the forum. Last, this study analyzed what participants inquired in the forum, and whether these inquiring activities were also related to participants’ changes of views of the nature of scientific theories. Due to the large amount of data, only half of the inquiry topics were selected for this analysis.

Table 1. Coding table of the activities in the forum

Types of activity	Item	Description
Contribution activity	- Number of notes contributed	- Note contribution as a fundamental online activity in the discussion forum.
Reading activity	- Number of notes - total times for all notes read	- Reading others’ notes indicates community awareness (i.e. whether a participant cares about others’ ideas or not). - The total number of times of all notes read indicates the intensity of reading activity.
Improvement activity	- Number of notes revised - number of times scaffolds used	- Number of note revisions indicates that to what degree a participant reflects on his/her ideas. - Number of scaffolds used represents the degree of higher-order thinking in relation to idea advancement by a participant.
Collaborative activity	- Percentage of notes connected with others’ notes, - Percentage of build-on notes	- Connecting with others’ notes indicates that a participant collaborates with others to improve the ideas and discuss about related issues. - Build-on notes (i.e. replying to other’s notes) show that a participant responds and discusses by working with others’ ideas.

3. Result

3.1 Changes in the views of the nature of scientific theories

As shown in figure 2, the results indicated that there were significant changes in the five aspects as assessed at the end of the semester. The detailed statistics are as follows: (1) “Theory-independent vs. Theory-dependent” ($t=-4.77$, $p<.001$); (2) “Single research method vs. Diverse research methods” ($t=-6.53$, $p<.001$); (3) “Non value-laden vs. Value-laden” ($t=-3.05$, $p<.05$); (4) “Discovery vs. Invention” ($t=-3.80$, $p<.001$); and (5) “Permanent vs. Temporary”, ($t=-4.35$; $p<.001$). In brief, participants’ views of the nature of scientific theories were initially inclined to a more uniform view that sees theory as objective and permanent truth. Toward the end of the semester, their views became more

informed and diverse; they tended to see theory was tentative explanation for certain observed phenomenon and could be modified or falsified.

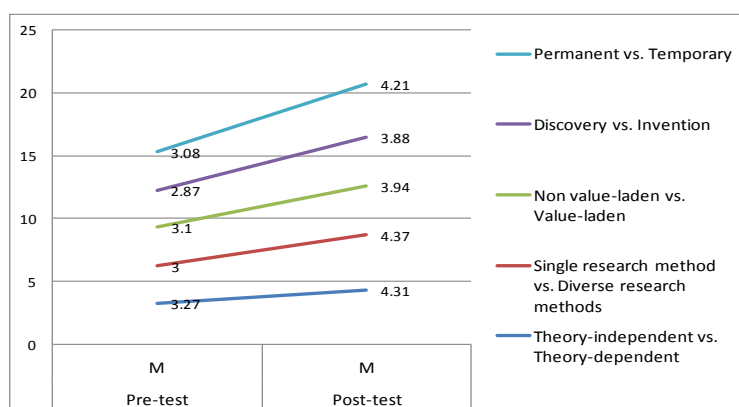


Figure 2. Students' pre- and post-survey results regarding their views of the nature of scientific theories

3.2 Relationship between forum activities and view changes

First, as baseline information, participants' basic online activities and the correlations among these activities were described as follows (see Figure 3 & Table 2). Furthermore, regarding correlations between participants' online forum activities and their changes in views of the nature of scientific theories, Table 3 shows the results. In this analysis, participants were divided into two groups based on the degree of changes in their views of the nature of scientific theories, with 50% as the cutoff point. Moreover, each category of the activity was divided into high- and low-frequency activities. A crosstab analysis was conducted to examine the relationship. Overall, the results showed that the range of participants' changes towards more diverse views of the nature of scientific theory at the end of the semester was highly related to the amount of activities on the computer-supported collaborative learning forum in this study: (1) the number of students with low pre-post change scores and low online activities is 58; (2), the number of students with high pre-post change scores and high online activities is 62; (3) the number of students with high pre-post change scores and low online activities is 42; and (4) the number of students with high pre-post change scores and low online activities is 46 ($X^2 = 4.93$, $p < .05$).

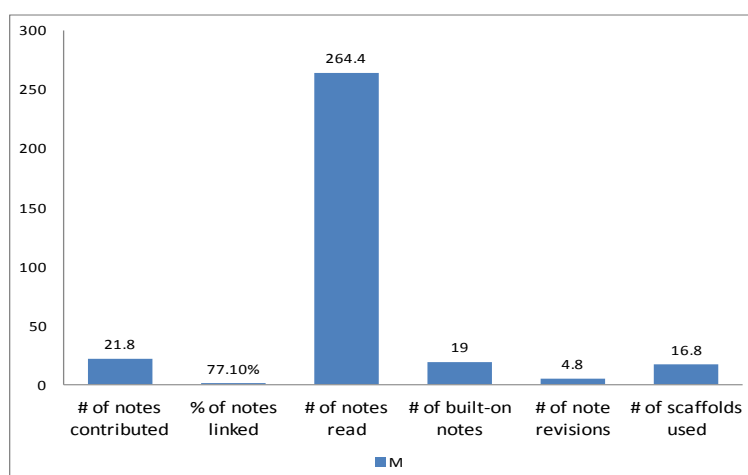


Figure 3. Descriptive analysis of participants' activities in the forum

Table 2. Pearson correlation among forum activities

	1	2	3	4	5	6
1. # of notes contributed	1	0.46**	0.37**	0.86**	0.69**	0.47**
2. % of notes linked		1	0.19	0.38**	0.46**	0.95**
3. # of note revision			1	0.47**	0.29*	0.20

4. # of scaffolds used				1	0.69**	0.38**
5. # of notes read					1	0.43**
6. # of built-on notes						1

*<.05, **<.001

Table 3. Crosstab analysis of participants' change and online activities

Types of activity/ Views		Contribution		Reading		Improvement		Collaboration	
		Low	High	Low	High	Low	High	Low	High
Change between pre-post tests	Low scores	17	8	14	11	14	11	13	12
	High scores	9	18	12	15	12	15	13	14

*<.05

3.3 Relationship between participants' online inquiry activities and their view change

Further, we analyzed the overall topics discussed within groups. Because class members were randomly assigned to one of the two groups and there was too much data, we only randomly selected one group for further analysis. There were fifty-eight topics and eleven sub-topics inquired in the discussion of this group (Group A) over the whole semester. Each topic lasted for an average of 5.26 weeks (SD=3.31), had 7.89 participants on average (SD=4.97), included 11.55 notes on average (SD=9.7), and had been read by 20.3 students on average (SD=7.92). Moreover, the results indicated that in the first half of the semester, participants' discussion tended to involve social and evaluative languages (non-scientific concepts), and pre-scientific concepts. They tended to use their personal experience and conjecture without providing any scientific evidence. But in the latter half of the semester, participants started to use more structural scientific concepts, including hybrid concepts, basic scientific concepts, and scientific concepts. They brought scientific theories, scientific knowledge into their discussion of the topic and then debated or proposed new ideas for future development. Regarding relationship analysis, the results of Chi-square showed that during the first half of the semester, participants didn't provide convincing information in the discussion. After participating in the forum activities for nine weeks, they started to use more persuasive theories or scientific information to support their arguments, and they also discussed or debated more with others. Using Chi-square analysis, there is a significant change from phase 1 to phase 2 in terms of the (high vs. low) level of scientific concepts students discussed in their inquiry ($X^2=7.50$, $p<.05$).

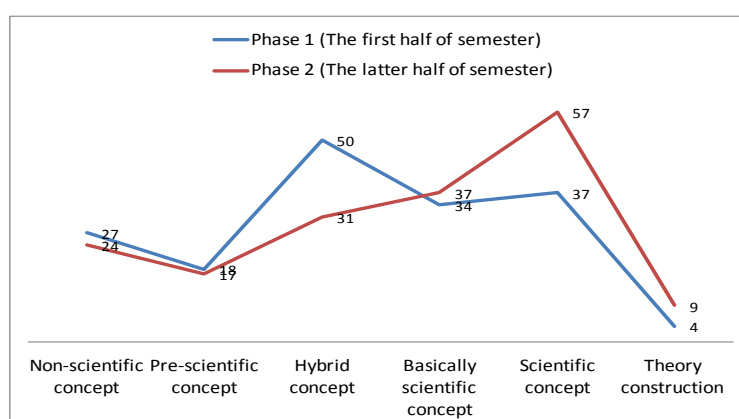


Figure 4. Assessment of the quality of online inquiry between Phase 1 (weeks 1-9) and Phase 2 (weeks 10-18)

4. Conclusion

The purpose of this study was to investigate whether a computer-supported collaborative learning environment that was designed based on knowledge building pedagogy and principles could guide students to develop more informed and diverse views of the nature of scientific theories. First, the results indicated that participants' views of the nature of scientific theory changed significantly after they participated in the forum activities. Second, the results showed that forum activities were

positively correlated with participants' view change. Finally, it was also found that participants used more structural scientific ways to discuss and debate with others towards the latter half of the semester than in the first half. This was similar to how scientists conduct scientific investigation. In addition, it was found that more structural ways of inquiry was also related to participants' view change. Through the use of a computer-supported collaborative knowledge building environment that provided students with more autonomy and flexibility to inquire and discuss online, students were able to change from using more subjective personal opinions and experience to support their arguments, to using more structural and explanatory scientific ways of inquiry to support their knowledge work. As a result, they also developed more constructivist-oriented and diverse views of the nature of scientific theories, which help them to see theories as improvable and falsifiable, instead of unchanged and authoritative.

References

- Gloor P.A. (2006) *Swarm creativity: competitive advantage through collaborative innovation networks*. New York : Oxford University.
- Lee, Y. M. (2002). *A Research of Elementary Students' Views Toward the Nature of Science*. (Unpublished master dissertation). Taipei Municipal University of Education. Taipei, Taiwan.
- Palmquist, B. C., & Finley, F. N. (1997). Preservice teacher' s views of the science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching*, 34(6), 595-615.
- Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67-98). Chicago: Open Court.
- Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge: Cambridge Univ.
- Songer, N. B., & Linn, M. C. (1991). How do students view of science influence knowledge integration ? *Journal of Research in Science Teaching*, 21(4), 409-421., 28, 761-784.
- Tsai, C. C. (1998). An analysis of scientific epistemological beliefs and learning orientations of Taiwanese eighth graders. *Science Education*, 82(4), 473-789.
- Zhang, J., Scardamalia, M., Lamon, M., Messina, R., & Reeve, R. (2007). Socio-cognitive dynamics of knowledge building in the work of 9- and 10-year-olds. *Education Tech Research Dev.* ,55, 117-145