Proc. Natl. Sci. Counc. ROC(D)
Vol. 8, No. 2, 1998. pp. 86-91

Enhancing College Students' Attitudes toward Science through the History of Science

HUANN-SHYANG LIN

Department of Chemistry
National Kaohsiung Normal University
Kaohsiung, R.O.C.

(Received May 11, 1998; Accepted September 2, 1998)

Abstract

This study explored the effect of teaching college chemistry with the history of science on student attitudes toward science. Sixty-one non-chemistry major freshmen in two classes participated in this study. Using a quasi-experimental design, the experimental group of students were taught three historical cases of chemistry in one school year. At the end of the school year, the action research reaped fruitful outcomes. The quantitative data with Analysis of Covariance, using post-treatment attitude score as the dependent variable and pre-treatment attitude score as the covariate, reveals that the experimental group (taught the history of chemistry) outperformed its counterpart in their attitudes toward science. Qualitative interview data provide additional evidence of this teaching strategy's effect.

Key Words: science history, attitudes toward science, science teaching

I. Introduction

Student attitudes toward science have long been regarded as one of the most important outcomes of science teaching. The report for Project 2061 (AAAS, 1989) pointed out that science education should help students to become compassionate human beings; the National Science Teachers Association (NSTA, 1982) also officially announced that the goal of science education is to develop scientifically literate individuals who understand how science, technology, and society influence one another. Such individuals both appreciate the value of science and technology in society and understand their limitations.

The possible relationship between attitudes toward science and course participation (or career selection) has been investigated in many studies (Fox, 1977; Greenfield, 1996; Taber, 1992). Recently, Koballa (1988) confirmed the existence of the attitude-behavior link. In addition, it was found that students' attitudes toward science are highly related to their achievement in science (Lin, 1992; Simpson & Oliver, 1990). Knowing the importance of student attitudes toward science, the National Assessment of Educational Progress (NAEP, 1978; 1983) has periodically diagnosed how American students performed in this field. Unfortunately, based on the reports of NAEP (1978), students at ages 9, 13, and 17 all declined generally in knowledge, skills, and understanding of science as determined in the 1970, 1973 assessments to 1978 assessments.

Extensive research conducted to investigate students' attitudes toward science has attracted science teachers' and educators' attention. Efforts to improve science teaching in order to promote students' interest have been made in the science education community. For instance, in Canada, an attempt to reform science education was made and various approaches to science curriculum development and science education was advocated in the 1980s. However, Ebenezer and Zoller (1993) found that no change in students' attitudes toward science could be detected. The two researchers suggested that alternative strategies should be considered and developed.

Recently, Matthews (1994) noted the importance of integrating the history of science into science teaching. He further listed several potential benefits of this teaching approach: it promotes better comprehension of scientific concepts; it connects the development of individual thinking with the development of scientific ideas; it enhances understanding of the nature of science. Although Matthews (1994) did not explicitly point out the potential benefit of promoting student attitudes toward science, he mentioned that "History... humanizes the subject matter of science, making it less abstract and more engaging for students" (p. 50) and "There is evidence that this makes science and engineering programs more attractive to many students" (p. 7). In fact, the potential benefits described by Matthews (1994) have been confirmed by some researchers. For example, as early as 1963, Klopfer and Cooley successfully demonstrated the approach's effect of promoting high school students' understanding of science and scientists. More recently, Solomon, Duveen, Scot, and McCarthy (1992) conducted an action research and found that students improved in their understanding of the nature of science after they were taught with the history of science. Jensen and Finley (1995) reported that a historically rich teaching intervention effectively promoted students' conceptual change in biology. Lin (1998a) also concluded that integrating history in science teaching could facilitate student conceptual understanding of chemistry. In addition, the inclusion of history in pre-service teacher education programs has created fruitful results on students' understanding about the nature of science (Lin, 1998b).

From the above literature review, it can be seen that, to date, little research has focused on examining the potential of positive effect of teaching the history of science on student attitudes toward science, especially at the college level. It is believed that with the addition of empirical evidence, more science teachers and educators will pay attention to this teaching approach. Therefore, the purpose of this study was to investigate the efficacy of using historically rich supplemental material in teaching freshman chemistry.

II. Methodology

1. Instrument

A revised version of the Wareing Attitude toward Science Protocol (WASP) (Wareing, 1982) was used to assess students' attitudes toward science. The original 50 items of the protocol were translated into Chinese and validated by Lin (1992) with reliability of 0.91 and satisfactory validity. The Chinese version of WASP is comprised of 44 items. After each item's statement, there is a Likert-scale format with 1=strongly disagree, 2=disagree, 3=undecided, 4=agree, and 5=strongly agree. The numbers stand for each item's score. However, items with negative statement (e.g., science discourages curiosity) were scored in the reverse order. Therefore, a high total score indicates a positive attitude. The highest possible total for this questionnaire is 220.

2. Treatment

Three cases from the history of chemistry were used as the treatment in this study. All historical statements used in these cases were derived from the article of Gorin (1994) and the following four books: 1. *The Norton History of Chemistry* (Brock, 1992), 2. *The General History of Chemistry* (Chao, 1992), *Harvard Case of Histories in Experimental Science* (Conant, 1957), *The Development of Chemical Principles* (Langford, 1969).

The first case introduced how Boyle used a J tube to confirm the compressibility of air and the pressure of air in the seventeenth century. Although Boyle's method of measuring volume was crude, he obviously became very interested in the numerical relation between pressure and volume of the air inside the short leg of the J tube. Boyle supported Torricelli's idea of atmospheric pressure while most scientists at that time believed in the doctrine of "horror vacui". For example, when Torricelli explained that in his experiment, the mercury in a tube did not fall because the earth is surrounded by a sea of air that exerts pressure, Thomases asked why the mercury did not fall if the barometer was placed inside a large glass vessel that was sealed off from the surrounding air. In order to provide evidence that the pressure inside the enclosing vessel was the same as the atmospheric pressure when the vessel was first closed off, Boyle used a pump to remove the air from the vessel and successfully showed that the mercury fell. Though Torricelli and Boyle consistently confirmed the property of air, objections arose. For example, Linus hypothesized that the space above the mercury column in a Torricellian tube contained an invisible membrane. In support of his hypothesis, Linus reported that if the upper end of the Torricellian tube was closed with a finger, one could feel the flesh being pulled in. Linus further hypothesized that the membrane could draw the mercury up to a maximum height of 29 inches. However, Boyle knew that the pressure of the outside air pushed the flesh of one's finger into the top of a barometric tube. He used a J tube and an air pump to pull up a column of mercury which is several times of 29 inches. This experiment enabled Boyle to reject Linus' postulation.

The second case described how the phlogiston theory was overthrown and the existence of oxygen was proven. In the eighteenth century, the phlogiston theory was almost universally accepted by scientists.

It hypothesized that a substance called phlogiston existed in combustible substances, such as charcoal. When charcoal was burned with a metallic ore to produce a metal, according to the phlogiston theory, phlogiston escaped from charcoal in the process and combined with air. The fact that combustion soon ceased in an enclosed space was taken as evidence that air had the capacity to absorb only a finite amount of phlogiston. However, when sulfur was burned, Lavoisier found that it gained weight instead of loosing weight. This quantitative observation created great difficulties for those who believed in the phlogiston theory. Lavoisier suspected that "something" was taken up from the atmosphere in combustion. This was exactly opposite to the phlogiston doctrine. He continued to conduct experiments in decomposing the red oxide of mercury (HgO) to collect gas from a reflective furnace. After examining the properties of the gas, Lavoisier finally showed clearly that air is a mixture of two gases, one "highly respirable", the other "unable to support combustion".

The third case explained the development of atomic theory, the atomic weight table, the formula of water, and Avogadro's molecular hypothesis. Based on this historical development, students were able to learn that any element can be used as a reference, and that its atomic weight can be assigned any numerical value. For example, Dalton used hydrogen=1; Berzelius defined oxygen=100; and Cannizzaro introduced carbon=12 by calculating its relative atomic weight to the lightest atom of hydrogen, which was assigned as 1 again; after knowing that most elements are mixtures of isotopes, chemists in the International Unions of Pure and Applied Chemistry agreed to change the reference substance to carbon-12. In the description of Avogadro's molecular hypothesis, students were introduced to the scientific debate over the distinction between the concept of the atom and that of the molecule. The history of how Avogadro's molecular hypothesis was accepted by the scientists at that time was also described in this case. Although Avogadro created this hypothesis in 1814, it was not accepted until the 1860's Karlsruhe conference, which was four years after he died. One of the major reasons why it takes so long time described by historians is that Avogadro's hypothesis was not supported by Dalton, who was one of the major leaders in science community at that time. It was believed that students could develop a better understanding of these concepts from these historical descriptions. They were provided with opportunities to learn how a scientific theory is accepted by scientists, to learn that earlier scientists held misconceptions, and to appreciate the creative nature of science.

3. Procedure

Two classes of non-chemistry major freshmen (who were from the Department of Industrial Technological Education, N=61) participated in this study. One class was taught by the investigator, who is interested in history of science and very curious about its effectiveness in science teaching. The other class was taught by an experienced chemistry professor, who is not only much more experienced than the investigator in teaching, but has been recommended as a teaching performance evaluator and a reviewer of science fairs for more than 10 years. The students all used the same textbook (Snyder, 1995), in which attempts were made by the author to relate chemistry concepts to daily lives, and to enable students to make reasoned judgments on societal issues.

At the beginning of the school year, all the students were asked to respond to the revised version of WASP. The three history of chemistry cases were used as supplemental materials and taught to the experimental group. The other class taught by the experienced professor was used as the control group and was taught using only the textbook without the history of chemistry. All the students met for two hours a week in class. After one year of teaching, all the students responded to the questionnaire again. During the year, semi-structured interviews were conducted to assess the experimental group students' understanding and perceptions of the history of chemistry.

4. Data Analysis

Both quantitative and qualitative methods of data analysis were conducted. In the quantitative part, Analysis of Covariance (ANCOVA) was used to check whether there was a significant difference in student attitudes toward science between the two groups. In addition, dependent t-tests were employed to examine the two groups' progress in terms of pre- and post-test differences. All the statistical analysis was carried out using the SAS program on a VAX computer. Interview results are transcribed, abstracted, and briefly presented in the following "Results" section. Although the study appeared to employ a quasi-experimental design, the main intention was not to compare the differences of student attitudes toward science between the experimental and the control group. Instead, an attempt was made to discover significant ways of improving student attitudes toward science. Therefore, with this understanding in mind, although the design which employed different teachers in the two groups could bring into question the validity of the findings, the results of the study nevertheless provide clear evidence of change in student attitudes toward science. In other words, this study was more like an action research. It tested the effectiveness of integrating history into science teaching and obtained evidence of change in student attitudes toward science throughout the period of teaching.

III. Result

1. Quantitative Part

The Cronbach alpha reliability of the WASP for the pre- and post-tests was 0.87 and 0.92 respectively. This reveals the high consistency of the measurements of the instrument. The pre- and post-tests of the WASP mean scores and standard deviations of the experimental and control groups are shown in Table 1. It can be seen that both groups made progress in their attitude-toward-science scores. The further ANCOVA result (Table 2) reveals that the progress of the experimental group was significantly higher than that of its counterpart at the $p<0.05$ confidence level.

Additional dependent t-test results shown in Table 3 indicate that both groups made significant progress in their WASP score. The experimental group improved 9.24 ($p<0.01$) while the control group produced a gain of 2.70 ($p<0.05$).

Table 1. WASP Means and SDs of the Two Groups

test	experimental group			control group		
	N	mean	SD	N	mean	SD
pre-test	30	171.10	11.89	31	174.19	9.72
post-test	25	181.28	14.21	30	177.33	11.72

Table 2. ANCOVA Result of the WASP Score between the Two Groups

sources	df	SS	MS	F	P
between groups	1	466.96	466.96	4.56	*
pre-test	1	3512.13	3512.13	34.32	**
residual	52	5321.58	102.34		

*: $p<0.05$ **: $p<0.01$

Table 3. Dependent t-tests of the WASP Scores

group	N	mean difference	t	p
experimental	25	9.24 (2.71)[a]	3.41	**
control	30	2.70 (1.22)	2.22	*

a: Numbers in ( ) are standard deviations.
*: $p<0.05$ **: $p<0.01$

2. Qualitative Part

After each of the three historical cases were taught, six students were randomly selected as interview subjects to determine their perceptions and attitudes toward the supplemental teaching material. All of the six students reacted positively toward the material. For example, student A liked the historical descriptions because they helped him to better understand how scientific theories are created and accepted by people.

> Investigator: This week we reviewed the development of Boyle's law. Since this is the first time I used this material, I would like to get some feedback from you in order to make further improvement in the future. Tell me, how do you like it ?
> Student A: I like the material.
> Investigator: Why do you like it ?
> Student A: It makes me to think more about what science is. When I was in high school, all the concepts and knowledge were represented as final products to be learned. After learning about the development of Boyle's law, I realize that scientists argue with other scientists who have different beliefs.

Student B was impressed by the mistakes made by previous scientists (in the case of atmospheric pressure). She liked that part because it helps her to clarify in her mind the target concept and to avoid the same mistake.

> Investigator: What makes you like the history of science ?
> Student B: It helps me to understand air pressure.
> Investigator: How does it help you ?
> Student B: Frankly speaking, I had the same misunderstanding as the previous scientist did who thought that air would exert no pressure when it was enclosed in a container. The description of how Boyle disproved this idea helps me avoid the same error. I am happy to know that scientists make mistakes, too!

Students C accepted the history of chemistry because it describes the developmental and societal nature of science.

> Investigator: In the topic of atoms and molecules, what

differences do you see between high school chemistry and the college general chemistry we just studied ?

Student C: I have learned more about how the concept of the molecule is distinguished from the concept of the atom from college general chemistry.

Investigator: Which one do you like better ?

Student C: College general chemistry.

Investigator: What are your reasons ?

Student C: It was interesting to find out that it took earlier scientists 50 years to distinguish the difference between the atom and the molecule.

IV. Discussion and Implication for Chemistry Teaching

The result of positive student attitude change in both of the groups is encouraging to those who are interested in the history of science and in curriculum design which relates chemistry to the real world. The textbook used in this study presents chemistry in a way that helps students understand and resolve social problems. The three cases of history describe how scientific concepts develop. All together, they significantly promoted the students' attitudes toward science in this study. As mentioned earlier in the "Introduction" section, research studies previously found not only that students lose interest in science as they progress in school, but also that students are less interested in science after taking a science course than they were at the beginning of the course (Yager, 1986). It is not easy to motivate positive student attitudes simply by continuing to emphasize terms and laws, or by continuing to test for mastery. If chemistry teachers and science educators intend to foster in their students' positive attitudes toward science, the way of integrating historical materials into classroom instructions as reported in this study provides an additional alternative approach to teaching chemistry.

Both types of data collected, quantitative and qualitative, offer substantial evidence that the teaching of historical cases in chemistry made a significant contribution to the students' positive change of attitudes toward science. Although from the quantitative results, one may suspect that the main effect (positive student attitude change) could have been due to the teacher instead of the treatment (the history of science), the fact that the qualitative results from interviews corroborated the results from the questionnaire quantitative analysis provides a clearer picture indicating that the experimental students liked the historical material, and that their appreciation for science increased. Researchers in the field of the history of science have suggested potential benefits of integrating the history of science into teaching (Conant, 1957; DeBerg, 1989; Duschl, 1985; Duschl 1990; Matthews, 1994). This study followed their suggestion and further confirmed through empirical data the initial benefit of promoting student attitudes toward science. Nevertheless, there is much more work to be done in the future. For instance, additional studies larger in scale or with control of the teacher effect are encouraged to confirm its practical utility.

Acknowledgment

The author gratefully thank the two anonymous reviewers for their constructive contributions to this article. In addition, this study was made possible by financial support from the National Science Council, R.O.C. (NSC 85-2511-S-017-005).

References

American Association for the Advancement of Science (AAAS), (1989). *Science for all Americans*. Washington, DC: Author.

Brock, W. H. (1992). *The Norton history of chemistry*. New York: Norton.

Chao, K. (1992). *The general history of chemistry*. Hsin-Chu, Taiwan: Fan-Yi Publication.

Conant, J. B. (1957). *Harvard case histories in experimental science*.: Cambridge, Massachusetts: Harvard University Press.

De Berg, K. C. (1989). The emergence of quantification in the pressure-volume relationship for gases: A textbook analysis. *Science Education*, **73**(2), 115-134.

Duschl, R. (1985). Science education and philosophy of science: Twenty five years of mutually exclusive development. *School Science and Mathematics*, **87**(7), 541-555.

Duschl, R. (1990). *Restructuring science education*. New York: Teachers College, Columbia University.

Ebenezer, J.V. & Zoller, U. (1993). Grade 10 students' perceptions of and attitudes toward science teaching and school science. *Journal of Research in Science Teaching*, **30**(2), 175-186.

Fox, L. H. (1977). *Women and mathematics: Research perspectives for change*. Washington, DC: National Institute of Education.

Gorin, G. (1994). Mole and chemical amount–A discussion of the fundamental measurement of chemistry. *Journal of Chemical Education*, **71**(2), 114-116.

Greenfield, T. A. (1996). Gender, ethnicity, science achievement, and attitudes. *Journal of Research in Science Teaching*, **33**(8), 901-933.

Jensen, M. & Finley, F.N. (1995). Teaching evolution using historical arguments in a conceptual change strategy. *Science Education*, **79**(2), 147-166.

Klopfer, L.E. & Cooley, W.W. (1963). The history of science cases for high schools in the development of student understanding of science and scientists. *Journal of Research in Science Teaching*, **1**, 33-47.

Koballa, T. R. (1988). Attitude and related concepts in science education. *Science Education*, **72**(2), 115-126.

Langford, C. H. & Beebe, R. A. (1969). *The development of chemical principles*. New York: Dover.

Lin, H. S. (1992). *Trend analysis and prediction of students' science attitude and achievement in Taiwan, Republic of China*. Unpublished Doctoral Dissertation, University of Minnesota,

Minneapolis, MN.
Lin, H. S. (1998a, in press). The effectiveness of teaching chemistry through the history of science. *Journal of Chemical Education*.
Lin, H. S. (1998b, April). Promoting pre-service science teachers' understanding about the nature of science through history. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, California.
Matthews, M. B. (1994). *Science teaching: The role of history and philosophy of science*. New York: Routledge.
National Assessment of Educational Progress (NAEP) (1978). *Three national assessments of science education: Changes in achievement 1969-1977*. Denver: Author.
National Assessment of Educational Progress (NAEP) (1983). *NAEP Newsletter*, **16**(1).
National Science Teachers Association (NSTA) (1982). *Science-Technology-Society: Science education for the 1980s*. Position paper, Washington, DC: author.
Simpson, R. D. & Oliver, J. S. (1990). A summary of major influences on attitudes toward and achievement in science among adolescent students. *Science Education*, **74**(1), 1-18.
Snyder, C. H. (1995). *The extraordinary chemistry of ordinary things*. New York: John Wiley & Sons.
Soloman, J., Duveen, J., & McCarthy, S. (1992). Teaching about the nature of science through history: action research in the classroom. *Journal of Research in Science Teaching,* **29**(4), 409-421.
Taber, K. S. (1992). Science-related and gender appropriateness of careers: Some pupil perceptions. *Research in Science and Technology Education*, **10**, 105-115.
Wareing, C. (1982). Developing the WASP: Wareing Attitudes toward Science Protocol. *Journal of Research in Science Teaching*, **19**(8), 639-645.
Yager, R.E. (1986). What's wrong with school science? *The Science Teacher*, **1**, 145-146.

以科學史提升大學生對科學的態度

林煥祥

國立高雄師範大學化學系

摘　要

本研究探討了在大一普通化學中融入科學史教學，是否具有提升學生「對科學的態度」之效益。共有兩個非化學系的班級合計61位大一學生參與這個具有行動研究精神的準實驗研究。在為期一年的期間，研究者將三個科學史的單元融入現有課程中，對實驗組的學生進行教學。學年結束時，將量的數據進行共變數分析。以後測之科學態度量表得分為依變項，前測得分為共變項，所得結果發現，實驗組學生「對科學的態度」表現顯著優於控制組。另外由晤談所得之質的資料，也可看出科學史的教學具有正面之效益。