AN INVESTIGATION OF TAIWANESE EARLY ADOLESCENTS' VIEWS ABOUT THE NATURE OF SCIENCE

Chao-Ming Huang, Chin-Chung Tsai, and Chun-Yen Chang

ABSTRACT

This study developed a Pupils' Nature of Science Scale, including the subscales of the invented and changing nature of science, the role of social negotiation on science, and cultural context on science, to assess early adolescents' views about the nature of science. More than 6,000 fifth and sixth graders in Taiwan responded to the Scale. The study revealed that the adolescents had quite different perspectives toward different subscales of the nature of science. Moreover, male adolescents tended to express more constructivist-oriented views toward the nature of science than did their female counterparts. The adolescents of different grades and races also displayed varying views toward the nature of science.

INTRODUCTION

There is no doubt that science is one of the major school subjects for adolescent students. The goal of science education is not only to help students acquire scientific knowledge, but to understand its development. In other words, science education should not only teach what science is, but also how scientific knowledge is constructed through a series of complex interactions among different views, such as cultural and social. Traditional science education focuses mainly on the acquisition of scientific facts, but very little on the process as well as the nature of developing scientific knowledge (Duschl, 1990). That is, sci-

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Chao-Ming Huang, Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan.

Chin-Chung Tsai, Center for Teacher Education and Institute of Education, National Chiao Tung University, Hsìnchu, Taiwan

Chun-Yen Chang, Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan.

Requests for reprints should be sent to Prof. Chin-Chung Tsai, Center for Teacher Education and Institute of Education, National Chiao Tung University, 1001 Ta Hsueh Rd., Hsinchu 300, Taiwan. E-mail address: cctsai@mail.nctu.edu.tw

ence curricula, teachers, and students may not have an appropriate understandings of the nature of science, and most of them express empiricist-aligned (in contrast to constructivist) views about the nature of science (Lederman, 1992).

During the past five decades, many studies have investigated teachers' and students' views about the nature of science and their potential impacts (Elby & Hammer, 2001; Pomeroy, 1993; Songer, & Linn, 1991; Tsai, 1998a,b, 2002). In these previous studies, a consensus had probably emerged that views about the nature of science would influence or relate to the learning process and the ways of constructing knowledge in science. For example, Tsai (1998b) indicated that students' views about the nature of science were significantly correlated with their cognitive structure outcomes. Moreoever, these views may guide their capacity for metacognition (Tsai, 2001). Consequently, an exploration of students' views about the nature of science is an important research issue for science educators. Some instruments have been developed to assess these views. For example, Pomeroy (1993) developed a questionnaire to investigate conceptions of the nature of science. This type of questionnaire often employed a one-dimensional assessment to represent the nature of science. The students' final scores on the nature of science questionnaire would be used to categorize them into two or three poles, such as constructivist versus non-constructivist (Tsai, 1998a), traditional views of science versus non-traditional (Pomeroy, 1993), or static, mixed, and dynamic (Songer & Linn, 1991).

Some researchers proposed the multiple-dimensional characteristics of the nature of science (e.g., Tsai, 2000a, 2002; McComas, 1996), in which the student's views regarding the nature of science would vary with different epistemological dimensions (Tsai, 2002). For example, a person may disagree with the constructivist-oriented assertion that "observations are theory-laden," but he or she may support the other constructivist-oriented perspective that "social negotiations play an important role for science." In other words, a student might be categorized as "constructivist" in one dimension, but as "non-constructivist" (or have an empiricist view) in other dimensions of the nature of science (Tsai, 2002). Since previous studies seemed not to carefully assess students' views about the nature of science in multiple dimensions, this study tried to develop such an instrument.

After reviewing related articles about the nature of science (e.g., Duschl, 1990; Lederman, 1992; Tsai, 1998c), three important dimensions were selected for investigation. The first dimension addresses the perspective that scientific knowledge is invented and changing; i.e., that scientific knowledge originates from scientists' invention and

the state of scientific knowledge is tentative and dynamic. Therefore, the development of science is a process of conceptual evolution or sometimes revolution.

The second dimension of the nature of science is related to the role of social negotiation in the development of scientific knowledge. Not only is scientific knowledge invented by scientists, but it is also required that it be accepted by other contemporary scientists. All scientific knowledge must be carefully examined and confirmed by the scientific community. This process involves a series of negotiations until a consensus is reached.

The third dimension of the nature of science is the impact of cultural context—that the development of scientific knowledge cannot be isolated from the cultural context. In sum, this study selected these three major dimensions of the nature of science: the invented and changing nature of science, the role of social negotiation, and the role of the culture.

Although some researchers have tried to explore students' views of the nature of science, most paid more attention to older students. Therefore, this study developed a questionnaire to help understand early adolescents' (5th and 6th graders) views of the nature of science in multiple dimensions. Research also reveals that early adolescents have already developed their own conceptions of the nature of science (e.g., Smith et al., 2000). In administering the questionnaire, grade and gender differences were analyzed. Further, since the sample included aboriginal students, a comparison of their views and those of non-aboriginal adolescents was undertaken.

METHOD

The Questionnaire

To develop the Pupils' Nature of Science Scale (PNSS), three subscales were constructed on adolescents' views of the nature of science, i.e., the invented and changing nature of science, the role of social negotiation, and the cultural context. Based upon the work of Pomeroy (1993) and Tsai (1998a, 1999a, 2002), and by consulting with experts in science education, 15 items were chosen for the questionnaire. Each subscale contained 5 items. All items were presented in the Chinese language. The following three statements are samples of the respective subscales.

1. The development of science knowledge requires scientists' creativity and imagination (invented and changing nature of science).

2. Acceptable science knowledge needs to be recognized by most scientists in the field (the role of social negotiation on science).
3. Science knowledge is not different based on the scientists' cultural background (the cultural context on science, stated in a reverse manner).

The questionnaire consisted of bipolar agree-disagree statements on a 5-1 Likert scale. Some items in the PNSS stated from an empiricist-oriented (or non-constructivist-oriented) perspective were scored in a reverse manner. Students who attained high scores on the subscale of invented and changing nature of science tended to believe that the development of science knowledge involved many invented acts and that science knowledge is always changing. Students with high scores on the subscale of social negotiation tended to support the idea that the role of social negotiation among scientists is very important for the accumulation of knowledge. Students with high scores on the subscale of cultural context expressed the view that the science knowledge was affected by complicated cultural factors. Thus, students with high scores had constructivist views about science.

One might argue that since early adolescents may not yet be confident about their views on the nature of science, the data may not be of value for further analyses. Therefore, to assess respondents' certainty about their views, they were asked to answer the following question: "Concerning your choice, I am (1) Sure (2) Unsure." Students who noted that they were "unsure" about any item would not be considered valid respondents for this study. Additionally, non-responses, unintentional omission, or unidentifiable marks on items resulted in the exclusion of those respondents from the final analysis. In sum, only students who completed 15 items with certainty were regarded as appropriate for the study.

Sample

The study was conducted in I-Lan county located in northeast Taiwan. All questionnaires were mailed to 71 local schools. All 5th and 6th graders were asked to complete the PNSS. After excluding the incomplete questionnaires and those with uncertain responses (about 2000) 6,167 valid questionnaires remained for statistical analysis—3,038 boys (49.3%) and 3,129 girls (50.7%). This sample size was considered large enough to represent early adolescents in Taiwan.

Data Analysis

An exploratory factor analysis was applied to clarify the structure of item factors. Principle component analysis with varimax rotation to

reveal the structure of PNSS was used. The PNSS response differences on some variables, such as grade level, gender and race, which were analyzed by a series of independent t-tests, were investigated further.

FINDINGS

Three factors, as expected, were revealed in PNSS. A questionnaire item was retained only when it loaded greater than 0.50 on the relevant factor, and less than 0.50 on the nonrelevant factor. As a result, the initial 15 items were reduced to 11 items.

Table 1 shows that the eigenvalues of the three factors (invented and changing nature of science, the role of social negotiation, and cultural context) from the principle component analysis were all greater than one: 2.91, 1.96, and 1.04, respectively. These three factors (subscales) accounted for 53.73% of the variance. Internal reliability, alpha coefficient, was acceptable for the three subscales (0.68, 0.62, and 0.69, respectively).

Table 2 shows students' descriptive results on the three subscales. The mean item score for invented and changing nature of science was 4.36, for the social negotiation of science it was 3.91, and for the cultural context on science it was 2.78. These results might imply that the early adolescents, on average, held constructivist-oriented views toward the first two dimensions of the nature of science, but that they probably did not strongly support the view that the cultural context had an essential impact on the development of science. In particular, although the respondents had grown up in a non-western cultural environment, they still believed that the cultural context might not have played an important role in the development of science. This finding also seems to coincide with that revealed in Tsai's (2002) study that people may have different perspectives on different dimensions of the nature of science, i.e., an individual may be more constructivist-oriented about the invented and changing nature of science, but may have less such views about the role of cultural context.

Table 3 presents an analysis of results by grade level, indicating a significant difference in the invented and changing nature of science subscale when the responses of 5th graders and 6th graders ($t = -3.51$, $p < .01$) are compared. The results suggest that the 6th graders were more constructivist-oriented on the dimension of the invented and changing nature of science than were 5th graders.

Table 4 shows the results by gender. There were significant differences by gender on the subscales of the invented and changing nature

of science and the role of social negotiation of science ($p < .01$). Male early adolescents tended to show significantly more agreement in their perspectives on the invented and changing nature of science and the role of social negotiation than did their female counterparts. The findings indicate that male students tended to have a better understanding of the nature of science than did females on these two dimensions.

Table 5 displays the results based on race. Respondents had been classified into two racial categories: non-aboriginal ($n = 5{,}875$) and aboriginal students ($n = 292$). In the invented and changing nature and cultural context subscales, the scores of non-aboriginal students were significantly higher than those of the aboriginal students ($p < .05$). These results suggested that the aboriginal students tended to express less constructivist-oriented views toward the invented and changing nature of science and the role of cultural context than did non-aboriginal students.

CONCLUSIONS

This study provides a relatively detailed exploration of early adolescents' views of the nature of science on the basis of three dimensions. Thus, the questionnaire developed for this study can be helpful to elementary school science educators who are interested in exploring students' views about the nature of science.

Very few studies have explored gender differences on the nature of science, while numerous studies investigated gender differences on science achievement and attitudes (e.g., Kenway & Gough, 1998). Previous research on adolescents' views about the nature of science have focused on the change in their views through instruction, (e.g., Khishfe & Abd-El-Khalick, 2002; Smith et al., 2000), or explored the relationship between views of the nature of science and learning orientations (e.g., Tsai, 1998a). The present study revealed some differences between boys and girls in their views about the nature of science; male adolescents tended to express more constructivist views than their female counterparts. Research has also supported the finding that constructivist-oriented views about science help students develop better knowledge frameworks and learning strategies in science (Tsai, 1998a,b, 1999b, 2000b). Science teachers are encouraged to utilize various strategies to enhance female adolescents' understanding of the nature of science; for example, Science-Technology-Society instruction (an integrated teaching approach which emphasizes the complex interplay among science, technology, and society).

Table 1

Rotated Factor Loadings and Cronbach's Alphas for the Three Factors of the PNSS (N = 6,167)

Item	Factor 1	Factor 2	Factor 3
1	0.662		
2	0.686		
3	0.691		
4	0.726		
5		0.693	
6		0.794	
7		0.614	
8			0.713
9			0.807
10			0.596
11			0.715
Eigenvalue	2.91	1.96	1.04
Variance (%)	26.46	17.79	9.48

Note. Factor 1: invented and changing nature of science (α = 0.68); Factor 2: the role of social negotiation (α = 0.62); Factor 3: cultural context (α = 0.69). Total variance explained: 53.73%.

Table 2

Students' Scores on the PNSS Subscales (N = 6,167)

Subscale	Items	Range	M (per item)	SD
Invented and changing nature of science	4	4–20	17.42 (4.36)	2.39
The role of social negotiation	3	3–15	11.74 (3.91)	2.40
Cultural context	4	4–20	11.10 (2.78)	3.90

Table 3

Students' Scores on the PNSS Subscales, by Grade (N = 6,167)

Subscale	Grade	M (per item)	SD	t
Invented and changing nature of science	5	17.32 (4.33)	0.61	-3.51**
	6	17.53 (4.38)	0.59	
The role of social negotiation	5	11.72 (3.91)	0.81	-0.57
	6	11.76 (3.92)	0.79	
Cultural context	5	11.17 (2.79)	0.98	1.42
	6	11.03 (2.76)	0.97	

Note. n = 3,047 for 5th graders; n = 3,120 for 6th graders. **p < .01

Table 4

Students' Scores on the PNSS Subscales, by Gender (N = 6,167)

Subscale	Gender	M (per item)	SD	t
Invented and changing nature of science	Male	17.53 (4.38)	0.60	3.34**
	Female	17.32 (4.33)	0.59	
The role of social negotiation	Male	11.86 (3.95)	0.82	3.90**
	Female	11.62 (3.87)	0.78	
Cultural context	Male	11.11 (2.78)	1.03	0.16
	Female	11.10 (2.77)	0.92	

Note. n = 3,038 for males; n = 3,129 for females. **p < .01

Table 5

Students' Scores on the PNSS Subscales, by Race (N = 6,167)

Subscale	Race	M (per item)	SD	t
Invented and changing nature of science	Non-aboriginal	17.44 (4.36)	0.59	2.60*
	Aboriginal	17.03 (4.26)	0.66	
The role of social negotiation	Non-aboriginal	11.73 (3.91)	0.80	-1.60
	Aboriginal	11.93 (3.97)	0.72	
Cultural context	Non-aboriginal	11.14 (2.79)	0.97	3.52**
	Aboriginal	10.32 (2.58)	0.99	

Note. n = 5,875 for non-aboriginal; n = 292 for aboriginal. *p < .05, **p < .01

This study revealed the differences between non-aboriginal and aboriginal early adolescents' views about the nature of science. Teachers in Taiwan need to develop instructional activities that improve aboriginal students' understanding of the nature of science; integration of science instruction with some aboriginal or indigenous theories about nature may help students understand the invented feature of scientific knowledge as well as the cultural impact.

This study presents a convenient tool for science teachers to assess early adolescents' views of the nature of science across different dimensions. Through use of this tool, educators and researchers can move to deeply explore the role of early adolescents' views about the nature of science.

REFERENCES

Elby, A., & Hammer, D. (2001). On the substance of a sophisticated epistemology. *Science Education, 85,* 554–567.

Duschl, R. A. (1990). *Restructuring science education: The importance of their development.* New York: Teachers College Press.

Kenway, J., & Gough, A. (1998). Gender and science education in schools: A review "with attitude." *Studies in Science Education, 31,* 1–30.

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of the nature of science. *Journal of Research in Science Teaching, 39,* 551–578.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29,* 331–359.

MaComas, W. F. (1996). Ten myths of science: Reexamining what we think we know about the nature of science. *School Science and Mathematics, 96,* 10–16.

Pomeroy, D. (1993). Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education, 77,* 261–278.

Smith, C. L., Maclin, D., Houghton, C., & Hennessey, M. G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction, 18,* 349–422.

Songer, N. B., & Linn, M. C. (1991). How do students' views of science influence knowledge integration? *Journal of Research in Science Teaching, 28,* 761–784.

Tsai, C. C. (1998a). An analysis of scientific epistemological beliefs and learning orientations of Taiwanese eighth graders. *Science Education, 82,* 473–489.

Tsai, C. C. (1998b). An analysis of Taiwanese eighth graders' science achievement, scientific epistemological beliefs and cognitive structure outcomes after learning basic atomic theory. *International Journal of Science Education, 20,* 413–425.

Tsai, C. C. (1998c). Science learning and constructivism. *Curriculum and Teaching, 13,* 31–51.
Tsai, C. C. (1999a). The progression toward constructivist epistemological views of science: A case study of the STS instruction of Taiwanese high school female students. *International Journal of Science Education, 21,* 1201–1222.
Tsai, C. C. (1999b). Laboratory exercises help me memorize the scientific truths: A study of eighth graders' scientific epistemological views and learning in laboratory activities. *Science Education, 83,* 654–674.
Tsai, C. C. (2000a). Relationships between student scientific epistemological beliefs and perceptions of constructivist learning environments. *Educational Research, 42,* 193–205.
Tsai, C. C. (2000b). The effects of STS-oriented instruction on female tenth graders' cognitive structure outcomes and the role of student scientific epistemological beliefs. *International Journal of Science Education, 22,* 1099–1115.
Tsai, C. C. (2001). A review and discussion of epistemological commitments, metacognition, and critical thinking with suggestions on their enhancement in internet-assisted chemistry classrooms. *Journal of Chemical Education, 78,* 970–974.
Tsai, C. C. (2002). A science teacher's reflections and knowledge growth about STS instruction after actual implementation. *Science Education, 86,* 23–41.