Science & Education **10:** 51–70, 2001.

History, Philosophy and Sociology of Science in Science Education: Results from the Third International Mathematics and Science Study

HSINGCHI A. WANG
US TIMSS, College of Education, Michigan State University, East Lansing, MI 48824, USA; E-mail: wanghs@pilot.msu.edu

WILLIAM H. SCHMIDT
US TIMSS, College of Education, Michigan State University, East Lansing, MI 48824, USA; E-mail: bschmidt@pilot.msu.edu

Abstract. Throughout the history of enhancing the public scientific literacy, researchers have postulated that since every citizen is expected to have informal opinions on the relationships among government, education, and issues of scientific research and development, it is imperative that appreciation of the past complexities of science and society and the nature of scientific knowledge be a part of the education of both scientists and non-scientists. HPSS inclusion has been found to be an effective way to reach the goal of enhancing science literacy for all citizens. Although reports stated that HPSS inclusion is not a new educational practice in other part of the world, nevertheless, no large scale study has ever been attempted to report the HPSS educational conditions around the world. This study utilizes the rich data collected by TIMSS to unveil the current conditions of HPSS in the science education of about forty TIMSS countries. Based on the analysis results, recommendations to science educators of the world are provided.

1. Introduction

The mission of science education has been to prepare individuals who would develop a certain level of scientific understanding after their formal education in school. These scientifically literate individuals would be capable of applying their knowledge and skills acquired in science, whenever personal or socially relevant issues demanded such understanding. For instance, by having an understanding of science contents such as Physiology, Biology, and Chemistry, scientifically literate individuals would be able to use reason to form their opinions and draw their conclusions about such health-related issues as nutrition awareness and medicine usage, rather than being misled or duped by propaganda or positions not supported by evidence. Scientifically literate citizens would know how to evaluate cases when DNA evidence was involved in criminal trials. They would also be able to understand who the qualified scientists are and what they are doing, what processes they anticipate will be involved in their research investigations, and how their findings

matter to the welfare of society. Some of these scientifically literate individuals might develop a passion for and confidence in science and decide to become scientists. Perhaps some of these scientifically literate individuals who are capable of making reasonable judgements would become policymakers, and they might then decide to provide support for the budget of some critical science research and development projects.

The history of science, philosophy of science, and sociology of science (HPSS) inclusion has been found to be an effective way to reach the goal of enhancing science literacy for all citizens (Anderson and Smith 1986; Brush 1974; Conant 1964; Finley 1983; Klopfer 1969; Klopfer and Watson 1957; Matthews 1994; 1999; Quattropani 1977; Rutherford and Ahlgren 1990; Villani and Arruda 1998; Wandersee 1985; 1990). HPSS were included in the first nationwide content standards document for American K-12 school science, *Benchmarks for Science Literacy* (American Association for the Advancement of Science 1993). Other national standards documents in science education, including the *National Science Education Standards*, also state that students should know the HPSS (National Research Council 1996). Wang and Marsh (2001) report that the recommendation to include the history of science, in recent science education reform reports, is based on a specific rationale: to provide a meaningful context for both scientific information and the operation of the scientific enterprise. The rationale also applied to the inclusion into science education of the philosophy of science and sociology of science.

The three eras in American science education reviewed by Wang and Marsh (2001) – *The Golden Age of Science Education: Post-Sputnik Reactions*, *Science Education for Enlightened Citizenry*, and *Standards-Based Science Education Reform* – have shown that to include the HPSS is not a new proposal to humanize science in American science education. Although Matthews (1994) reports that HPSS inclusion is also not a new educational practice in other parts of the world, nevertheless, no large scale study has ever been attempted to report the HPSS educational conditions around the world.

This study utilizes the rich data collected by TIMSS to unveil the current conditions of HPSS in the science education of about forty TIMSS countries. Specifically, the report of HPSS educational conditions in this study includes: (1) educational officials' reports of HPSS coverage, (2) curriculum guides' HPSS coverage, (3) science textbooks' HPSS coverage, and (4) teachers' report of HPSS practices. Through this report, it addresses the questions concerned by science education worldwide: How much are students expected to learn in HPSS? What are the educational opportunities in delivering HPSS? The results from this study can serve as a framework to further probing serious issues, such as: What have students learned in HPSS worldwide? How does the way HPSS is delivered or learned relate to students' general achievement in the sciences?

2. Third International Mathematics and Science Study

The Third International Mathematics and Science Study (TIMSS) is the most extensive and far-reaching cross-national comparative study of mathematics and science education ever attempted (Beaton et al. 1996; Schmidt and McKnight 1995; Schmidt et al. 1997). It includes comparisons of the official curricula, textbooks, teacher practices, and student achievement of 20 to 50 countries (the number depending on the particular comparison subject groups) Thousands of official documents and textbooks were analyzed. Thousands of teachers, principals, and other experts responded to survey questionnaires. More than half a million children in over 40 countries were tested in mathematics and science. These tests were conducted for nine-year-olds (grades three and four, in the US), thirteen-year-olds (grades seven and eight, in the US), and students in the last year of secondary school (twelfth grade, in the US).

Meaningful measurement of educational systems requires a comprehensive conceptual framework and a corresponding array of measures designed to relate the various parts of the system to each other and with their outcomes. The Conceptual Framework (Figure 1) behind TIMSS was developed to achieve this objective and has been widely presented in various TIMSS publications (Schmidt et al. 1996; Schmidt et al. 1997; Schmidt and McKnight 1995). This model describes delivery of content-related educational experiences that was used to in the design of measures and analyses for the TIMSS. The links in this model were accomplished through the TIMSS. It is our belief that this design can assist us in delineating the relationships we intend to study about the HPSS educational conditions and their relationships toward achievement in the TIMSS countries.

TIMSS data were coded using multiple methods. In this study, we report the HPSS conditions based on the HPSS areas included in the *Content Codes* (Robitaille et al. 1993), which are:

1.4.3.1	Influence of Science, Technology on Society
1.4.3.2	Influence of Society on Science, Technology
1.5	History of Science & Technology
1.7.1	Nature of Scientific Knowledge
1.7.2	The Scientific Enterprise

The data used in this study originated from TIMSS: (1) Grades one through twelve's HPSS curriculum coverage in the educational officials' reports, which is known as the *General Topic Tracing Map (GTTM)*, (2) HPSS coverage in the curriculum guides for the middle school years, (3) HPSS coverage in the science textbooks for the middle school years, and (4) HPSS instructional practices in terms of the proportion of the middle school teachers who have reported that they taught HPSS, and the percentage of their time spent teaching HPSS topics. Following

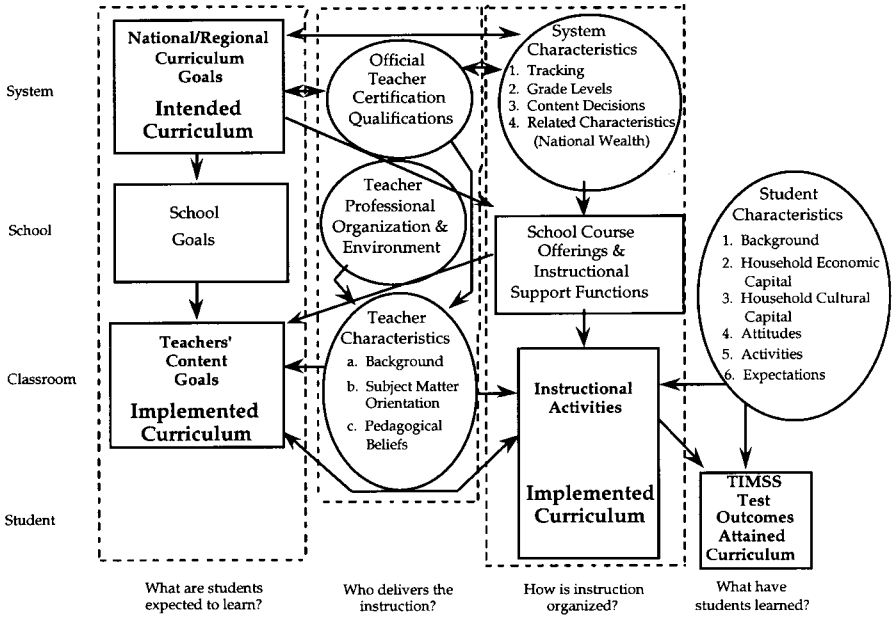


Figure 1. TIMSS conceptual framework: A model of educational experiences.

are further descriptions of the data sources. More detailed information as to how these data were collected, organized, and analyzed is provided in TIMSS technical reports:

1. *General Topic Tracing Map (GTTM).* Respondents to the GTTM were educational officials of each nation utilizing their national content standards or an aggregate of regional standards. They indicated intended coverage of a content area in a given grade by circling the age corresponding to the age most students were at the beginning of that grade. Therefore, the upper grade of Population One in TIMSS should correspond to age 9 (lower grade should be age 8), the upper grade of Population Two in TIMSS is age 13 (lower grade is age 12). Population Three GTTM data may be more difficult to read because, unless otherwise noted in their identifier, it was to be for students not in the specialist group. Thus, the last grade reported in the GTTM data may not be the last grade in school, because it may not be typical in all countries for nonspecialists to take math or science in their last year(s) of school.
2. *Official Curriculum Guides.* TIMSS national document samples of the curriculum guides comprised, as appropriate for each country, (a) the national science curriculum guide or guides (if any) covering each grade, and (b) regional, provincial, state, or cantonal science curriculum guides covering each grade (if needed). The resulting sample for the 48 TIMSS countries included 77 science curriculum guides for the upper grade of Population One, 111 for the upper grade of Population Two, and 62 for the physics specialists in Population

Three, for a total of 250 curriculum guides (Schmidt et al. 1997). The data in this study originated from the coding results of 111 curriculum guides at Population Two.

3. *Science Textbooks*. TIMSS national document samples of the science textbooks included (a) official national science textbooks (if any), and (b) the most widely used commercial textbooks if "officially" provided books were not used. The resulting sample for the 48 TIMSS countries included 75 science textbooks for the upper grade of Population One, 155 for the upper grade of Population Two, and 60 for the physics specialists in Population Three, for a total of 290 sampled science textbooks (Schmidt et al. 1997). Only the Population Two data were applied in this study.
4. *Teachers Responses*. Data collected from teachers were mainly based on their returned responses to TIMSS Teacher Questionnaires. The questionnaires were given to the teachers of the sample student populations. The questionnaires were extensive in terms of areas to be explored and required an average of 60 minutes to fill out. In this study, we only used the data of the Science Topics section from Population Two, and specifically the questions of:

   0037: How long did you spend teaching each of these topic areas to your class this year?
   Topic (t) Science, technology, and society
   Topic (u) History of science and technology
   Topic (v) Nature of science

   The data collected from teachers were organized into: (1) the proportion of teachers who reported that they taught HPSS, and (2) the percentage of time they spent teaching HPSS.

TIMSS science test was designed to test students' general science achievement; HPSS areas were only one small part of the test. Compared to the other two Populations, the test items in Population Two included relatively more HPSS areas. In a follow-up study, students' achievement results used are those of Population Two. Table I displays the sample size and the average age of the eighth graders who participated in TIMSS achievement tests.

3. Intended and Implemented HPSS

3.1. THE HPSS CURRICULUM COVERAGE IN GRADES ONE THROUGH TWELVE

While advocacy is growing for spending more time enhancing students' experiences in HPSS, the actual state of HPSS areas in the school science curricula of 42 TIMSS countries is illustrated in Figures 2 to 6; these data originated from the GTTM survey, to which each nation's educational officials responded. The topic of *History of Science and Technology* was reportedly included, in at least one grade level in 29 out of 42 countries, as the most popular topic of HPSS areas.

Table I. Participating TIMSS countries (Population Two)

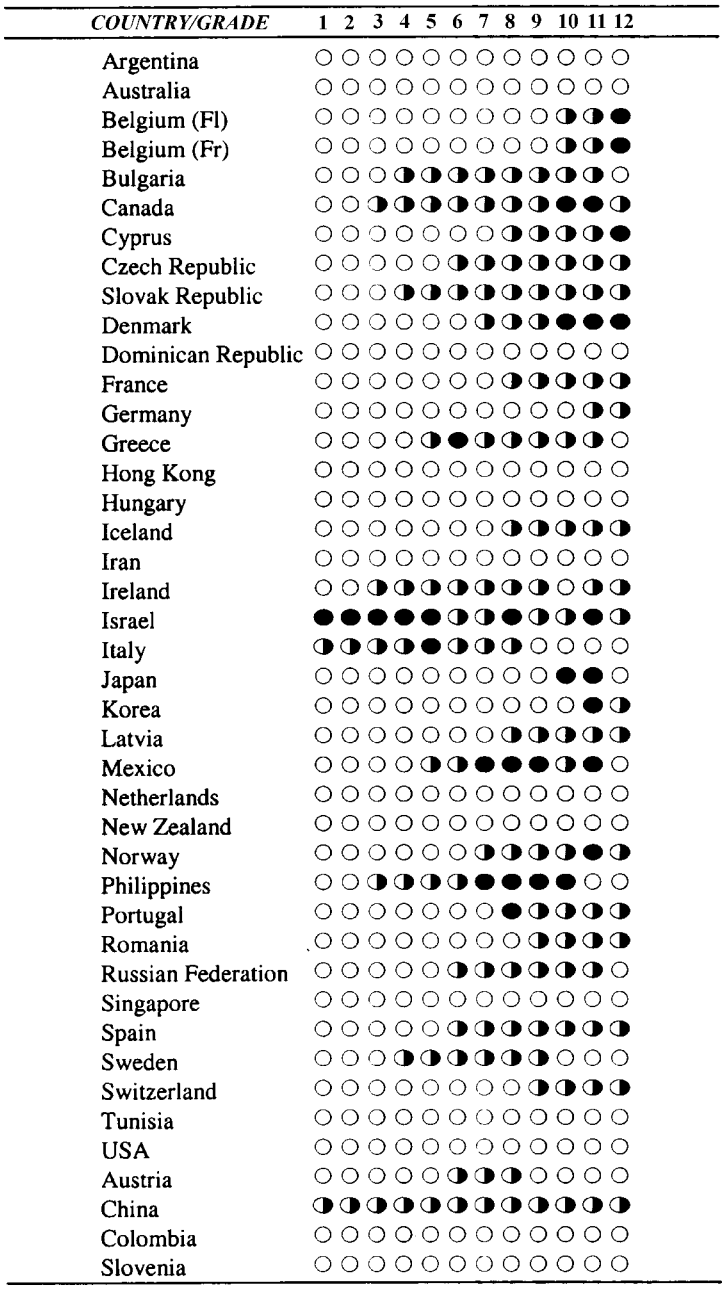
COUNTRY	SIZE	AGE of 8th graders
Australia	17843.0	14.2
Austria	8028.0	14.3
Belgium (Fl)	10116.0	14.1
Belgium (Fr)	10116.0	14.3
Bulgaria	8435.0	14.0
Canada	29248.0	14.1
Colombia	36330.0	15.7
Cyprus	726.0	13.7
Czech Republic	10333.0	14.4
Denmark	5205.0	13.9
England	48533.0	14.0
France	57928.0	14.3
Germany	81516.0	14.8
Greece	10426.0	13.6
Hong Kong	6061.0	14.2
Hungary	10261.0	14.3
Iceland	266.0	13.6
Iran	62550.0	14.6
Ireland	3571.0	14.4
Israel	5383.0	14.1
Japan	124961.0	14.4
Korea	44453.0	14.2
Kuwait	1620.0	15.3
Latvia	2547.0	14.3
Lithuania	3721.0	14.3
Netherlands	15381.0	14.3
New Zealand	3493.0	14.0
Norway	4337.0	13.9
Portugal	9902.0	14.5
Romania	22731.0	14.6
Russian Federation	148350.0	14.0
Scotland	5132.0	13.7
Singapore	2930.0	14.5
Slovak Republic	5347.0	14.3
Slovenia	1989.0	14.8
South Africa	40539.0	15.4
Spain	39143.0	14.3
Sweden	8781.0	13.9
Switzerland	6994.0	14.2
Thailand	58024.0	14.3
USA	260650.0	14.2

Influence of Science, Technology on Society was reported as a curriculum topic by 28 countries as the second most popular topic to science classrooms worldwide. Whereas the topic *The Scientific Enterprise* was only reported by 13 countries as a curriculum topic, the least likely HPSS topic being introduced to science classrooms worldwide.

Most countries, as shown in Figures 2 to 6, have exhibited a trend, which is that any HPSS topic could be "introduced" (the half-shaded circle) in any grade level, but rarely has any particular topic become a "focused" (the full-shaded circle) topic in science classrooms for a nation. This trend has few exceptions; The French curriculum official reported that the *Nature of Scientific Knowledge* topic was introduced in grades one through three and started to be a focused topic from grades four through twelve. France, as shown in the Figure 5, was the only country to exhibit such an emphasis on an HPSS topic. The Israeli curriculum official reported the *History of Science and Technology* topic as being a focused science topic from grade one through five and staying in the curriculum for sixth through twelfth grades, but Figure 2 indicates that it became a focused topic in grades eight and eleven. Philippine curriculum officials indicated that in grades seven through ten, every HPSS topic except *The Scientific Enterprise* was a focused science topic. These HPSS topics in the Philippines were introduced at grade three and ended at tenth grade. *The Scientific Enterprise* was introduced at grades seven and eight and focused at grades nine and ten in the Philippines (Figure 4). The Danish curriculum official indicated that for more than five years the topic of *Influence of Society on Science, Technology* had been a focused science topic later on in Denmark students science education (Figure 6).

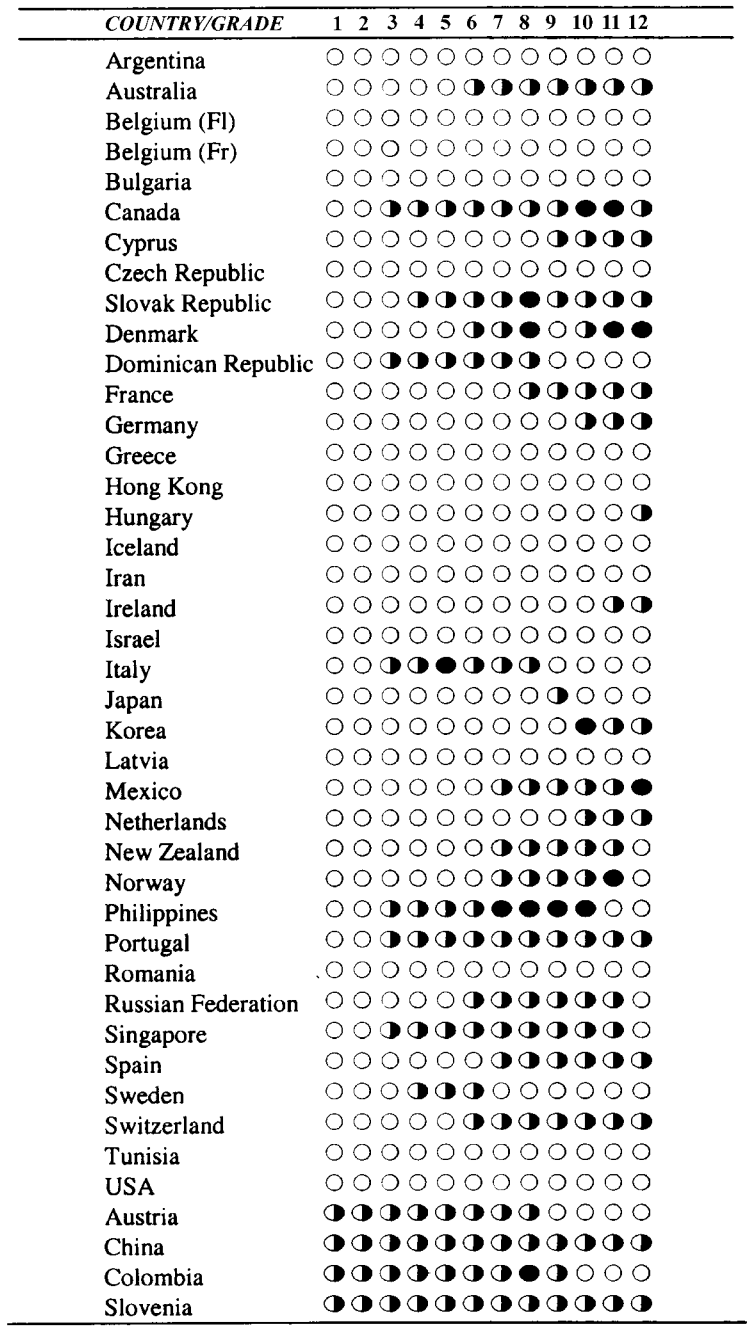
There are countries that covered some HPSS topics at every grade level. *Influence of Science, Technology on Society* was introduced in every grade level in China and Slovenia (Figure 3). *History of Science and Technology*, as stated above, was reported to be covered in every grade in Israel and introduced to every grade in China (Figure 2). *Nature of Scientific Knowledge* was covered in every grade reported by curriculum officials of Canada, Cyprus, France, Portugal, the United States, and Slovenia (Figure 5). Canada and Slovenia are the only two countries reported to be covering *The Scientific Enterprise* in every single grade's science education (Figure 4).

According to Figures 2 to 6, it would be difficult to infer what is the appropriate grade to introduce HPSS topics to the science classroom; yet as reported by the officials, the most common years of introducing any HPSS topic are grades one,[1] three, [2] and seven. [3] There are some countries' curriculum officials, however, who indicated that HPSS topics have never been covered in any grade of pre-college science education curricula; they are Argentina, Hong Kong, Iran, and Tunisia.



○ Not Included in the Curriculum; ◑ Included in the Curriculum; ● Focused in the Curriculum

Figure 2. Presence of the topic *History of Science & Technology* in grades 1–12 for the TIMSS countries.



○ Not Included in the Curriculum; ◑ Included in the Curriculum; ● Focused in the Curriculum

Figure 3. Presence of the topic *Influence of Science, technology on Society* in grades 1–12 for the TIMSS countries.

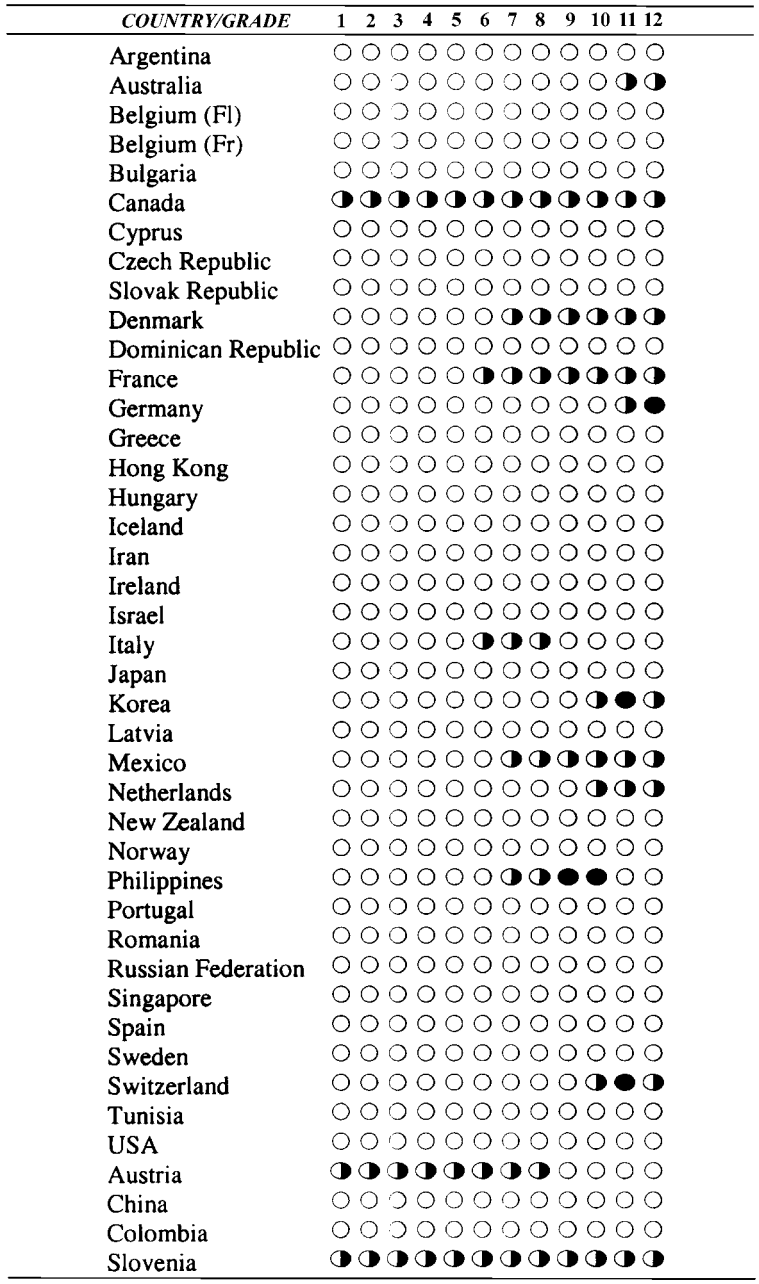


Figure 4. Presence of the topic *The Scientific Enterprise* in grades 1–12 for the TIMSS countries.

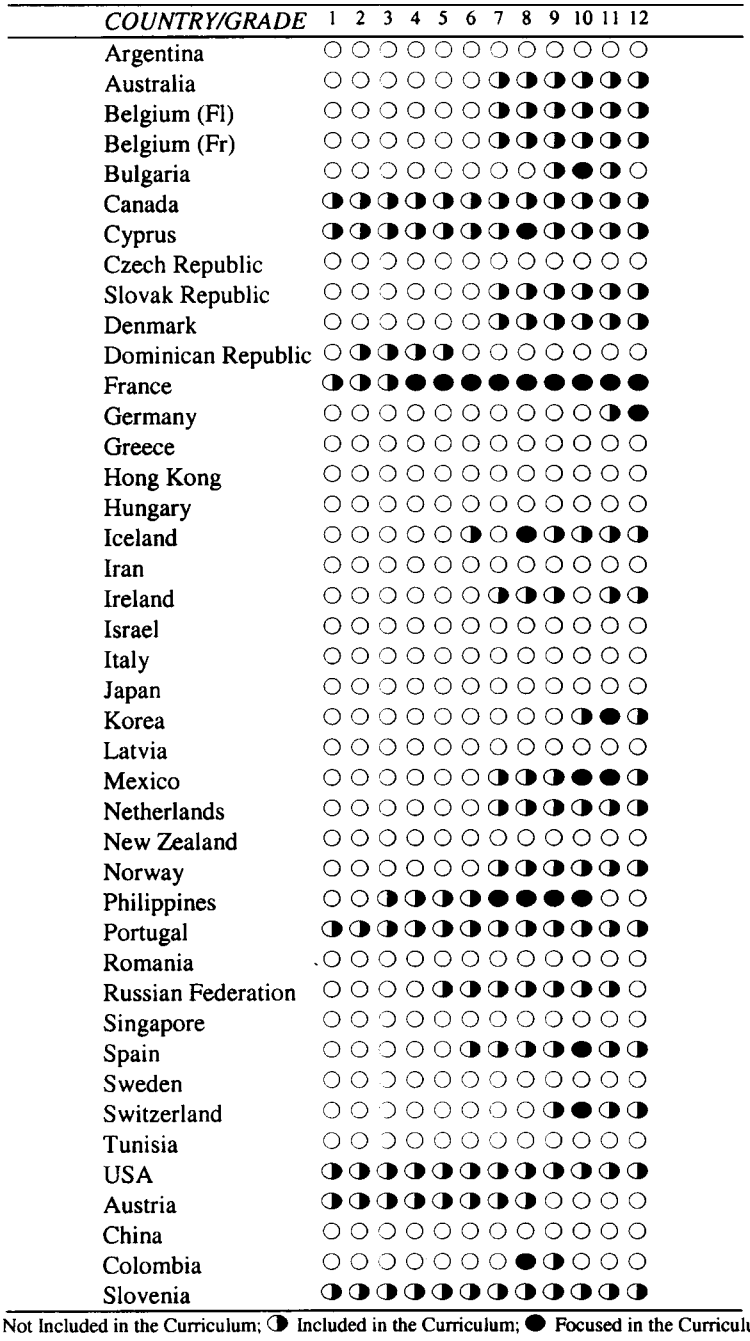


Figure 5. Presence of the topic *Nature of Scientific Knowledge* in grades 1–12 for the TIMSS countries.

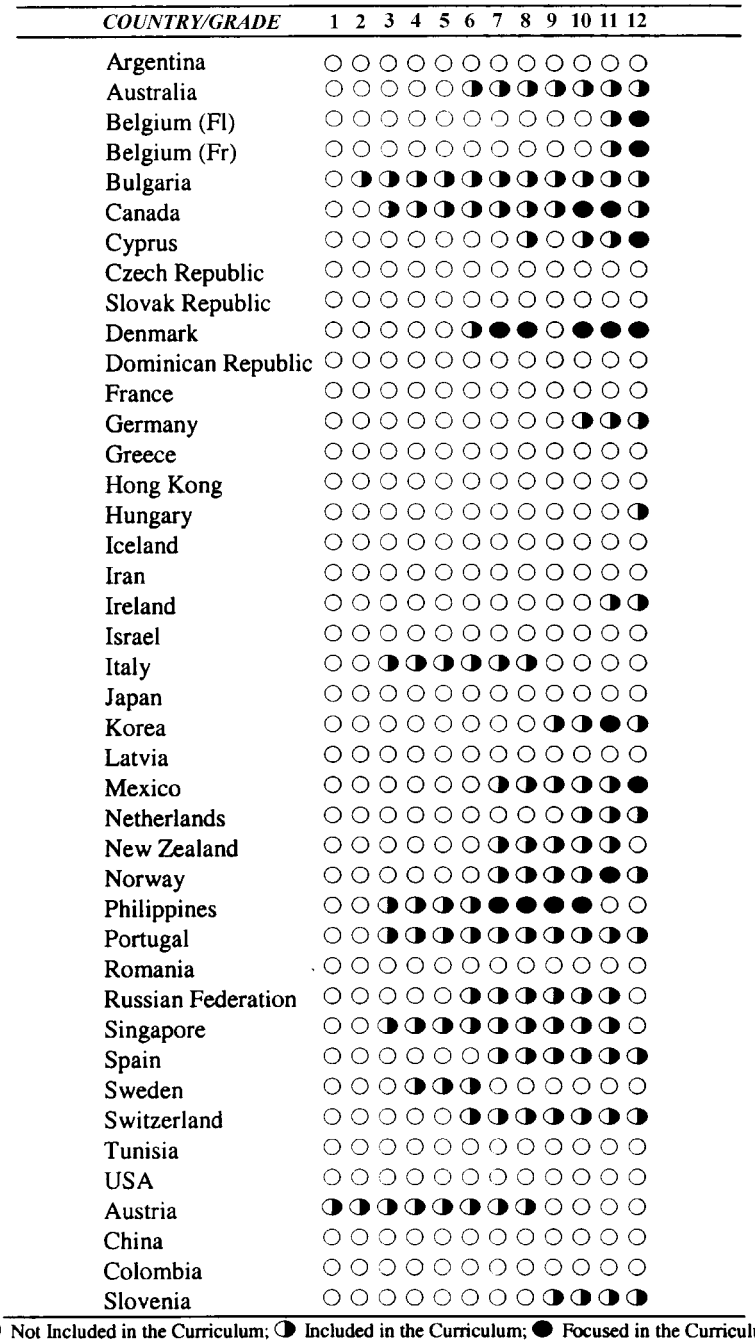


Figure 6. Presence of the topic *Influence of Society on Science, Technology* in grades 1–12 for the TIMSS countries.

3.2. THE HPPS COVERAGE IN CURRICULUM GUIDES AND SCIENCE TEXTBOOKS OF EIGHTH GRADERS

In TIMSS countries, curricular decisions on national goals, instructional content, examinations, and so on were made by groups, agencies, individuals in authority, or some combination of these (Schmidt et al. 1997). Despite the various conditions in the decision making, virtually all educational systems within TIMSS use some form of curriculum guide to structure science education. These guides set forth the system's goals for a nation's science education. "Countries differ widely in the structure and details of their guides and in how they are meant to be used" (Schmidt et al. 1997, p. 38). Furthermore, as described by Schmidt et al. (1997), TIMSS data showed that the decisions concerning textbooks were made jointly in about 42 percent of the systems and subsystems, most often involving a central authority and the school using the text. Individual teachers chose the textbooks for their classes in only about 9 percent of the systems and subsystems. Textbook data have indicated that the lengths of content vary, the sizes of the books vary, the formats vary, and the levels of decoration vary from country to country.

Figure 7 pins down issues regarding the educational intentions in HPSS areas from 36 TIMSS countries, that is, the countries that have both guide and textbook information for eighth grade. Nine out of 34 countries have included every HPSS topic in their guides. Only two out of these nine countries also covered every HPSS topic in their science textbooks.[4]

Issue of alignment between the textbooks and guides. Since 1986, the year the first national mathematics educational standards document was published in the United States, there has been an increase in the production of every subject's educational standards for American education. This exercise has further brought the American educational community to a discussion of the alignment between the intended educational objectives (standards or curriculum guides) and implemented education (instruction and instructional resources). Textbooks are perceived as "potential" implemented education because textbooks have persistently had a great influence on what is taught and how it is delivered in science. American science teachers were known to rely heavily on textbooks when they delivered science instruction (Hams and Yager 1981; Weiss 1978). Despite the new wave of science education reform that advocated that science instruction shift away from textbook-based instruction to kit-based instruction (Wang and Marsh 2001), TIMSS data indicate that teachers throughout the world base about 50 percent of their weekly teaching time on textbooks. Thus, there exists the need to examine the appropriateness of science textbooks in terms of their alignment with the guides.

The symbol "+"in Figure 7 represents countries that were found to have covered an HPSS topic in their textbooks; the symbol "$\bigcirc$" represents countries with an HPSS topic in their guides; and the symbol "$\oplus$" represents countries with an HPSS topic covered in both their guides and their textbooks. The topic *History of Science and Technology* was found again to be the most consistent topic covered by both

	Influence of S, T on Society	Influence of Society on S, T	History of S & T	Nature of Scientific K.	Sci. Enterpr.
Australia	○	○	⊕	⊕	○
Austria	⊕			○	
Canada	⊕	⊕	⊕	⊕	○
Colombia	○		○		
Czech Republic	+				
Denmark	○	○	○	○	○
Dominican Republic					
France	⊕	○	○		
Germany	○	○	+	○	
Greece					
Hong Kong				○	
Hungary	○	○	⊕	○	
Iceland	⊕	+	+	⊕	⊕
Ireland	○	○	⊕	⊕	
Israel			+	○	
Japan					
Korea	○		⊕		
Latvia	○	○	⊕	○	○
Mexico	○		⊕	○	
Netherlands	○	○		⊕	○
New Zealand	⊕	⊕	⊕	⊕	⊕
Norway	○	○	⊕	○	⊕
Philippines	+		+		
Portugal	⊕	⊕	⊕	⊕	○
Romania			○		○
Russian Federation	○	○	⊕	○	
Scotland	+		+	○	○
Singapore	○	○		○	
Slovak Republic	○	○		○	○
Slovenia	⊕	○	⊕	○	○
Spain	⊕		⊕	○	⊕
Sweden	○	○	⊕		
Switzerland	○	○	⊕	○	
USA	⊕	⊕	⊕	⊕	⊕

+ Covered in Textbook; ○ Covered in Guide; ⊕ Covered in Both Guide & Textbook

Figure 7. Coverage of HPSS topics in 8th grade as found in curriculum guides and textbooks.

guides and textbooks (16 countries showed this consistency). *Influence of Science, Technology on Society* is another topic that has relatively more consistency between guides and the textbooks (9 out of 34 countries). New Zealand and USA are the only two countries showing perfect alignment in all five HPSS topics between the guides and the textbooks. Additionally, four out of 34 countries showed at least 60 percent alignment between the guides and textbooks in HPSS areas; they are Canada, Iceland, Portugal, and Slovenia. Denmark had every HPSS topic in its guide, yet nothing was found in its textbooks. Similarly, Singapore and the Slovak

Republic were found to have HPSS topics in their curriculum guides, yet, on examining their science textbooks, no HPSS was found. Conversely, Czech Republic, Dominican Republic, Greece, Japan, and the Philippines were found to have no coverage in their guides. Czech Republic's science textbooks included one HPSS topic – *Influence of Science, Technology on Society*, while the Philippines science textbooks included both *Influence of Science, Technology on Society* and *History of Science and Technology*, despite no HPSS topic being covered in both countries' guides.

Figure 8 are representations of the percentage of books devoted to each HPSS topic from 42 TIMSS countries that had their science textbooks coded by TIMSS researchers.

Overall, Canada, and USA were found to have over 15 percent of their textbooks' space devoted to HPSS areas. he grand average coverage of the five HPSS topics in science textbooks of these 42 countries was 4 percent. Twenty-seven of the 42 countries were found to have less than 4 percent of their science textbooks related to any HPSS topic. On the topic of *Influence of Science, Technology on Society*, Canada's textbooks were found to have 7 percent; Cyprus's textbooks had an average of 6 percent; and USA's textbooks had an average of 5 percent. Compared to this topic, *Influence of Society on Science, Technology* was found to have almost *no* coverage in science textbooks worldwide. Furthermore, science textbooks in Iceland, Italy, and Slovenia covered more than 5 percent of the content topic *History of Science and Technology*. The HPSS topic *Nature of Scientific Knowledge* took up 5 percent or more textbook space in the countries of Canada, Portugal, and USA.

3.3. INSTRUCTIONAL CONDITIONS OF HPSS AREAS

There were 36 TIMSS countries who completed the teacher instructional questionnaire. Two out of the 36 (Israel and Kuwait) only had eighth grade teachers responded to the questionnaire. The remaining 34 countries gave responses from teachers of both seventh and eighth graders. Table II shows a ranking of the percentage of teachers per country, who reported that they taught at least one or more HPSS topics, and it also shows the average percentage of instructional time devoted to HPSS areas for both seventh and eighth graders.

As indicated in Table II, 84 percent of American eighth grade teachers reported that they taught HPSS areas in their science classrooms; this made the US the number one country in terms of HPSS coverage with around 20 percent more teachers teaching these topics than the second country the Russian Federation (65%). Percentage of yearly instructional time devoted to HPSS topics in the US was five percent for eighth grade, which along with Canada ranked as the top country. Overall, 32 percent of seventh grade teachers and 36 percent of eighth grade teachers worldwide reported that they have spent time in teaching HPSS content. Nearly 60 percent of the countries have more than one-third of their teachers reported to be

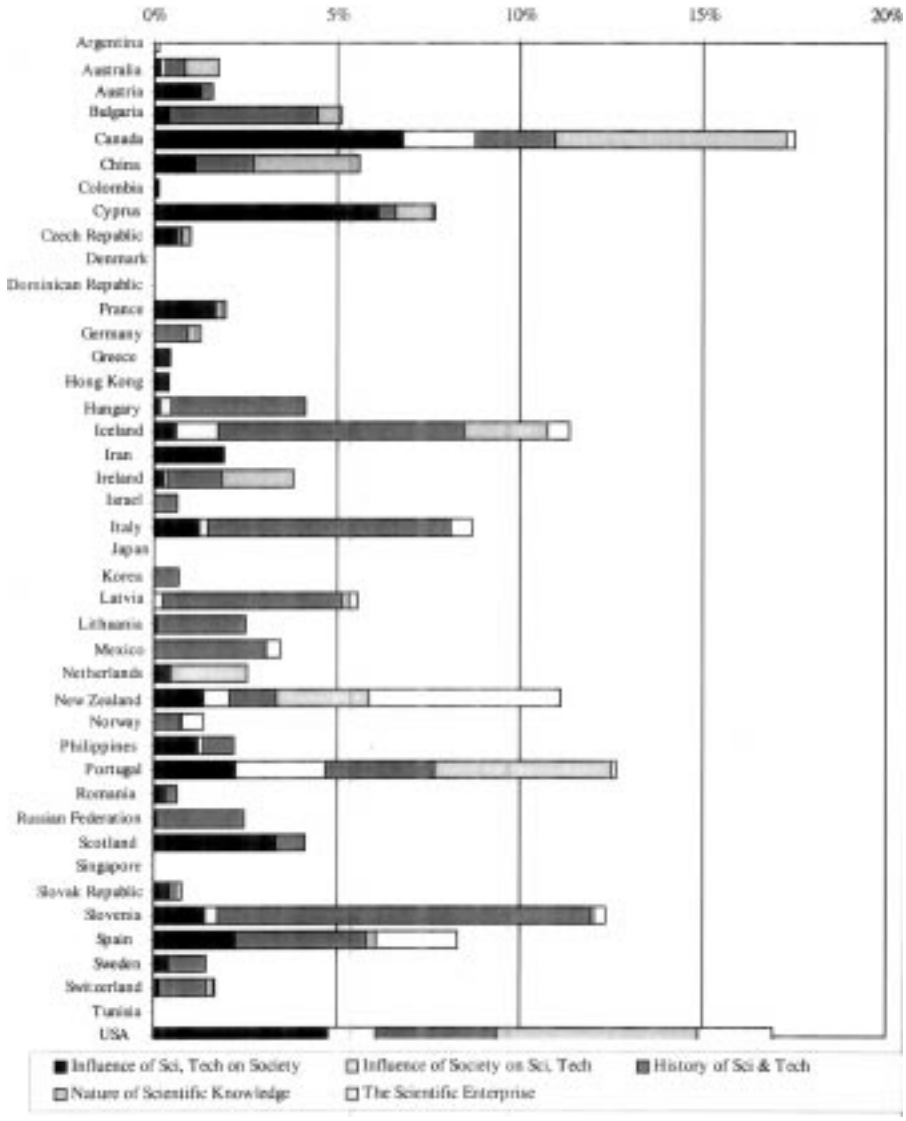


Figure 8. Textbook coverage of HPSS topics in TIMSS countries.

giving HPSS instruction to the eighth graders of the country. However, the average time worldwide for HPSS instruction per school year is 3 percent for eighth grade, and 2 percent for seventh grade. According to Table II, those high performing countries in TIMSS on the science test, the Czech Republic, Japan, Netherlands, and Singapore are not among the top tier in terms of percentage of teachers or percentage of instructional time devoted to HPSS content.

Table II. The percentage of teachers and the percentage of instrutional time associated with HPSS topics in TIMSS

% of 7th Graders' Teacher		% of 8th Graders' Teacher		Inst. Time for 7th Graders'		Inst. Time for 8th Graders'	
USA	82%	USA	84%	USA	6%	USA	5%
Russian Fed.	61%	New Zealand	65%	Thailand	5%	Canada	5%
Australia	54%	Canada	64%	Canada	5%	Hungary	4%
Canada	53%	Russian Fed.	61%	New Zealand	4%	Iceland	4%
New Zealand	49%	Australia	51%	Hungary	4%	Slovenia	4%
Slovak Republic	46%	Colombia	50%	Hong Kong	4%	Cyprus	4%
Thailand	46%	Cyprus	50%	Australia	4%	New Zealand	4%
Slovenia	45%	Slovenia	49%	Russian Fed.	3%	Germany	4%
Colombia	44%	Slovak Republic	44%	Slovenia	3%	Slovak Republic	3%
Korea	40%	Sweden	41%	France	3%	Sweden	3%
Singapore	40%	Iceland	41%	Cyprus	3%	Russian Fed.	3%
Spain	35%	Germany	40%	Slovak Republic	3%	Portugal	3%
Cyprus	34%	Lithuania	40%	Singapore	3%	Australia	3%
Hungary	33%	Norway	40%	Germany	3%	Lithuania	3%
Hong Kong	32%	Spain	39%	Colombia	2%	France	3%
Average	32%	Portugal	39%	Korea	2%	*Average*	3%
Ireland	30%	Czech Republic	36%	Sweden	2%	Romania	2%
Germany	30%	*Average*	36%	Czech Republic	2%	Norway	2%
Sweden	29%	Hungary	35%	Netherlands	2%	Czech Republic	2%
Lithuania	29%	Singapore	35%	Romania	2%	Thailand	2%
Czech Republic	28%	Israel	32%	Norway	2%	Austria	2%
Romania	27%	France	28%	Spain	2%	Colombia	2%
Portugal	24%	Korea	27%	Ireland	2%	Netherlands	2%
Norway	22%	Hong Kong	27%	Belgium (Fl)	2%	Israel	2%
Netherlands	21%	Thailand	27%	*Average*	2%	Greece	2%
France	21%	Ireland	26%	Lithuania	1%	Spain	2%
Japan	21%	Netherlands	25%	Austria	1%	Korea	2%
Switzerland	18%	Iran	25%	Belgium (Fr)	1%	Latvia	2%
Belgium (Fr)	16%	Romania	24%	Portugal	1%	Hong Kong	2%
Iran	16%	Japan	23%	Iceland	1%	Belgium (Fr)	1%
Belgium (Fl)	14%	Greece	23%	Japan	1%	Belgium (Fl)	1%
Iceland	13%	Latvia	21%	Switzerland	1%	Ireland	1%
Austria	10%	Switzerland	20%	Iran	1%	Singapore	1%
Greece	9%	Austria	16%	Latvia	1%	Japan	1%
Latvia	8%	Belgium (Fr)	16%	Greece	1%	Iran	1%
	-	Belgium (Fl)	14%		-	Switzerland	1%
	-	Kuwait	14%		-	Kuwait	1%
AVERAGE	33%		37%		3%		3%

4. Discussion and Conclusions

Throughout the history of enhancing the public scientific literacy, Conant (1951), one of the important advocators, has postulated that since every citizen is expected to have informal opinions on the relationships among government, education, and issues of scientific research and development, it is imperative that some appreciation of the past complexities of science and society be a part of the education of both scientists and non-scientists. Because of the increasingly scientific nature

of our society and the individual needs of its members, every person must be scientifically literate in order to function effectively. Furthermore, the generation of scientific knowledge is a dynamic process with social, historical, psychological, and other contextual rather than purely abstract and formal determinants. Science is an enterprise in which dynamic change and alteration are the rules rather than the exceptions. The dynamic characteristic of science can help individuals to cultivate scientific habits of perception and to be capable of practicing rational thinking and logical reasoning.

In science education, the critical role of HPSS has been continuously identified as a powerful way to enhance the public's scientific literacy. The findings from TIMSS reflect one crucial message – little of it is done worldwide other than in the US and a handful of other countries, and the top achieving countries are not among them. In addition, according to the attempt of TIMSS researchers to understand the relationships among the *intended*, *implemented*, and *attained* curriculum, students' performance in the HPSS area *does* have a significant effect on general school science performance. However, there are more lessons needed to be learned from the TIMSS results.

1. *To teach HPSS alone will not result in greater performance; the science content knowledge also has an impact*. According to the results presented above, we found that countries such as Japan, Korea, and the Czech Republic were not among the top tier of countries in any aspect of the *intended* or *implemented* curriculum for HPSS. However, their performance on both the general science test and for HPSS items in particular were more satisfactory than those other countries that had significant indications of HPSS coverage in textbooks, curriculum guides, or on the part of teachers. This seems to imply that without the substance of science, classrooms with a heavier focus on HPSS might confuse students more and may just be another social studies class in a science disguise.

2. *Teacher preparation and training may be the key to reach the goal of enhancing scientific literacy through HPSS*. For advocates of HPSS, good news was found in the results: despite the fact that very little instructional time was allocated, science teachers worldwide did practice the inclusion of HPSS to some extent. One critical factor that may need to be addressed to make this instruction more effective may be the quality of teachers, that is the teachers may not have adequate training in HPSS worldwide. With inadequate training and insufficient background knowledge, teachers' misconception in HPSS may do more harm than good.

Lastly, the information reported in this paper is not to have every country conform and adopt identical strategies to improve the scientific literacy of the citizens worldwide. Some people would suggest that what a country should do is to figure out who is the top achieving country, say Singapore. What you then do is to find out what Singapore does educationally and copy it – bring it to your country and put it into the educational system and everything will be fixed. This is a fairly naïve approach. One cannot simply take what is done in one cultural context and lift it out of that context and place it into another one and somehow expect it to work. That

is a misguided implication; which is *not* the way we learn from an international study. What we can learn is that there is not only one way to provide quality science education. HPSS inclusion to achieve scientific literacy can be approached in so many diverse ways. What appeared sensible and successful in one nation (to emphasize more history of science yet downplay the sociology of science) may not be an effective way for another nation (where the sociology of science or not teaching HPSS directly may evidently assist students to learn more effectively). HPSS approach has increasingly received satisfactory learning outcomes, findings presented in this study can serve as a direction or topic of dialogue about HPSS in science education for every country worldwide.

Notes

[1] At first grade, three countries started to introduce *History of Science & Technology*; seven countries started to introduced *Nature of Scientific Knowledge*; and three countries reported introducing the topic of *The Scientific Enterprise*.

[2] At grade three, six countries reported starting to introduce *Influence of Science, Technology on Society*; five countries started to introduce *Influence of Society on Science, Technology*; three countries introduced the topic of *History of Science & Technology*.

[3] At grade seven, nine countries started to introduce *the topic of Nature of Scientific Knowledge*; and three countries reported introducing the topic of *The Scientific Enterprise*.

[4] Notice that the information about the guides is different from what the educational officials reported in the GTTM survey, as shown in Figures 2 to 6. Despite the differences in the collection of the data of GTTM and guides (see previous paragraph for detailed information), a discrepancy exists between these two sources of *intended* curriculum in HPSS areas. In contrast to the ten countries found in the guides, only five countries' educational officials reported that every HPSS topic was covered at the eighth grade level. Only two of these five countries are like those ten countries in having that information in their guides: Canada and Denmark. This result signaled a critical implication for future research methods of this sort, a choice needs to be made between "self-reporting" and "content analysis of written documents".

References

American Association for the Advancement of Science: 1993, *Benchmarks for Science Literacy*, Oxford University Press, New York.

National Research Council: 1996, *National Science Education Standards*, National Academy Press, Washington, DC.

Anderson, C. W. & Smith, E.: 1986, 'Teaching Science', in V. Koehler (ed.), *The Educator's Handbook: A Research Perspective*, Longman, New York.

Beaton, A. E., Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., Smith, T. A. & Kelly, D. L.: 1996, *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS)*, Boston College, Chestnut Hill.

Brush, S. G.: 1974, 'Should the History of Science be Rated "X"?' *Science* **18**, 1164–1172.

Conant, J. B.: 1964, 'Introduction', in J. B. Conant and L. K. Nash (eds), *Harvard Case Histories in Experimental Science* (1), vii–xvi.

Finley, F.: 1983, 'Science Processes', *Journal of Research in Science Teaching* **20**, 47–54.

Harms, H. & Yager, R. E.: 1981, *What Research Says to the Science Teacher*, 3, NSTA, Washington DC.

Klopfer, L. E.: 1969, 'The Teaching of Science and the History of Science', *Journal of Research in Science Teaching* **6**, 87–95.

Klopfer, L. E. & Watson, F. G.: 1957, 'Historical Materials and High School Science Teaching', *The Science Teacher* **24**, 264–265, 292–293.

Matthews, M. R.: 1994, *Science Teaching: The Role of History and Philosophy of Science*, Routledge, NY.

Matthews, M. R.: 1999, *Time for Science Education: How Teaching the History and Philosophy of Pendulum Motion Can Contribute to Science Literacy*, Plenum Publishing Company, New York.

Quattropani, D. J.: 1977, *An Evaluation of the Effect of Harvard Project Physics on Student Understanding of the Relationships Among Science, Technology, and Society,* Ph.D. Dissertation. University of Connecticut.

Robitaille, D. F., Schmidt, W. H., Raizen, S., McKnight, C., Britton, E. & Nicol, C.: 1993, *TIMSS Monograph No. 1: Curriculum Frameworks for Mathematics and Science*, Pacific Educational Press, Vancouver.

Rutherford, F. J. & Ahlgren, A.: 1990, *Science for All Americans: Scientific Literacy*, Oxford University Press, New York.

Schmidt, W. H. & McKnight, C. C.: 1995, 'Surveying Educational Opportunity in Mathematics and Science: An International Perspective', *Educational Evaluation and Policy Analysis* **17**(3), 337–353.

Schmidt, W. H., Jorde, D., Cogan, L. S., Barrier, E., Gonzalo, I., Moser, U., Shimizu, K., Sawada, T., Valverde, G., McKnight, C., Prawat, R., Wiley, D. E., Raizen, S., Britton, E. D. & Wolfe, R. G.: 1996, *Characterizing Pedagogical Flow: An Investigation of Mathematics and Science Teaching in Six Countries*, Kluwer, Dordrecht/Boston/London.

Schmidt, W. H., Raizen, S. A., Britton, E. D., Bianchi, L. J. & Wolfe, R. G.: 1997, *Many Visions, Many Aims, Volume II: A Cross-National Investigation of Curricular Intentions in School Science*, Kluwer, Dordrecht/Boston/London.

Villani, A. & Arruda, S.: 1998, 'Special Theory of Relativity, Conceptual Change and History of Science', *Science and Education* **7**(1), 85—100.

Wandersee, J. H.: 1985, 'Can the History of Science Help Science Educators Anticipate Students', Misconceptions?' *Journal of Research in Science Teaching* **23**(7), 581–587.

Wandersee, J. H.: 1990, 'On the Value and Use of the History of Science in Teaching Today's Science: Constructing Historical Vignettes', in D. E. Herget (ed.), *More History and Philosophy of Science in Science Teaching*, Florida State University, Tallahassee, pp. 278–283.

Wang, H. A. & Marsh, D. D.: 2001, 'Science Instruction with a Humanistic Twist: Teachers' Perception and Practice in Using the History of Science in Their Classrooms', *Science & Education* **10**(3), forthcoming.

Weiss, I. R.: 1978, *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*, U.S. Government Printing Office, Washington, DC.