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ABSTRACT

This paper discusses both the extent and manner in which the history of science is included in current secondary school physics textbooks. The study investigates what qualifies as history of science in a physics textbook; the focus, extent, and pervasiveness of the history of science content as it actually appears in a textbook; the focus of content standards in policy documents with regard to the history of science inclusion; and the degree of alignment between the standards documents and secondary school physics textbooks. Contains 16 references and 11 tables. (WRM)

A CONTENT ANALYSIS OF THE HISTORY OF SCIENCE IN THE NATIONAL SCIENCE EDUCATIONAL STANDARDS DOCUMENTS AND FOUR SECONDARY SCIENCE TEXTBOOKS

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Introduction

The history of science (HOS) was included in the first nationwide content standards document for K-12 school science, *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993). Other national standards in science education, including the *National Science Education Standards* also state that students should know the history of science (National Research Council, 1996). Wang and Marsh (in press) report that the recommendation to include the HOS 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.

Unlike the standards documents that seek to guide curriculum, instructional materials are concrete to practitioncrs who use them in their daily routine. Science textbooks have been known for decades as a dominant instructional tool in science education. It is the textbook that in thousands of classrooms determines the content of instruction and guides the teaching procedures.

This view may not be in accord with the usual theory of education, but it is supported by the facts as reported by supervisors and state inspectors of schools for the past few decades. Recently, this phenomenon was again evidenced by the Third International Mathematics and Science Study (TIMSS) (Schmidt, Raizen, Britton, Bianchi, & Wolfe, 1997) in which it is shown that teachers throughout the world use textbooks to guide their science instruction, with science teachers basing about 50 percent of their weekly teaching time on textbooks. Science textbooks have great influence over how content is delivered and even what should be taught.

The curriculum findings of TIMSS also indicates that the long-time admonition of "Less is More!" has rarely been followed (Schmidt et al., 1997). Even though the core science topics are similar across the 50 states, nevertheless, with state administrators selecting topics based on their visions of education, only a few topics are common to all the States. Thus, a highly competitive textbook market has caused publishers to include as many topics as they can, and this has resulted in the thickest textbooks to be found in the world—however shallow they may be in content elaboration. The nature of the instructional strategies for teaching and learning a specific topic must be elaborated so as to provide teachers with appropriate idea about how to explore specific concepts with their students to reinforce learning. Addressing the problems associated with instructional materials is an important function of education reform.

Good (1993) alerts that few individuals deny the important roles of science teachers in transforming current science education. However, while science teacher seems to use textbooks most of the time, it is curious that so little effort has been devoted to analyzing curriculum materials; despite this urgent need. Among six Science Teaching Standards stated in the National Science Education Standards (NRC, 1996), one sub-standard of *Teaching Standard D* describes explicitly that

> Effective science teaching depends on the availability and organization of materials, equipment, media, and technology . . . Teachers must be given the resources and authority to select the most appropriate materials and to make decisions about when, where, and how to make them accessible. (NRC, 1996, p. 44-45)

However, without an effective and efficient approach to evaluating instructional materials, curriculum developers will always fail to provide teachers a wealth of well-selected, analyzed, and proper instructional materials, including textbooks. Recognizing the role of science textbooks in instruction is not intended to encourage teaching by textbooks but to bring educators' attention to which: Standards-based science education reform will need more than the documentation of science standards reports; there is a pressing need to investigate the readiness of science textbooks to approach quality science instruction.

Purposes of the Study

This study is intended to investigate both the *extent* and *manner* in which the history of science is included in current secondary school physics textbooks. The study approaches involved investigations of: (1) What qualifies as history of science in a physics textbook; (2) the focus, extent, and pervasiveness of the history of science content as it actually appears in a textbook; (3) the focus of content standards in policy documents with respect to the history of science inclusion; and (4) the degree of alignment between the standards documents and the secondary school physics textbooks.

One rationale of selecting to examine the historical elements of science is that such inclusion is perceived as an effective way to reach the goal of enhancing science literacy for all citizens (Wang & Marsh, in press). With the long-standing recommendation for inclusion of the historical approach, the history of science ought to be in current science textbooks by now. Yet, the *extent* and *manner* in which the history of science is to be included in science textbooks has been poorly elucidated; and now is the foci of this study.

Methodology

Research Questions

This study examined the inclusion of the history of science in physics textbooks, especially as related to the proposed value of the history of science for scientific literacy by the national science education standards documents. The following research questions guided the research.

1. What is the rationale for the inclusion of the history of science as offered by science education scholars and historians of science, and how such rationale reflect on the two science standards documents, Benchmarks for Science Literacy (AAAS, 1993) and National Science Education Standards (NRC, 1996)?

2. To what extent is the history of science included in current secondary school physics textbooks?

    (a) To what extent are science history elements applied to present the scientific concepts, ideas, definitions, models or findings in current secondary school physics textbooks?

    (b) To what extent are science history elements applied to present the scientific modes of inquiry in current secondary school physics textbooks?

    (c) To what extent are science history elements applied to present issues of economic, cultural, political, or social discourse of science or scientists in current secondary school physics textbooks?

3. How is the history of science treatment integrated with the other content in current secondary school physics textbooks, and how is it presented and supported for understanding?

4. To what extent do the history of science inclusions found in current secondary school physics textbooks match up with the two science standards documents?

Samples

Three contemporary secondary physics textbooks (Table 1) have been selected for content analysis of their history of science inclusion. Unit One of *Project Physics* was also analyzed to serve as comparative baseline. Wang (1998) provides detailed descriptions of the process of selecting these textbooks, the profile of these textbooks and the profile of the researcher.

Table 1

Textbooks Information

Title of Book	*Author(s)*	*Year*	*Edition*	*Publisher*
PSSC Physics	Haber-Schaim, Dodge, Gardner, & Shore	1991	Seventh Edition.	Kendall/Hunt
Conceptual Physics	Hewitt	1993	Seventh Edition	Harper Collins
Physics	Wilson & Buffa	1997	Third Edition	Prentice Hall
Project Physics Unit 1	Holton, Rutherford, & Watson	1975	First Edition	Holt, Rinehart & Winston, Inc.

Instruments

Three instruments were developed during the analysis processes: (a) History of Science Unit Code Book that defines what is perceived as a codeable HOS unit in a science textbook (four historians of science and three science educators were involve in assessing the reliability of this code book; inter-rater reliability alpha was found .92). (b) History of Science Conceptual Framework that guided the analysis of the textbooks and the two standards documents. (c) History of Science Analytic Rubric for Textbooks that specified the criteria for the instructional pervasiveness of the historical elements. This rubric is a three by eight matrix that defines three levels (limited to extensive use of the history of science elements) of the eight subdomains described within the history of science conceptual framework. The rubric includes textbook passages that illustrate each cell of the matrix (intra-rater reliability of the rubric was found .79).

In addition to the three instruments, this study applied a relational database computer program *ACCESS* from Microsoft™ Office to store data collected from the textbooks. This technology application fosters the analysis of such large amount of descriptive data. The techniques and preparations of using the database are described in Wang's (1998) study.

Issue of Time Management

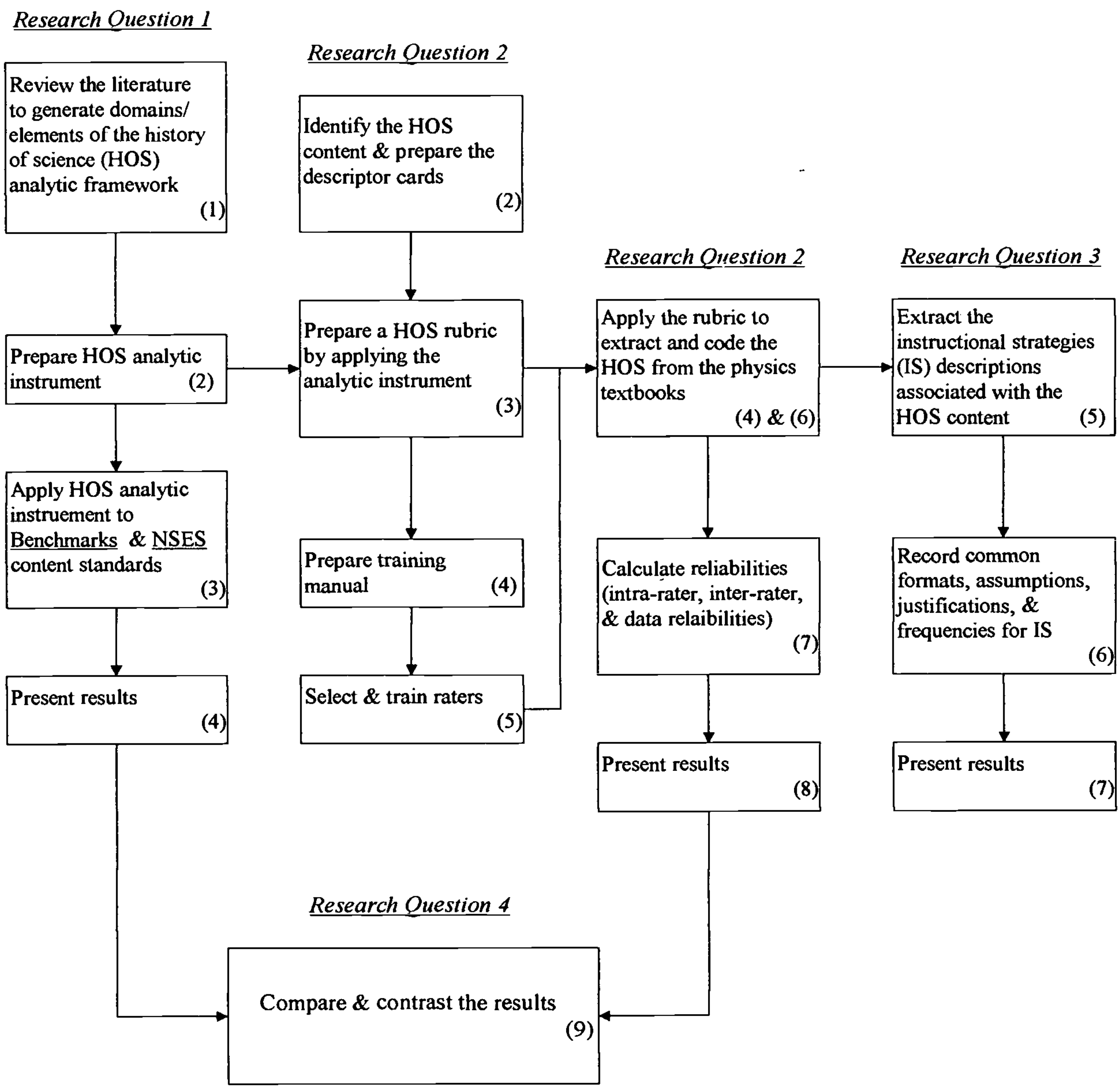
In the initial facet of eliciting the HOS units from the three textbooks, time spent on this process became an important issue in terms of the quality of coding. When time spent on coding one paragraph increased, I found the quality of coding decreased (as described in my methodology journal). Because that content analysis is an approach of making inferences of texts, to maintain the quality of the coding process, some researcher factors should be aware. Recognizing that any individual has limit in concentrating on a task, there is no exception to content analysis study. The time spent in coding Physics units in this study varied with the length of each unit (some paragraph is longer and some is shorter). With several measurement of the average time spent on coding each unit, the indicator to stop and take a break from the coding process is when one unit took more than five minutes for judgement. The indicator of stop for the coding the identified HOS units is when one HOS unit took more than ten minutes. This time control issue of coding process is important and is not widely reported in content analysis studies. In a recent personal communication with Schmidt (personal communication) about the content analysis of TIMSS curriculum materials, we found that this time management issue was also addressed in their coder-training sessions for TIMSS.

Data Analysis

When all the identified HOS units being analyzed by the Analytic Rubric and all the results being stored in the database, several procedures were conducted to find both quantitative and qualitative information about the extensiveness and nature of HOS inclusions in the textbooks (Wang, 1998). Figure 1 shows the process of this research.

Figure 1.

Figure 3.4: Procedures to Answer the Research Questions



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Findings

Finding One

The foci of the history of science passages (called HOS units) included in the textbooks were found to be aligned with the foci of the standards documents. Each textbook analyzed was found to have a significant number of HOS units, mostly associated with the Conceptual Understanding subdomains of the rubric (to facilitate an understanding of science content, or to facilitate an understanding of the nature of scientific knowledge).

Wang and Marsh (in press) review the rationale for including the history of science in science instruction as offered by science education scholars and historians of science and generate the History of Science Conceptual Framework (see Figure 2).

Figure 2.

The History of Science Conceptual Framework

1. Conceptual Understanding	Historical elements are included with the description, presentation, comparison, or contraction of scientific (a) thoughts, ideas, concepts, notions, plans, schemes; (b) definition, explanations, models, illustrations, graphics, instrumentation; (c) findings, standards, laws, theories to 1.1 Enrich the presentation of scientific knowledge 1.2 Emphasize the tentative nature of scientific knowledge
2. Procedural Understanding	Historical elements provide the descriptions to facilitate: 2.1 Process of thinking or thought experiment 2.2 Process of investigation 2.3 Process of concluding, inferring, elaboration, reporting, and application.
3. Contextual Understanding	Historical elements provide information of: 3.1 Psychological factors involved in the science making (e.g., motivation, incentives, purposes, etc) 3.2 Social factors (e.g., peer influences, public attitudes, social needs, or politic factors that effect on the scientists action to communicate, confirm, confront, or contribute) 3.3 Cultural factors associated to the science research (e.g., personalities, culture of family, organization, social, or ethics, etc.)

The conceptual framework was applied to examine the chapter on Historical Perspectives in the *Benchmarks for Science Literacy* (AAAS, 1993) and the Content Standards of History and Nature of Science in *National Science Education Standards* (NRC, 1996). The content or paragraphs within the standards documents selected for analysis that met the selecting criteria as described by Wang (1998) are presented in Table 2.

Table 2.
Selected Content from the *Benchmarks* and *NSES* for HOS Analysis

Benchmarks	*NSES*
Coding Content Chapter Ten: Historical Perspectives.	**Coding Content** Chapter Six: Content Standards—History & Nature of Science.
Content Analyzed • pp 237-238 (introduction) • content standards for grades nine through twelve • history of physical science (10A, 10B, 10C, 10E, 10G)	**Content Analyzed** • pp 200-201 • p. 204 (except the content under the title—*References for Further Reading.*)

The analysis findings are: **First**, the benchmarks document provides a few historical episodes to demonstrate what the inclusion of the history of science will be. Three out of ten examples of historical episodes in *Benchmarks* are about the history of physics. Compared with *Benchmarks* in which there is an extensive discussion of the instructional effects of these episodes, *NSES* does not specify what HOS content should be. However, the *NSES* content standards do refer readers to the historical episodes described in *Benchmarks* and advise science instructors to "incorporate other historical examples to accommodate different interests, topics, disciplines, and cultures" (p. 200) to help students reach science understanding. In addition to the examples of historical episodes, specific descriptions of what students can learn from these historical episodes were presented in both *Benchmarks* and *NSES.*

Second, the content standards were focused mostly on the Conceptual Understanding Domain and Contextual Understanding Domain, less on the Procedural Understanding Domain. Overall, 53 percent of the content standards descriptions were centered around Conceptual Understanding. *Benchmarks* was found to have placed more emphasis on how historical elements serve to enrich science; as one of its principle rationales for promoting science history states: "generalizations about. . .scientific enterprise. . .will be empty without concrete examples" (p.237). However, unlike *Benchmarks*, the *NSES* devoted its complete attention on understanding the nature of scientific knowledge through science history.

Third, after the Conceptual Domain, Contextual Understanding was the next most emphasized through the historical elements inclusions for both standards documents. Science as a human endeavor and the interplay between science and society were perceived as major accomplishment by the documents when students received information about historical examples. This aspect was equally distributed in both standards documents. Specifically, the understanding of the scientist as an individual and the interaction or influence of science in the public welfare were the intended learning outcomes as history was introduced. There was no discussion proposing that students should be able to understand what motivates scientists or how scientists focus or persist in their task. That is the psychological aspect of science as described in the HOS Conceptual Framework, which was not an explicitly intended learning outcome, when introduced in the information about the history of science.

Fourth, The domain of Procedural Understanding was not anticipated when the historical elements were introduced. The standards documents provided less than 10 percent of their content standards in describing the learning that students might acquire if science history were introduced. Both standards documents only stressed that the history episodes were perceived to enhance students' understanding of how one science concept might contribute to the development of another science concept. Learning the story that about scientists designing or conducting an experiment in history was not anticipated to as an intention to enhance students' understanding or ability in "doing" science.

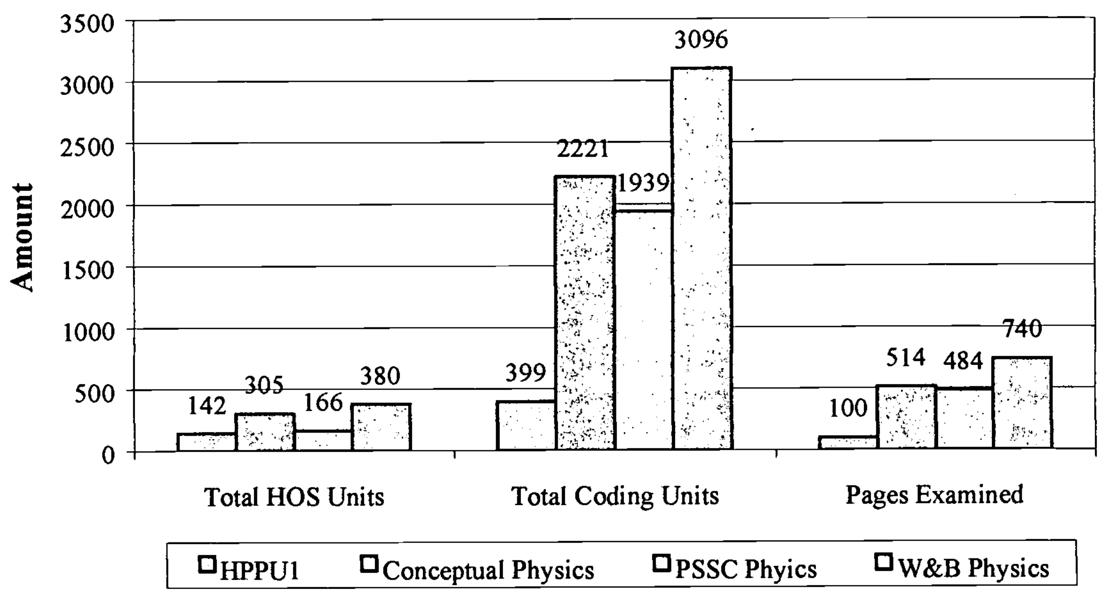
Finding Two

Most history of science content found in the textbooks is superficial and lacks in-depth elaboration. The history of science content is merely another "add-on" in the textbooks. However, integrating the HOS passages to foster the Conceptual Understanding in science requires "depth" rather than "breadth."

The findings obtained from applying the Code Book criteria to the examination of the

Table 3.

Findings of HOS Units, Coding Units, and the Number of Pages Examined in Each Textbook



three physics textbooks, *Conceptual Physics* (HCP), *PSSC Physics*, *Physics* (WBP), and the Unit One of *Project Physics* (HPPU1), are presented in Table 3.

Among the three contemporary physics textbooks, the *Physics* by Wilson and Buffa (1997) is the thickest text. A total of 740 pages were examined in this book; and this text has the most HOS units (N=380). *Conceptual Physics*, the second thick book with 514 pages examined, had a total of 305 HOS units. Compared to these two texts, *PSSC Physics* is not as thick (N. of pages examined = 484); therefore the total HOS Units are fewer.

Perhaps it would be logical to assume that as the number of pages increases, the likelihood of finding HOS units also increases; therefore, if textbook writers intend to have more HOS units, they should increase the number of pages in their texts. However, this assumption can be overruled by examining *PSSC Physics* and *Project Physics*. Unit One of *Project Physics* has almost the same number of HOS units identified (N=142) as *PSSC Physics* has (N=166). However, only 100 pages were examined in *Project Physics*, whereas in *PSSC Physics*, 484 pages were examined. Within *Project Physics*, on average, there is at least one HOS unit on every page (1.42 units/page), whereas in *PSSC Physics* an HOS unit appears in every three pages (0.34 units/page). HOS units are difficult to find in *PSSC Physics* even compared to the other two contemporary textbooks. For Wilson and Buffa's *Physics* and *Conceptual Physics*, on average, an HOS unit appears in every two pages (0.51 units/page for WBP; 0.59 units/page for HCP).

Increasing the number of paragraphs or code-able units will not help to increase the number of HOS units. By the rule of Defining a Coding Unit, as stated in the Code Book (Appendix A), *Physics* by Wilson and Buffa (1997) tends to have many short paragraphs, (number of Coding Units = 3096); and yet the ratio of HOS units to coding units is .12. With fewer coding units (N=2221), *Conceptual Physics* has a larger font size and tends to have longer paragraphs, but the ratio of HOS units to coding units is .14, which is not much different from Wilson and Buffa's. For these two textbooks, on average, every ten code-able units will have one HOS unit. *PSSC Physics* was found to have 1939 coding units. The ratio of HOS units to coding units for this text is .09, even smaller than the previous two contemporary textbooks. The reference book *Project Physics* has slightly fewer paragraphs compared with the other textbooks, yet, it has a ratio of .36. That is, on average, there would be one HOS unit in every three coding units, the most abundant text. In Table 4, a summary of ratios of HOS units to number of pages examined, and ratios of HOS units to coding units are presented.

Table 4.

Findings about the HOS Units in Each Textbook

	N. of HOS Unit vs. Pages Examined	N. of HOS Unit vs. N. of Coding Unit
Project Physics (Unit One)	1.42	.36
Conceptual Physics	.59	.14
PSSC Physics	.34	.09
Physics	.51	.12

Finding Three

The textbooks examined and the standards descriptions both showed that the textbook authors integrated science history elements more to enrich the presentation of the science concept(s) within the unit, and less to emphasize the nature of scientific knowledge. However, such enrichment effect was found mostly limited because of limited inclusion.

Furthermore, in terms of the Procedural Understanding of science literacy (the process of thinking, investigation, and application) is almost a "non-issue" of the historical approach to science education. However, the two standards documents include a chapter on the Procedural Understanding without integration with the history of science instructional approach.

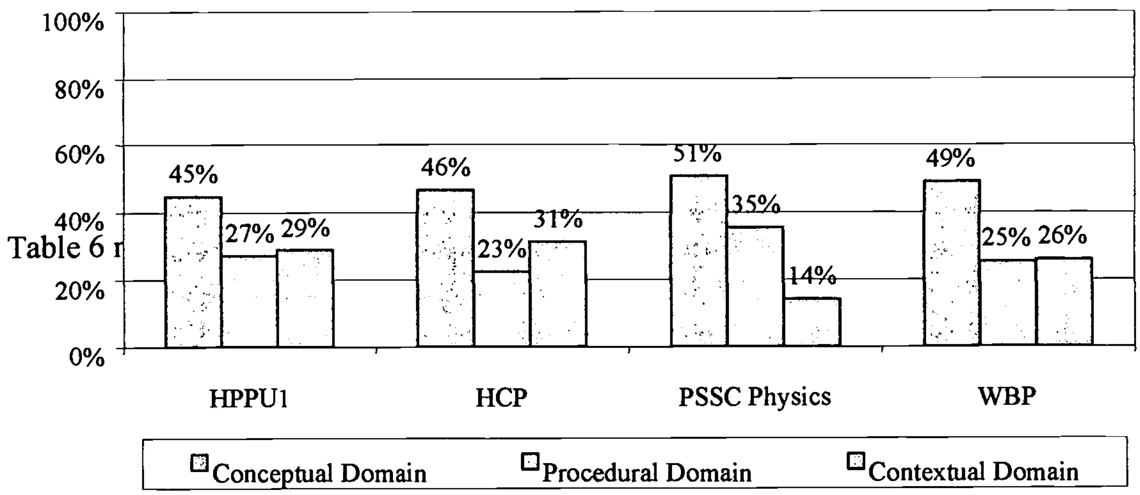
The Conceptual Framework in Figure 2 includes three domains: Conceptual Understanding Domain, Procedural Understanding Domain, and Contextual Understanding Domain. Every Domain has its subdomains. These subdomains were used to categorize the HOS units found in the textbooks

The Analysis found that the history of science elements in the textbooks concentrated around the Conceptual Domain. In all textbooks examined, except *PSSC Physics*, Contextual Domain was found as the second focus, then Procedural Domain. According to the analysis guidelines, an HOS Unit may contain more than one code. In every textbook, the sum of the HOS Units under every Domain will exceed the total amount of HOS Units found. Therefore, Table 5 presents the relative percentage of HOS Units devoted to each Domain in the Conceptual Framework (CF). That is, the sum of HOS Units under every Domain became the denominator, instead of the total HOS Units found in the textbook.

As shown in Table 5, the Conceptual Understanding Domain received the largest amount of attention in every textbook examined. The historical elements included, were mainly intended to enrich the concept(s) or emphasize the nature of scientific knowledge.

Table 5

Proportion of the HOS Units Devoted to CF's Domains in Each Textbook



In Table 6, every textbook has more Limited Conceptual HOS units than Moderate or Extensive Conceptual units. Unit One of *Project Physics* was found to have an almost equal distribution among the Limited, Moderate, and Extensive levels of Conceptual Domain. Half of the HOS units in *Conceptual Physics* were recognized as Limited; the other half were distributed between Moderate or Extensive. In both Wilson and Buffa's *Physics* and *PSSC Physics* it has been recognized that the historical elements that are included in the HOS units serve a limited function in facilitating either an understanding of the nature of scientific knowledge or the enrichment of science concept(s).

Table 6 .

Level of Conceptual Understanding Domain in Each Textbook

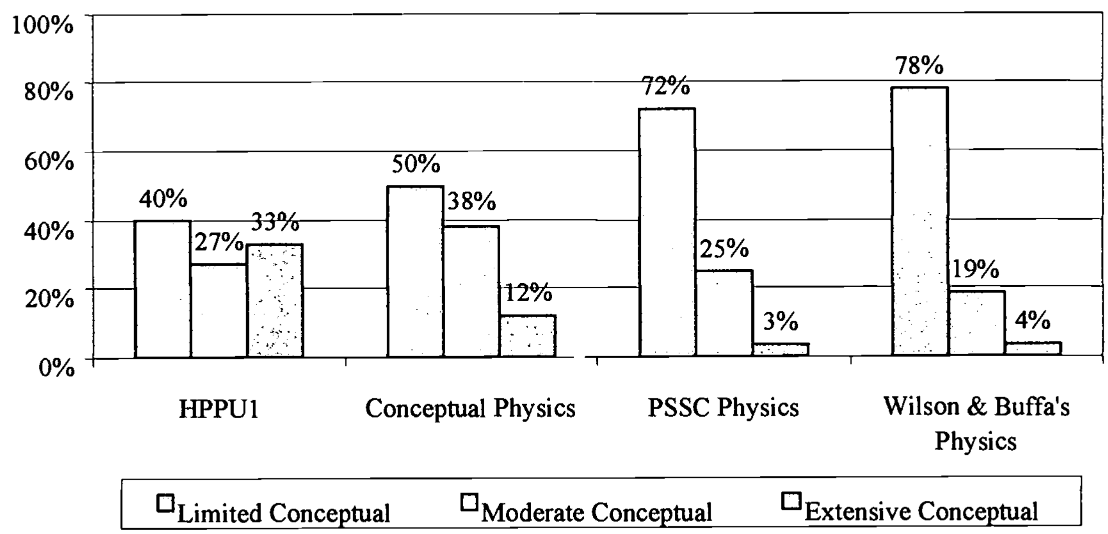
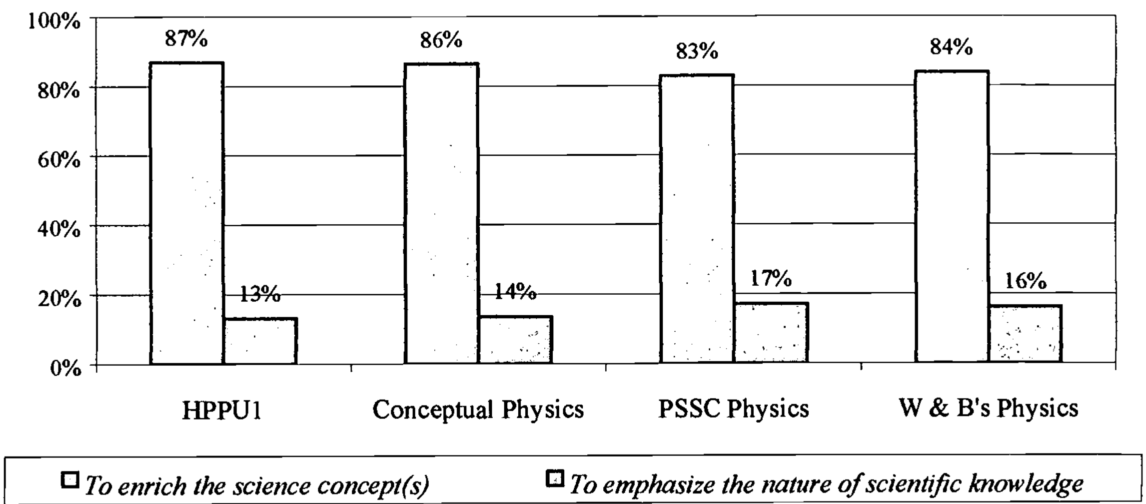


Table 7 illustrates the distribution of these HOS units between the two subdomains of Conceptual Understanding—1.1: To enrich the science concept(s), and 1.2: To emphasize the nature of scientific knowledge. As shown in the Table 7, the distributions of the HOS units between the subdomains and their effect on the Conceptual Domain are about the same for every textbook examined. More than 80 percent of those units with Conceptual Understanding effects include historical elements to enrich the science concept(s) within the unit. The authors of these textbooks are less likely to focus on the use of historical elements to emphasize the nature of scientific knowledge.

Table 7.

Distribution of HOS Units in Conceptual Subdomains for Each Textbook



According to Table 5, the Procedural Understanding Domain is the least emphasized function for all textbooks examined except the *PSSC Physics*. Table 8 demonstrates the distribution of the level or degree of emphasis of procedural understanding for each textbook. As with the Conceptual Domain, every textbook has more Limited HOS units found for Procedural Understanding. According to Table 5, *PSSC Physics* was the only contemporary textbook having more than one third of its HOS units being perceived as having Procedural Understanding. However, from Table 8, 75 percent of those inclusions provided Limited effect. In contrast, Unit One of *Project Physics* was found to have a significant numbers of HOS units ranked as Extensive Procedural Understanding. Again, Procedural Domain is not the focus of either *Conceptual Physics* or Wilson Buffa's *Physics*. Even with little focus on such domain, the inclusion is mainly limited to help such understanding in science.

Table 8

Level of Procedural Understanding Domain in Each Textbook

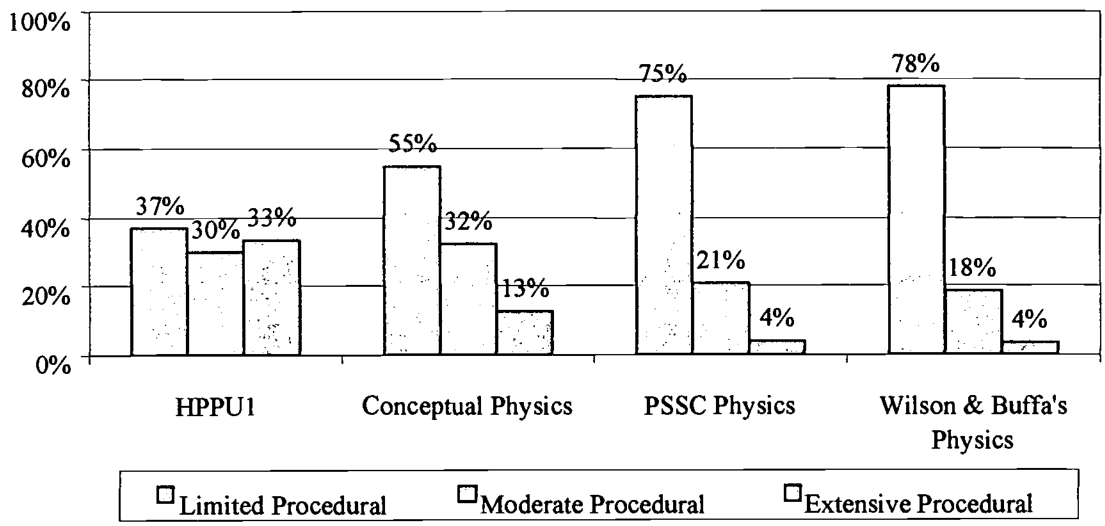
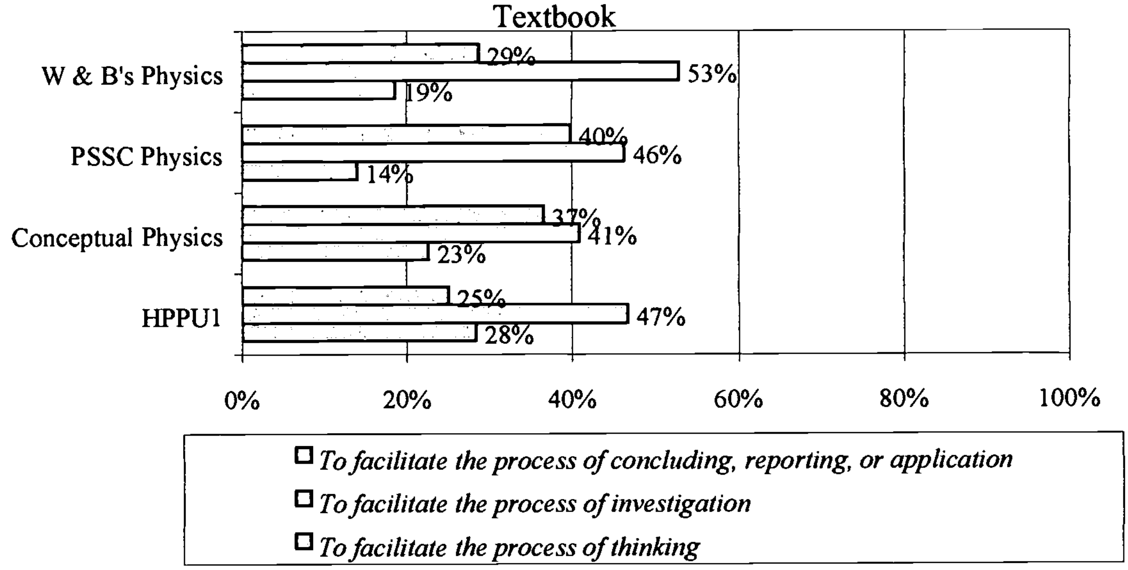


Table 9 provides further information about the distribution of HOS units in the three subdomains of Procedural Understanding—2.1: To facilitate understanding in the process of thinking, 2.2: To facilitate understanding in the process of investigation, and 2.3: To facilitate understanding in the process of concluding, reporting, or application. The distributions in the subdomains of the HOS units with effects on the Procedural Domain were about the same for the three contemporary physics textbooks. The data show that whenever historical elements were included in the selective textbooks to facilitate Procedural Understanding, the objective was more to facilitate understanding in the process of investigation. Following the process of investigation, the process of making conclusion, reporting findings, or making application was the next most commonly distributed by the three contemporary textbooks. The facilitation of understanding in the process of thinking was the weakest aspect within all three selected contemporary physics textbooks. In contrast, Unit One of *Project Physics* seemed to have more HOS units related to the scientists' thinking process.

~~Table 9~~.

Distribution of HOS Units in Procedural Subdomains for Each Textbook



Finding Four

Although Contextual Understanding was found to be the second most prevalent domain, few HOS units were found to foster science as a human endeavor. Contextual Understanding through the history of science content also pertains to an understanding of science development in its various cultural aspects. Yet, multicultural understanding, as expressed in the selected textbooks through their inclusion of the history of science, was found to have only superficial coverage and was limited to Western heritages, which is insufficient to meet the goal of a multicultural science education.

Table 10 shows that the HOS units with effects in the subdomains of the Contextual Domain were similarly distributed among the three contemporary physics textbooks. These textbooks have more Limited HOS units found in this domain. Deviating from this norm, Unit One of *Project Physics* was found to have more Moderate effects on Contextual Understanding. The historical elements included in *Project Physics* were enough to facilitate moderate understanding of the psychological, social, or cultural aspects of science. Moreover, unlike its contemporary counterparts, *Project Physics* had about one quarter of its HOS units being perceived as Extensive Contextual Understanding; whereas, the three contemporary physics textbooks had on average less than one-tenth of their HOS units that could be recognized as in the Extensive Contextual Domain.

Table 10 .

Level of Contextual Understanding Domain in Each Textbook

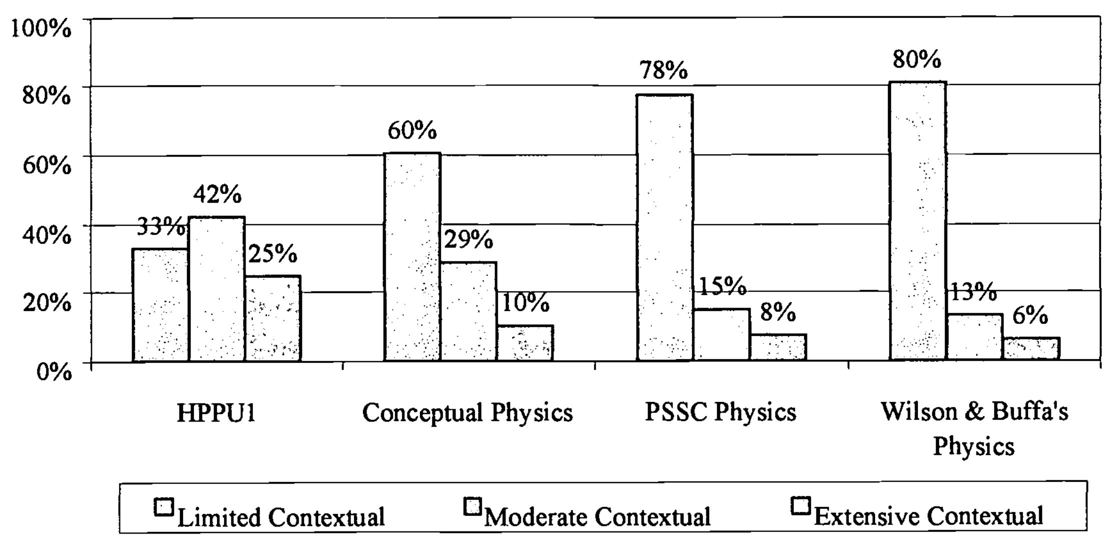
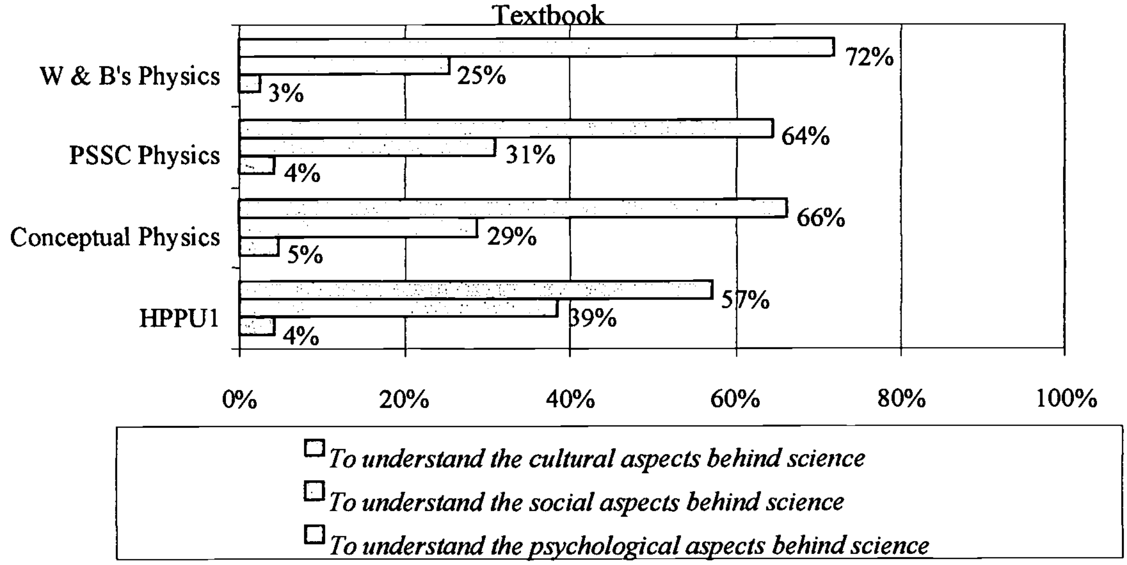


Table 11 provides further information about how the HOS Units were distributed in the three sub-domains of Contextual Understanding—3.1: To facilitate understanding in the psychological aspects behind science, 3.2: To facilitate understanding in the social aspects behind science, and 3.3: To facilitate understanding in the cultural aspects behind science. Although historical elements were included to facilitate Contextual Understanding, the objective was more to facilitate understanding in the cultural aspects behind science. Such findings were consistent across all textbooks examined. The cultural aspects behind science as stated in the Conceptual Framework refer to the personal character of scientists, family or cultural background, social environment, or ethnicity-related issues. More specific examples are provided in Wang (1998).

As shown in Table 11, next to the cultural aspects, these textbooks had more discussions in the social aspects behind the science. The psychological aspects behind the science were neglected by all textbooks. Historical elements included in all textbooks paid almost no attention in information about what motivated scientists, and what incentives drove scientists to conduct research.

Table 11 .

Distribution of HOS Units in Contextual Subdomains for Each Textbook



Conclusions

Benchmarks for Science Literacy (AAAS, 1993) and *National Science Education Standards* (NRC, 1996) both describe standards of what students should know and learn from the history of science. Science textbooks are known for their significant role in teaching and learning science. Consequently, to foster standards-based science education reform, contemporary science textbooks should be evaluated by their correspondence to those recognized learning standards.

This study examined three current secondary school physics textbooks—*Conceptual Physics* (Hewitt, 1993), *PSSC Physics* (Haber-Schaim, Dodge, Gardner, & Shore, 1991), and *Physics* (Wilson & Buffa, 1997)—for their inclusion of the history of science content, and determined their readiness for science literacy benchmarks judging on the history of science content included. In this study, science literacy through learning the history of science was categorized into three domains—Conceptual Understanding, Procedural Understanding, and Contextual Understanding. Together with subdomains, these three domains compose the conceptual framework that was used to guide the analyses of the textbooks and the standards documents. The two sets of results, from the textbooks and the standards documents, were then compared.

Discussions

1. Standards documents have influenced the content included in the science textbooks. However, lack of a strategic vision of learning outcomes—that is, clear and demanding performance standards—has led to a situation in which instructional materials fail to serve the needs of students.

The study findings show that the distribution of HOS among the three defined domains of the HOS Conceptual Framework in current physics textbooks is closely aligned with the proposed standards in *Benchmarks* and *NSES*. Both content standards documents were found to advocate most strongly Conceptual Understanding, through the history of science, then Contextual Understanding, with the least emphasis on Procedural Understanding. This pattern was reflected also in the three selected current secondary school physics textbooks. The inclusion of HOS elements in the textbooks is consistent with the directions in the standards documents. However, the standards-based contents in the physics textbooks were mostly found to be less comprehensive in terms of fostering understanding. There are reasons for this result.

Each textbook analyzed was found to have a significant number of HOS units designed to help students develop conceptual understanding. Despite the pervasiveness of the use of the conceptual framework, the HOS units found represent a low level of conceptual understanding. From Finding Two, it was reported that authors of these textbooks did "decorate" the main text with some historical elements. Names of scientists, years they lived, their nationalities, sometimes brief biographies—these fringe historical facts are the most commonly integrated elements for science textbook preparation. This commonly applied strategy has been found to enrich the science content presentation and to make it more interesting and engaging. This phenomenon reflects the call from *Benchmarks*: "Generalizations about how the scientific enterprise operates would be empty without concrete examples" (AAAS, 1993, p.237). Those elements were the *concrete* examples; yet, how effective they are in engaging student learning is under question. To engage readers, it is important to make the textbooks interesting to read by adding some spice and flavor. Yet, the chief function of instructional materials, such as textbooks, should extend beyond engaging students to learn. The focus should be, What is there to learn?

Moreover, this study also found that all the current secondary school physics textbook examined typically include STS (science, technology, and society), real-life applications, hands-on activities, or approaches using the ideas of multiple intelligence; in short, whatever is a "hot" issue among the science education community, one can find it in the textbook. However, because of this "cover-it-all" intention, the textbooks are very diffuse and confusing. In the standards documents, beyond the history of science chapter, it is clearly stated that the content material is to be spread out from kindergarten to twelfth grade. Never is it the intention that it be covered in one single textbook. Ironically, the current physics textbooks cover almost all the topics listed in the standards documents.

Conceptual Understanding in science requires "depth" rather than "breadth." The thickest science textbooks in the world are found in the United States. Heroic instructors may well intend to teach everything in the textbook, and ambitious or eager students may read the textbook cover to cover. Yet, how much can anyone really absorb from physics "encyclopedias"? Our textbooks provide so many steps, explanations, and crude exercises that they leave little space for thinking. It is almost a "dumb-down" strategy that merely betrays the fear that students will not "get" it, but the result is that it leaves no space for students to grow. Imagination and creativity are stifled by this "hand-feeding" fashion of presentation.

These "cover-it-all" strategies and perfunctorily cranked-out learning exercises are evidence that textbook writers should be clear about their objectives and expectations toward students' learning outcomes when students use their textbooks.

2. Science literacy is unlikely when standards documents focus merely on the science content knowledge through the history of science; the process and application of science should also be emphasized. Consequently, authors of textbooks will have to provide strategic procedural understanding that is embedded in the history of science.

The Procedural Understanding domain of science literacy, as defined in this study, contains three "processes" of science—the process of thinking, the process of investigation, and the process of concluding, reporting, and application—when science history is introduced into the curriculum. Overall the science standards documents did not address the history episodes that would be used as tools to enhance students' scientific processing skills. If any were addressed, only the process of investigation was briefly mentioned. In accordance with the standards documents, attention to the domain of Procedural Understanding was found to be lacking in the studied physics textbooks.

Within the history of science for science education literature, it has been common practice to recommend that science teachers assign readings about scientists' thinking processes, or how scientists generated ideas, conducted experiments, and made inferences. But little is known about how well reading transfers to a cognitive understanding that enhances habits of thinking or skills of scientific investigation; so, what is to be the role for science textbooks? What has been understood is that knowledge can be transferred within a specific domain (Clark & Blake, 1997). Thus, in order to assist students in the domain of Procedural Understanding, science textbooks need to introduce specific reading about scientists' thinking processes, experimenting processes, and charting, reporting, or application processes.

Moreover, on the eve of a new millennium, more educators recognize that the well-educated citizens of the twenty-first century are individuals who are able not only to master the essential "basics" but also to perform active or creative thinking. The habit of active thinking needs to be delivered in a subject context. Science is known as a logic of thinking, which makes science a perfect discipline to use as a tool to foster the logical thinker. In the history of science, many episodes can be identified that demonstrate the habits of creative thinking and problem solving in a logical fashion. *Project Physics* presents many such examples, whereas in current physics textbooks these episodes are either absent or else poorly elucidated.

3. There were few examples presented that showed the scientists as human beings who faced issues such as ethics or personal fears. Their motivation, persistence in science, and personal character were treated as a non-issue in the selected physics textbooks.

Although Contextual Understanding was found to be the second major domain that textbooks and standards documents emphasize when including the history of science, only trivial information was sprinkled through the presentation indicating what professions the scientists had, what countries they were from, and so forth.

When the styles of presenting the historical elements were examined, most textbooks showed a pattern of usually including the scientists' names (Wang, 1998). However, little sense of the scientists' actual lives comes across in these textbooks, such as information about scientists' working conditions, why and how these conditions were forced on them, how such conditions influenced or shaped their research characteristics, or how they were similar to or different from their scientist contemporaries. There were some superficial discussions about the religious or political atmosphere in society that was in conflict with or hostile toward science.

The examined textbooks included the names of scientists to pay tribute to these giants who contributed their intellectual products and to guide readers to these scientific works and concepts, but they did so at the expense of understanding the scientists as real persons. Moreover, interests or attitudes and all other psychological aspects related to science making were rarely addressed by any of the selected textbooks; issues of psychological aspects in science were almost a non-issue (see Table 11).

Science education researchers found that vignettes and quality biographies of scientists can vividly bring out scientist's true lives, delineate the relationships between the lives and works of the scientists and their contemporaries, and clarify the image of scientists. This proposal to include the biography was found in all textbooks examined. Unfortunately, extensive and quality vignettes or biographies were rare in the textbooks analyzed.

4. Although Contextual Understanding was found to be the second dominant domains when science history was included, few HOS units can be recognized to foster science as a human endeavor, owing to the fundamental belief of the textbook writers.

The common belief running through all current physics textbooks is that students should master science concepts. This is reflected in every introduction or prologue of the selected textbooks and has resulted in pages of problem solving exercises and strategies of "how to." The idea of science as a human endeavor is, then, the expansion of this belief. Mastering science concepts through elaborated problem solving exercises is the goal of all three textbooks, whereas Contextual Understanding is less than a major concern for enhancing the mastery of concept; the information included is considered to be more a fringe *about* science than an integral part of science.

Even so, the domain of Contextual Understanding was the second dominant realm analyzed in the HOS Units found (except the HOS units found in the *PSSC Physics*); nevertheless, the inclusion demonstrated limited effect when compared with the effect of the exemplary HOS physics textbook, *Project Physics*. One quarter of the HOS units analyzed in *Project Physics* were judged to be serving an *Extensive* effect in fostering Contextual Understanding, whereas, only one-tenth, on average, of the HOS Units of all three current selected textbooks could be recognized as *Extensive* Contextual units (see Table 10). One can almost conclude that the "mastery in science concept" and "understanding of science as a human endeavor" are two divergent and independent beliefs as portrayed in these three current textbooks.

While humanizing science to enhance science literacy for all students has been advocated for nearly four decades, this important notion seems not to be shared by the writers of the examined textbooks. The humanities, such as art, music, and social and political sciences are human endeavors, but so is science. Science can be presented not only as a logic of thinking; science can be taught from a holistic perspective. It is the human that is behind the science making. This position is best described by the Alfred P. Sloan Foundation, a society that actively promotes scientific literacy for all citizens:

> Science in this century has become a complex endeavor. Scientific statements may reflect many centuries of experimentation and theory, and are likely to be expressed in the language of advanced mathematics or in highly technical terms. As scientific knowledge expands, the goal of general public understanding of science becomes increasingly difficult to reach. . . . Yet an understanding of the scientific enterprise, as distinct from data, concepts, and theories, is certainly within the grasp of us all. It is an enterprise conducted by men and women who are stimulated by hopes and purposes that are universal, rewarded by occasional successes, and distressed by setbacks. Science is an enterprise with its own rules and customs, but an understanding of that enterprise is accessible, for it is quintessentially human. And an understanding of the enterprise inevitably brings with it insights into the nature of its products." (Rees, 1988, p. ix)

Science is a language that human beings apply to understand nature. Taking science away from this context or from other aspects of human life creates confusion and obstacles to the enhancement of science literacy. Science should be understood as a collective human endeavor pursuing a logical and evidence-based method to understand nature. Because of its importance, this position needs to be embraced by textbook writers; otherwise, problem solving and "story-telling" will continue to be treated as two separate issues instead of one integral whole.

To illustrate, the following is an examination of examples of HOS Units containing references to Galileo, which contributed to this finding. Frequently, authors of the three selected textbooks, in explaining the concept of inertia, point to Galileo's contribution to this concept, but they do so without providing any further historical context. If, in stead, like the strategy found in the *Project Physics*, the historical aspect were to be included within a well-elaborated presentation, students could then learn the dynamic, scientific, knowledge-promoting process that guided Galileo's mind and how this mental idea-formulating method can relate to their own though processes.

5. Contextual Understanding through the history of science content pertains to an understanding of science development in its various cultural aspects. Yet, multicultural understanding, as expressed in the selected textbooks through their inclusion of the history of science, was found to have only superficial coverage and was limited to the Western heritage.

In the *Oxford Advanced Learner's Dictionary* (Hornby & Cowie, 1984), culture is defined as the evidence of intellectual development of body, mind and spirit by training and experience; development of art, science, social institutions; characteristics of community and race, and so forth, in human society. Rarely can the above understanding of "culture" be found when examining the selected physics textbooks. As with the intellectual processes of scientists and their characteristics in science development, science development among representative ethnic groups is absent in most selected textbooks. Even in *Project Physics*, Western perspectives of science are dominant whenever cultural elements are brought into the discussion. *Conceptual Physics* is the only textbook examined that includes various ethnic contributions to science development and what science means in different cultures.

In *Benchmarks*, it is stated that the history of science can bring about students' appreciation of Western heritage. Such a presumptious statement is misleading, and it diminishes the other, non-Western cultures. In modern society, the West needs to meet the East. A global science education requires a science education standard that guides science instruction to facilitate the student's global view of science. A global science education is intended to educate future generations to develop an appreciation of individual differences in various cultures and also address various cultural characteristics as they pertain to the advancement of science. As a result of the advancement of technology—the World Wide Web, for example—connections between different groups of people on various continents have brought the scientific industry to another era of advancement. Future citizens needs to know more than their own culture's heritage. The findings of this study again elucidate the importance for science educators to hasten their pace to reach a global science education objective.

Implications

Implications for Science Standards, Curriculum, and Textbooks

The TIMSS study of curricula found that most mathematics teachers were aware of the NCTM's standards document. The mathematics teachers supplemented instructional materials to help students achieve those stated standards. Unfortunately, when adding new materials, they failed to drop old, ineffective instructional materials. As a result, their intended mathematics lessons became increasingly difficult to finish within the scheduled time. Although they tried to finish all the lessons, students received mostly unfocused instruction that lacked depth (Schmidt, Jorde, Cogan, et al.,1996). The findings of this study echo TIMSS's findings in this aspect. The science textbooks studied appeared to add more and more things while failing to drop old "stuff."

The authors of textbooks continue revising their textbooks to bring them into alignment with the visions or aims stated in the educational policy reports—that is, the standards or curriculum frameworks. Old and ineffective approaches or contents are "obstinate" and usually stay in the textbooks. As a result, science textbooks become a collection of widely varying topics. An important implication of this study is that current science textbooks need major "surgery" that keeps only the essential content that is effective in science instruction and learning. This surgery needs two important steps.

First. "What is essential to learn in science?" should be answered before the textbook writers can start their revisions. The standards documents—*Benchmarks* and *NSES*—have clearly defined content standards for K-12 science education. This is not a sufficient step to answer the question, What is essential to learn? Beyond the education of K-12, what do we expect of our students? A portion of our high school graduates will immediately enter society to work. Another portion of the graduates will enter some kind of college (for example, occupational college) to prepare themselves for the workforce. Yet another portion of the graduates will enter an academic college and continue their education. Sooner or later, both groups of graduates who attend college will enter society and join their peers to contribute what they learned. Therefore, one might ask what science experiences students can have in K-12 and higher education that can best prepare them for future society. The answer to this question is the key to the previous question, What is essential to learn? This is not an easy question to answer, but it needs urgent attention from the science education community.

Benchmarks explicitly lists ten historical episodes as important examples of the content standards for the history of science. Most of these standards descriptions state what historic moments students should learn. Yet, neither *NSES* nor *Benchmarks* describes standards that also specify performance standards to show the connection between content mastery and excellent performance. One such performance standard might be: after learning science within its historical context, students should be able to compose a research grant proposal that demonstrates skills learned. While the vision of expected learning outcomes is essential to guide the preparation of instructional materials, science education standards documents need to address both content standards and concrete performance standards that are shared by all those who have a stake in science education.

Second. The reconstruction of science textbooks should be guided by a clear vision of science literacy. As one recalls the development of the HOS Conceptual Framework of this study: This conceptual framework can be extended to any content inclusion when science literacy is the intention. Science literacy covers three domains—Conceptual Understanding, Procedural Understanding, and Contextual Understanding. Every subdomain within this framework carefully provides directions for content presentation in science textbooks. It is believed that authors of science textbooks can use these tools to guide their revisions of science textbooks.

In addition to the demonstrated need to reconstruct current science textbooks, one finding of this study was also critical of textbook writers. At the beginning of the content analysis of the selected textbooks, a study unit was defined as "a complete paragraph." As the study continued, a pattern was found concerning the HOS inclusion. Most frequently, an *extensive* HOS unit could be designated when three or more units were identified as HOS units within a single page. This implies that in order to have an extensive HOS unit, a "widow" unit is not sufficient. More elaborate and extensive descriptions need to be present to complete the initial intention of inclusion. This finding again reflects the "mile wide and inch deep" tendency in the science curriculum, as described by TIMSS. Writers of textbooks need to elaborate on the historical elements when any domain of science literacy is intended to be achieved through the inclusion of the history of science. Simply throwing in one or two paragraph with historical elements serves very limited function in facilitating students' understanding of science.

Implications for Research in Science Education

For researchers of science education, a study of this kind is important. Content analysis of science textbooks without a specific conceptual framework grounded in learning standards serves limited function regarding its classroom implications. There are more issues in the standards documents that need to be addressed for their accordant status with instructional materials. Researchers need to understand that the key message of this study is that the extent of content coverage is not critical when the inclusion is superficial. Moreover, clear learning outcomes should be defined as being closely associated with the content standards, because a vision of clear learning outcomes can assist in the preparation of a comprehensive science textbook. In addition, an assessment system that is aligned with the stated learning outcomes should be constructed and established. Such action can reinforce the production of sounder, more effective instructional materials.

In addition to contributing to the research in science textbooks, this study also recognizes two important issues for researchers who are interested in the history of science inclusion for science instruction.

First. During the analysis of *PSSC Physics*, one missing aspect of the history of science was found: the verification process of science. In Galileo's era, the antique time of science history, there was little information in the selected textbooks about how scientific laws, principles, and theories were verified. By contrast, modern scientists were reported to have designed various experiments, activities, and demonstrations to help their colleagues replicate their studies. This is a verification process, a process to test the validity and reliability of results. In antique science history, verification also included public demonstrations of science discoveries. These public demonstrations took place in the fourteenth or fifteenth centuries and have continued to the modern era, only the formats are different. Galileo demonstrated his findings from a leaning building. Today, astronauts carry out demonstrations from their space ships in front of televised broadcasts. These verifications of science concepts were found to be an important focus in the *PSSC Physics*, especially in its last eight chapters, which are labeled "optional" chapters. A plethora of examples of modern activities, demonstrations, experiments to verify or elaborate on science concepts conducted by the scientific community are introduced. Future study to analyze the history of science inclusion should consider constructing a new subdomain of "the process of verification" in the domain of Procedural Understanding.

Second. The essential history of science content for future students to learn can be expanded beyond antique science history to 1900 and on. In any period of science history there are remarkable historical events that can serve as "enhancers" of the instructional purpose. One finding that was not reported in Chapter Four is that the extensive HOS units found in the three textbooks usually dealt with either the Galileo–Aristotle period or the modern physics era. The former period of history—Galileo–Aristotle—has been thoroughly studied in the history of science community. As to the modern science period, a major finding was that integrating the history of modern physics contributes to personal relevance because the historical context is much closer, compared to other historical episodes.

Historical moments in modern physics that are described are not alien to us. Such historical episodes portray today's scientists working in teams and publishing in journals; they attended conferences to report their research findings, and prepared persuasive proposals to compete for funding; they played musical instruments (such as Feynman and his drum), and the products they produced are sometimes still in use. Other references, in social, cultural, and political contexts, are easy to identify and relate to contemporary life, and that became one of our indicators that the HOS units about modern physics were being extensively presented. Such an important finding should be an important lesson when considering the integration of the history of science.

Implications for Teacher Preparation

In accordance with the findings of this study, Wang and Marsh (in press) found that K-12 science teachers share the same belief about integrating the history of science into science instruction. Their perceptions and practices in such a historical approach science instruction were found centered around the Conceptual Understanding Domain as well. The historical elements were found to be integrated in their science instructions to enrich the scientific knowledge presentation. However, when selected science teachers were interviewed, their responses all led to reporting the lack of instructional materials support in teaching the history of science. Although they were aware of the lack of depth phenomenon regarding to the level of content science textbooks presented. They believed that there were no quality search instructional materials that best meet their instructional objectives of teaching the history of science.

Teacher education and in-service or professional development workshops continue to emphasize bringing up-to-date educational strategies into teacher education. It happens so frequently that we squander incredible resources on these trends to "make sure" that "Hey, we are onto the *hottest* trend!" with little careful examination of these fashions or trends. The educator should not go after every trend but needs to act as a responsible and mature consumer of *valid* educational research. Before we bring these trends into teacher education, responsible educators need to scrutinize what the trend means to education, how valid the trend is, and what evidence there is that the trend will improve students' learning. Do we really understand brain research as it applies to multiple intelligent science instruction? Do we have scientific evidence to support radical or socially constructive science instruction?

Perhaps the necessary action for educators is not to follow the "fancy" trends but to reflect on past *traditions*, which indicate that schooling is composed of a sound system with qualified teachers and quality instructional materials. The need is to have a system that holds everyone who has a stake in it—policymaker, administrator, principal, teacher, student, parent, community member—accountable for good education. A challenging and quality education for future science classrooms requires teachers to have skills in facilitating students' learning. Such education also requires the system to prepare quality instructional materials to assist teachers. This call for action requires teacher education to design a program that prepares student teachers to be capable of preparing quality lessons guided by specific learning outcomes, and to be familiar with quality instructional resources. This call for action requires in-service workshops to model quality lessons that are reflected in successful students' learning and to provide time for teachers to exchange ideas about effective instructional materials they use when teaching science. This is the tradition of education.

Epilogue

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 example, by having an understanding of science contents such as Physiology, Biology, and Chemistry, scientifically literate individuals would be able to reason out health-related issues such as nutrition awareness or medicine usage, rather than buying into lack-of-evidence propaganda. 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. A group of these scientifically literate individuals might develop a passion for and confidence in science and decide to become scientists. Perhaps a group of these scientifically literate individuals would become policymakers capable of making reasonable judgments and then deciding to provide support for a science research and development (R&D) budget.

With such a noble educational mission—"every citizen can understand science"—for nearly forty years, it should be no surprise to learn that there are scientifically literate individuals among us. However, reality generally does not reflect our long-advocated educational mission: to prepare scientifically literate citizens. The progress in enhancing our citizens' level of scientific literacy has been reported to be diminishing during the past few decades. Recently, the high school students in the United States were found to be below the international average in a science literacy achievement test (Mullis, Martin, Beaton, Gonzalez, Kelly, & Smith, 1998). The disheartening findings of low achievement in science literacy were found to be significantly related to the many diverse visions and many aims in school science coming from various directions and inherent in the system's science education policies (Schmidt, Raizen, Britton, Bianchi, & Wolfe, 1997). Such a splintered vision of science education has led to an unfocused curriculum (Schmidt, McKnight, & Raizen, 1997) that is confusing to teachers and falls short of preparing our students for science literacy.

There is hope for our science education. The new standards-based science education reform, starting from the release of NCTM's mathematics standards, signals that a coherent vision can be reached. Such a mission requires participation from all those involved—policymakers, program designers, publishers, administrators, teachers, the community, parents, and students. Such a mission indicates that standards-based and systemic changes are necessary to reform our current schooling.

In this new wave of science education reform, the intended goals or purposes of science education have been clearly stated in standards documents. Consequently, the policymakers should design and prepare a system based on the premises of these science education purposes. This educational milieu is orchestrated by qualified instructional leaders such as principles, administrators, teachers, and responsive community members and parents to help students emulate those stated learning benchmarks. Those science education benchmarks also affect all educational programs. Educational researchers will apply the educational benchmarks to carefully evaluate the instructional materials and programs to ensure that quality and adherence to standards (standards-basing) are the essential prerequisites embodied in these programs and instructional materials.

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