Iowa Science Teachers Journal

Volume 31 | Number 1 Article 4

1994

An Analysis of Physical Science Textbooks for Scientific Literacy

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AN ANALYSIS OF PHYSICAL SCIENCE TEXTBOOKS FOR SCIENTIFIC LITERACY

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Introduction

Developing the scientifically literate individual is considered to be an important objective of science education in the United States (Blough and Schwartz 1990, Maarschalk 1988, Murane and Raizen 1988, National Science Teachers Association 1971, 1982; and Simpson and Anderson 1981). The scientifically literate person understands how science, technology and society influence one another, and is able to use this knowledge in everyday decision making (AAAS 1989, Yager and Harms 1981).

A comprehensive definition of scientific literacy was generated by Project Synthesis in the early 1980s. The purpose of Project Synthesis was to "examine the countenance of science education as it exists at the precollege level and to make basic recommendations regarding future activities in science education" (Kahl and Harms 1981, p.5). In defining the ideal state of science education, the researchers of Project Synthesis began with the assertion that there are four broad goals which justify the inclusion of science in the school program (Yager and Penick 1987). The goal clusters describe the scientifically literate person as (1) One who can utilize science for improving his/her own life and for coping with an increasingly technological world; (2) One who can deal responsibly with science-related societal issues; (3) One who can acquire the scientific and technological knowledge appropriate for his/her academic needs and (4) One who has an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests (Kahl and Harms 1981). The four goal clusters, (1) Personal Needs, (2) Societal Issues, (3) Academic Preparation and (4) Career Education/Awareness are described in *What Research Says to the*

Science Teacher--Volume 3 (Harms and Yager 1981). Thus, science education, as operationalized by the Project Synthesis Goal Clusters, incorporates far more than traditional content-laden instruction. Instead, it reflects a strong general education approach. That is, the Project Synthesis Goal Clusters describe an educational thrust which might be deemed appropriate for all citizens.

Purpose

Research indicates that the level of scientific literacy among the public is low (Miller 1983) and that most high school graduates are scientifically illiterate (Hurd 1986). More specifically, about 90 percent of all high school graduates are neither scientifically nor technologically literate (Voelker 1981, Yager and Penick 1983). Moreover, the research reviewed in Project Synthesis described a heavy reliance on the textbook by science teachers. Thus, in many instances, the textbook embodies the content of science courses. The purpose of this study was to analyze the most commonly used junior high school level physical science textbooks for scientific literacy as defined by Project Synthesis Goal Clusters. In so doing, this study identified the degree of emphasis given to each of the Project Synthesis Goal Clusters in the selected physical science textbooks. The following research questions were proposed for this study:

(1) With what frequency do the objectives within individual physical science textbooks relate to each of the Project Synthesis Goal Clusters?

(2) What percentage of objectives within individual physical science textbooks relate to each of the Project Synthesis Goal Clusters?

(3) How does the frequency of objectives in each goal cluster rank within individual physical science textbooks?

(4) To what extent do physical science textbooks differ with respect to their emphases on each of the four Project Synthesis Goal Clusters?

(5) Using the objectives from all the physical science textbooks as a whole, what is the relative frequency, percentage and ranking of each of the Project Synthesis Goal Clusters?

Textbooks and Objectives Selected for Analysis

The textbooks utilized in this study were commonly used junior high school (grades 6-9) physical science textbooks which contained

TABLE 1
Information on Physical Science Textbooks Analyzed For Scientific Literacy

Publisher and Title of Textbook	Authors	Grade Level	Copyright Date	No. of Objectives
Addison-Wesley Publishing Co. *Addison-Wesley Physical Science*	Johnson et al.	7-9	1988	155
Addison-Wesley Publishing Co. *Introduction to Physical Science*	Leyden et al.	6-9	1988	121
Merrill Publishing Co. *Focus on Physical Science*	Heimler & Price	6-9	1989	307
D.C. Heath and Co. *Heath Physical Science*	Carle et al.	6-9	1991	273
Holt, Rinehart and Winston, Pub. *Holt Physical Science*	Ramsey et al.	7-9	1986	179
Macmillan Publishing Co. *Macmillan Physical Science*	Eby & Horton	6-9	1988	200
Prentice-Hall, Inc. *Prentice Hall Physical Science*	Hurd et al.	6-9	1991	470
Scott, Foresman and Co. *Scott, Foresman Physical Science*	Heimler & Price	7-9	1990	309

objectives and which were published by a major publishing company no earlier than 1986. The sample of this study consisted of the entire population of objectives included within the selected physical science textbooks. A total of 2,014 objectives were analyzed. The number of objectives included within any individual textbook ranged from 121 to 470. (See Table 1.)

Instrumentation

For this study, the objectives of the selected physical science textbooks were categorized in relation to the four Goal Clusters of Project Synthesis. The descriptive portion of the instrument included coding directions as well as definitions and descriptions of the four Project Synthesis Goal Clusters. Eight sample objectives were provided (two for each of the four Project Synthesis Goal Clusters) along with an identification of the appropriate goal cluster to which each related. If an objective pertained to more than one goal cluster, the objective was classified according to its inferred major intent. For example, the objective "Define energy conservation and list ways to conserve energy," could be classified into two goal clusters. Although the first part of this objective "define energy conservation" is related to Goal Cluster III (Academic Preparation), its major intent (which appears in the second part, "list ways to conserve energy") is related to Goal Cluster II (Societal Issues). Thus, this objective was classified as Goal Cluster II. If an objective did not fit into any of the four goal clusters, it was classified as NA (Not Applicable).

In order to determine reliability of the coding process, twenty behavioral objectives were selected from the pool of objectives. After the senior author and two doctoral students in science education independently classified these objectives in relation to the Project Synthesis Goal Clusters, an assessment was made of the agreement between their classifications. Percentages of interscorer agreement were 95 percent, 90 percent and 85 percent.

Data Collection and Analysis

The total population of objectives from the eight physical science textbooks was listed by chapters or chapter sections, and the corresponding goal cluster was identified for each objective. Upon completion of the classification of objectives, frequencies and percentages of objectives in each goal cluster were calculated. These data provided the information necessary to answer the research question.

Results

Research questions #1 and #2 focused on the frequency and percentage of objectives related to the Project Synthesis Goal Clusters. Research question #3 focused on the rank of the objectives. Table 2 presents the frequencies, percentages and relative ranking of goal cluster-related objectives within each textbook.

The objectives within the individual physical science textbooks were disproportionately represented by the Academic Preparation Goal Cluster. Objectives classified into the Academic Preparation Goal Cluster (Goal Cluster III) comprised 86.8 percent to 96.7 percent of the total, while objectives classified into the Societal Issues Goal Cluster (Goal Cluster II) accounted for 2 percent to 9.9 percent. On the other hand, objectives classified into the Personal Needs Goal Cluster (Goal Cluster I) accounted for .6 percent to 3.3 percent while objectives pertaining to the Career Education/Awareness Goal Cluster (Goal Cluster IV) accounted for only 0 percent to .6 percent of the objectives within the individual physical science textbooks.

The objectives related to the Academic Preparation Goal Cluster (Goal Cluster III) received the greatest emphasis and ranked first relative to the other three goal clusters in each physical science textbook. The Societal Issues Goal Cluster (Goal Cluster II) was ranked second. In third rank was the Personal Needs Goal Cluster (Goal Cluster I). The Career Education/Awareness Goal Cluster (Goal Cluster IV) ranked fourth in five of the physical science textbooks. However, in three physical science textbooks the Career Education/Awareness goal cluster received no emphasis at all. These findings parallel the earlier finding of the research focus group of physical science as reported by Project Synthesis (1981). According to Anderson (1981), it was clear that "with the physical science area, fundamental knowledge [took] precedence over the other three goal clusters" (p. 39).

Research question #4 focused on the emphases of the objectives in relation to the Project Synthesis Goal Clusters. Little variation existed across the eight physical science textbooks with regard to the emphasis placed upon the different Project Synthesis Goal Clusters. A comparison of the textbooks revealed that objectives pertaining to the academic preparation goal cluster ranged from 86.8 percent to 96.7 percent. The emphasis placed upon the other three goal clusters (Personal Needs, Societal Issues, and Career Education/Awareness) was low and approximately the same throughout the textbooks. More specifically, the objec-

TABLE 2
Classification of Behavioral Objectives into the Project Synthesis Goal Clusters.

Title of Textbook	Project Synthesis Goal Clusters: Personal Needs *f	%	R	Societal Issues f	%	R	Academic Preparation f	%	R	Career Education f	%	R
Addison-Wesley Physical Science	4	2.6	3	9	5.8	2	141	91.0	1	1	0.7	4
Introduction to Physical Science	4	3.3	3	12	9.9	2	105	86.8	1	-	0.0	4
Focus on Physical Science	3	1.0	3	7	2.3	2	297	96.7	1	-	0.0	4
Heath Physical Science	8	2.9	2	8	2.9	2	256	93.8	1	-	0.0	4
Holt Physical Science	2	1.1	3	4	2.2	2	171	95.5	1	1	0.6	4
Macmillan Physical Science	3	1.5	3	4	2.0	2	187	93.5	1	2	1.0	4
Prentice Hall Physical Science	3	0.6	3	20	4.3	2	446	94.9	1	1	0.2	4
Scott, Foresman Physical Science	7	2.3	3	11	3.6	2	289	93.5	1	1	0.3	4

*f = Frequency; % = Percent of total; R = Rank of goal cluster within each textbook. i.e., 1 = greatest frequency of occurrence and 4 = lowest frequency of occurrence.

tives classified into the Personal Needs Goal Cluster ranged from .6 percent to 3.3 percent, while the objectives related to the Societal Issues and Career Education/Awareness Goal Clusters ranged from 2.2 percent to 9.9 percent and from 0 percent to 1 percent respectively.

Research question #5 focused on the frequency, rank and percentage of the total pool of objectives in relation to the four Project Synthesis Goal Clusters. These comparisons can be found in Table 3. The objectives related to the Academic Preparation Goal Cluster (Goal Cluster III) exceeded 90 percent of the total 2,014 objectives. Specifically, 93.9 percent of the objectives related to academic preparation. The percentages of objectives addressing the Personal Needs and Societal Issues goal clusters were 1.7 percent and 3.7 percent respectively. The Career Education/Awareness Goal Cluster comprised the lowest share, .3 percent.

These findings are similar to those of Staver and Bay (1987) and Torzynski (1987) when they analyzed science textbooks using the Project Synthesis Goal Clusters as a framework for analysis. Staver and Bay (1987), analyzing eleven elementary science textbooks, found that the Academic Preparation Goal Cluster received an emphasis in most science text prose up to 95.44 percent. They reported that "The vast majority of information in the chapters analyzed concentrate[d] on the Academic Goal Cluster. Attention given to the Personal, Career, and Societal goal clusters was minor" (p.637). Similarly, upon analyzing the objectives of five earth science textbooks at the junior-senior high school level, Torzynski (1987) found that 92.6 percent of the objectives she analyzed related to academic preparation.

Conclusions and Implications

Based upon the data for research questions #1 and #2, currently used physical science textbooks contain a disproportionate emphasis on academic preparation. Objectives classified into the Academic Preparation Goal Cluster (Goal Cluster III) comprised 86.8 percent to 96.7 percent of the total objectives. It is unlikely that scientific literacy will be promoted via the courses which use the physical science textbooks which were analyzed. If these textbooks are to be effective in promoting scientific literacy, they need to be modified and/or supplemented with additional materials that place more emphasis upon Personal Needs, Societal Issues and Career Education/Awareness.

The total number of objectives dealing with the non-academic goal clusters (i.e., Personal Needs, Societal Issues, Career Education/Aware-

TABLE 3
Classification Of The 2,014 Objectives Derived From The Eight Physical Science Textbooks Into The Project Synthesis Goal Clusters

Goal Cluster	Frequency	Percent	Rank*
Personal Needs	34	1.7%	3
Societal Issues	75	3.7%	2
Academic Preparation	1,892	93.9%	1
Career Education/Awareness	6	0.3%	4
Total	2,014	99.6% **	

* Rank of goal cluster within the eight textbooks, i.e., 1= the greatest frequency of occurrence and a 4 = the lowest frequency of occurrence.

** The percentage does not add to 100% because 7 objectives were classified as "Not Applicable" to any of the four goal clusters and are not shown in this table.

ness) ranged from 3.3 percent to 13.2 percent in the analyzed physical science textbooks. The overwhelming emphasis on the Academic Preparation Goal Cluster at the expense of the other three goal clusters (Personal Needs, Societal Issues, and Career Education/Awareness) suggests that the physical science courses are still traditionally taught; that is, the main focus is the teaching of scientific knowledge and facts. To serve its purpose as a general education course at the middle school level, a physical science course should also attend to the other three goal clusters of science education, i.e., Personal Needs, Societal Issues and Career Education/ Awareness.

A great deal of similarity exists among the textbooks with respect to their emphases on the different Project Synthesis Goal Clusters. Since the analyzed physical science textbooks are commonly used, physical science courses across the nation most likely reflect a similarity in emphases. Furthermore, if they tend to emphasize the Academic Preparation Goal Cluster at the expense of the other goal clusters, these physical science courses may not effectively be promoting scientific literacy among the learners. The imbalance among the four Project Synthesis Goal Clusters suggests that while the analyzed physical science textbooks may provide students with an academic basis in science, they will probably provide minimal experiences and practice with decision making strategies, with science-related societal issues, or with careers open to the students in science and technology.

Recommendations

(1) Additional studies are recommended to analyze textbooks and curricular material in other disciplines in science. These studies should include textbooks designed for courses such as general biology and chemistry.

(2) Research is recommended to find out the extent to which preservice and inservice science teacher education programs address a general education approach to science education, i.e., an approach which incorporates the application of scientific principles to science-related societal issues and personal needs.

(3) This present study and others like it (e.g., Torzynski's 1987 analysis of earth science textbooks) are recommended to be repeated at timely intervals to update the knowledge base with respect to the congruence

between goals for scientific literacy and commonly used textbooks. This recommendation for periodic replication is also advanced for research focused on general biology and chemistry, and on preservice and inservice science teacher education programs.

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