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ABSTRACT

The purpose of this paper from a symposium is to promote a discussion of implementation models by examining a current study assessment package for a national reform effort. The evaluation of Scope, Sequence, and Coordination (SS&C) implementation in Houston consisted of a formative and summative assessment. The formative assessment consisted of data from parents, administrators, and teachers. The summative data consisted of student attitude data; a longitudinal student data file with information on course choices, achievement, attendance, and graduation rate; student achievement test scores; and concept analysis. The results of a parent survey (n=232) on SS&C are presented. About one-third of the parents thought their children liked science must better this year compared to last. (PR)

Formative and Summative Assessment of a Reform Project: Models of Change

A Glimpse at the Texas Scope, Sequence and Coordination Project (SS&C)

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Formative and Summative Assessment of a Reform Project: Models of Change

The need for science education reform has been discussed extensively in the literature. However, few educational reform efforts have undertaken the task of documenting the process. The purpose of this symposium is to promote a discussion of implementation models by examining a current study assessment package that includes both formative and summative data for a national reform effort.

Project Background and Tenets

To better understand the implementation process, a brief examination of the underlying program paradigms is in order.

Research from the past 30 years provides clear implications for the three tenets of Scope, Sequence and Coordination Project (SS&C). Virtually all of this research supports the idea that concepts should be derived from hands-on experiences, with students acquiring these concepts from a number of learning opportunities, using different contextual settings. This information provides the first tenet of the SS&C reform. Research on the "spacing" effect (Dempster, 1988) demonstrated the second tenet, that each science discipline should be taught over a period of several years, not concentrated into one year. Dempster's studies indicated that both achievement and retention are increased when spacing is used.

The final tenet of the SS&C Project involves the coordination of the disciplines taught. Students often see biology, chemistry, earth/space sciences, and physics as separate entities having no bearing on one another. The SS&C program is designed to show that the sciences are interdependent and fit together to provide explanations for phenomena. By employing this approach, students see the core scientific concept connections between disciplines.

Implementation Overview

The Houston SS&C site was first developed and pilot tested in three schools. Currently, the full seventh and eighth grade SS&C science program has been developed, piloted and expanded to 35 middle schools within the Houston Independent School District (HISD), the fifth largest school district in the nation.

In order to examine the process of reform, aggressive documentation has been occurring since the beginning of the project. This symposium focuses upon the documentation design, both formative and summative, as well as outcomes to date.

Formative Assessment

Any successful reform effort must recognize the need to constantly monitor the implementation process and adjust program directions as needed. Key to the success of this effort is a well-designed and implemented formative assessment component. The Texas Center for Reform designed its assessment with the realization that implementation must focus on the entire school culture, including parents, administrators, teachers, as well as students.

Parents have been contacted and interviewed by phone using a stratified, random design. These interviews include questions about perceptions, understanding, involvement, concerns, effectiveness of public relation materials for the project, and opportunities to respond to questions. Interviews are conducted in both English and Spanish. Past use of this survey has provided insights into strategies for effective communication in different communities and parents' awareness level about the program. First year results have shown that the majority of parents have heard their children talking positively about science and their science classes.

Administrators are another integral component of the school community. The project works with administrators on all levels--school-based administrators as well as central administrations. Information is gathered through formal interviews and informal meetings. These meetings have allowed us to solve both school-based and district-based problems. Communication lines between teachers and administrators have been expanded.

Teachers also are monitored to determine their views and concerns. Throughout the program development, a series of meetings has been conducted to provide teacher feedback and offer suggestions for revision of materials. In addition, the Stages of Concern Questionnaire (SoCQ) is used as part of the CBAM approach. It is administered before the development process began and then twice yearly thereafter. According to the research conducted by Hall et al., the concerns of teachers over time should move from personal concerns to more external concerns. One interesting difference noticed from the original work conducted by Hall et al. is that the large group of urban teachers in this project has remained high on the collaboration scale.

Direct observations of teaching are also conducted. Formal observational techniques have been used to verify self-reported activities such as increased time spent on lab activities and increased use of open-ended questions. Much of these data have been collected using a computerized interaction analysis code, the Houston Assessment of Behaviors In Teaching (HABIT).

In addition to these sources of formative assessment, guided student journal entries have been used to monitor student perceptions of the program. Sample questions include: What did you like best?; What was difficult for you?; State three major ideas or concepts that you learned.; and List three questions over the material studied.

Summative Data

For any project, improvements in student achievement and interest are always a goal; this project also shares this goal for improvement in student performance. Initial results indicate that students are more interested and more proficient in science. In addition, there were immediate gains observed in the "at-risk" students.

To assess the potential gains of SS&C students in all domains, the following data have been collected, in addition to the formative data described earlier.

Attitude Data

The Preference and Understanding instrument was originally drawn from the attitudinal portion of the National Assessment for Educational Progress. This assessment was administered to all 6th, 7th and 8th grade students prior to beginning the program and twice yearly as a pre- and post-design indicator. Breakdowns by race, gender, and ethnicity; cross analyses by achievement and level of concept understanding have been run.

Student Data File

A student data file has been established to begin the longitudinal study of students involved in this project. This will provide information about future course choices, achievement, school attendance, and graduation rate.

Standardized Achievement Tests

Using district student files, student test scores on both state and national achievement tests have been gathered for analysis based on demographics and cross analyses with other data sets.

Concept Analysis

The Houston SS&C is a pilot for the NSTA CD-ROM Assessment Project. Trial use is scheduled for the winter of 1992-93, in time for preliminary results to be presented during the NARST annual conference.

Control Group Data

Three middle schools have been identified to serve as controls for comparisons to the original pilot sites. These control-group middle schools have similar socioeconomic levels and demographic distributions.

Summary

Many believe that the science education reform of the 1960s failed due to a flawed implementation process. The creation of new curriculum and the preparation of teachers will not lead to a lasting educational evolution. We must expose the process of reform if we truly expect the product to be different. This open forum will build from the implementation model presented and lay the ground work for a more holistic view of formative and summative assessment.

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Guiding Evaluation Questions
&
Present Approaches Employed

Pilot Program

1. How do teachers and administrators at each of the three pilot schools differ in their reactions to the proposed project?
   What are the specific advantages and disadvantages articulated by each school?
   What characteristics are common to all schools? Unique to each school?

Present Approaches include:

- A. Concerns Questionnaire
- B. Teacher Interview
- C. Meetings with Administrators
- D. Weekly Meetings with Teachers at the Schools

2. What logistical and technical problems must be addressed during the planning phase?
   Do the problems differ from school to school?
   What are district-level issues versus school-based issues versus state-level issues?

Present Approaches include:

- A. Teacher Interview
- B. Meetings with central Administration
- C. Weekly Meetings with Teachers at the Schools
- D. Meetings with Administrators
- E. Formation of Teacher Leadership Group

3. How are teachers' "stages of concern" in the curriculum adoption process best addressed?
What data from the measurement of "level of concern" can assist in describing the process?

Present Approaches include:

A. Teacher Interviews
B. Concerns Questionnaire
C. Weekly Meetings with Teachers at the Schools

4. How do students' interests in and understanding of science change as a result of the pilot project?

Present Approaches include:

A. Student Preferences and Understandings Questionnaire
B. Student Journals
C. Concept Analysis (NSTA CDI Assessment Project)
D. Parent Interview

5. What change in district-administered standardized test scores are noted in conjunction with the adoption of curriculum innovation?

Present Approaches include:

A. Analysis of Standardized Achievement Scores of both Pilot school Students and control School Students

B. Analysis of Standardized Achievement Scores broken down by district demographic data (i.e.. gender, ethnicity, Social Economic Status, & district tracking).

6. What are parent perceptions and degree of involvement in science innovation?

Present Approaches include:

A. Parent Interview

7. What communication and training techniques are effective for project management ad various project components?

Present Approaches include:

A. Written Feedback on Workshops and Meetings with Teachers, Administrators, and SS&C Staff.

8. Have classroom instructional strategies been affected by the newly sequenced curriculum?

Present Approaches include:

A. Classroom Observation
B. HABIT Coding
C. Teacher Interview (Self-reflective)

Report on the 1992 Parent Survey -- 7th-Grade SS&C Students

I. Purpose: The purpose of the survey is to find out the opinions of parents and guardians about the SS&C program and their children's participation in it. Survey results may be used as the basis for making changes in the program.

II. Background: The 1991-92 school year was the second year of the 7th-grade pilot program at Deady, Lanier, and Pershing middle schools. It was also the second year of the Parent Survey, which is administered annually. (Parents of 8th-grade SS&C students were also surveyed. Those results are presented in a separate report.)

III. Method: Parent Notification. Two weeks before beginning the survey, the survey coordinator provided each of the three schools with a memorandum to the parents from the project director and the school principal. The memo. in English or Spanish (according to each school's needs), prepared the parents for receiving a telephone call and requested their cooperation in responding to the survey.

Interviewers. The survey supervisor hired six interviewers (one of whom was not able to participate, leaving five). All attended an orientation and practice session prior to beginning. The interviews themselves started in late May before the end of school and continued through the first half of June. They were conducted in either English or Spanish, as necessary.

Call Sheets. For each family included in the sample pool (described below), a "call sheet" with the student's name and phone number was typed and given to an interviewer. The interviewer indicated the outcome of each attempted contact (busy, ring-no-answer, out-of-order, date/time to call back, refusal, interview completed, language barrier, or other specified outcome, such as a wrong number). As many as six attempts were made to reach each parent. In the case of a language barrier, call sheets were returned to the supervisor who redistributed them to a Spanish-speaking interviewer.

Questionnaire. The questionnaire was the same as that used for the 1990-91 survey, with a few modifications. These included questions to elicit details about school subjects that children talked about at home, specific science activities that parents recalled their children doing in class, and ways that parents received the parent newsletter, *NewScience*.. The standard introduction recited by the interviewers was also revised slightly (mainly to include standardized responses to any reservations a parent might express about the interview) and was moved from the questionnaire to the call sheet. A few other minor changes in the format were also made. The questionnaire was prepared in both English and Spanish versions.

Responses to the completed interviews were tabulated by the SS&C project staff and are summarized in Section IV, "Summary of the Data."

Sample. The goal was the same as the previous year's survey -- to interview at least ten percent of the parents. The 7th-grade student rosters, which were obtained from each school, were used to select a sample of residences to call. The rosters included the names of all 7th-graders, their addresses, and phone numbers. The rosters also indicated homes with an unlisted number or no telephone, as well as instructions for privacy (in other words, school-related phone calls were unwelcome). Homes in these cases were excluded from the list that the sample was drawn from. Also excluded were the names of students (and their homes) that each school had indicated were not participating in the SS&C program.

The survey supervisor used a "systematic" approach to select a sample pool of homes that would be representative of all SS&C students on the rosters. It was clear that the size of the sample pool for each school would have to be larger than the desired final sample of ten percent because of the probability that families would have moved and numbers would be wrong, interviews would be refused, parents wouldn't be at home, and so on. These and other factors were considered for each school's population. On the basis of those considerations, every n^{th} family was selected from each roster. For example, at Deady, every third family was selected. The table below shows the sample sizes for each school and in total.

In summary, the total pool of parents contained 349 homes (and therefore, 349 call sheets), or 21 percent of the 7th-grade SS&C student population of 1,634. The final sample (comprising parents who actually completed interviews) was 232, or 14 percent. Thus, the final sample, in contrast to last year's sample size of 8 percent, was even larger than the targeted 10 percent.

Sample Sizes by School and In Total

School	Total SS&C 7th-Graders	Sample Pool Size (% of school total)	Final Sample Size (% of school total)
Deady	758	195 (25.7%)	113 (14.9%)
Lanier	340	48 (14.1%)	34 (10.0%)
Pershing	536	106 (19.8%)	85 (15.9%)
All-School Totals	1,634	349 (21.4%)	232 (14.2%)

IV. Summary of Data: Seventy-five percent of the people interviewed were mothers. Twenty percent were fathers. The remaining interviews were with guardians and "others."

Science Class as a Conversation Topic. A large majority (80%) of the respondents said his or her child had talked about science class during the year. Of those 186 people, 38% said it was mentioned "quite often." Ten people (5%) said their child talked about it every day. Of the 20% (46 people) who said their child did not talk about science class, more than half said their child did talk about other subjects. The most frequently mentioned other classes were math and computer (which, together, were mentioned by 13 people).

In a related question, parents were asked if they could recall particular activities their children had done in science class this year. About 48% said "yes." Examples they gave included the following:

Deady	**Lanier**	**Pershing**
Dissection (9)	----------	Dissection (12)
Inventions; Clocks (4)	----------	Clocks/Telephone/Appliances (8)
Earth/Planets (7)	----------	Astronomy (1)
Human Body	----------	Human Body (4)
Plants (2)	Plants (2)	Plants (3)
Shark/Crocodile (1)	Snowcats (2)/Bugs (1)/ Viruses (2)/Pond Water (1)----------	Animals (1)/Food Chain (2)
Conduction Technology (1)/Gravity (1)	Sound/Light/Waves/Hydroelectric Power/ Pressure/Acceleration (8)	Electricity/Density (2)/ Bubbles (1)
Charts/Measuring (1)	Mean Average (1)	----------
Owl Pellets (1)	----------	----------
----------	Global Communication (1)	----------
Chemical Reactions (1)	----------	Food Coloring (1)
----------	----------	Environment (3)/ Weather (3)/Dripping Lab (1)

Popularity of Science Class. A large majority (77%) of all the respondents also thought their child liked science this year either "somewhat" (42%) or "very much" (35%), compared to only 14% who said "very little" or "not at all." The remaining 9% didn't know.

Close to one-third (30%) of the parents thought their child liked science "much better" this year compared to last. An additional 21% thought their child liked it "a little better." Thus more than half of the respondents said their child liked science better this year. That represents more than five times the number of people (22 or 10%) who said they thought their child liked it less. Some of the reasons given for liking it better (reasons that realistically might be ascribed to the program, rather than to some other factor, like improved English skills or a better teacher, which were also mentioned) include "more labs," "activities," "projects," a "hands-on" approach, and "less book work."

Science Grades. In Question #4, parents were asked to recall their child's science grade on the most recent report card: In the case of each of the three schools, the proportions of parents who said they thought their child had made an A or a B was much greater than the proportions who thought their child had made a C or below. For example, of the 87 Deady parents who recalled their children's grades, 80% thought their child had made an A or a B. Of the 68 Pershing parents who recalled, 69% thought their child had made an A or a B. And at Lanier, which is a magnet school for "gifted and talented" students, 91% of the 32 parents who recalled grades thought their child had made an A or a B. (The reliability of the parents' reports is highly uncertain, however, since their memories could be wrong or they could feel too embarrassed to report low grades. Also, the relatively high number of respondents -- 45 (19%) -- who said they didn't know their child's most recent grade could distort the data.)

[Judgments in Question #5 about whether grades had improved this year compared to last might be more realistic than for Question #4 since the response options ("better," "about the same," or "worse than last year"). don't require the same degree of negative disclosure . Furthermore, only 14 people (6%) responded "don't know." On the other hand, the fact that this question is linked to the previous one suggests that responses to #5 might not be any more reliable than those to #4. (In addition, the large discrepancy between the 6% and 19% answering "don't know" casts additional doubt on the reliability of Question #4.)]

In any case, question #5 was answered as follows: Excluding the 14 people who said "don't know" (leaving 218 respondents), 41 percent said the grades were "better"; 40% said "about the same"; and 19% said "worse than last year."

Sources of Program Information -- (a) Newsletter: Almost 87% of the respondents said they had not read the newsletter (*NewScience*). Of the 31 people who had read it, 15 said their child had brought it home; 13 said they had picked it up at school; 3 couldn't say how they had received it.

(b) Other Sources: Only 14% (33 people) had learned about SS&C from sources other than the newsletter, including for example, teachers, students, PTO and PTA, open house, local newspapers, etc. (Most of these people are Lanier parents; half of the 34 Lanier parents in the survey had learned about the program from such "other" sources as those named above.) The large majority of respondents -- 86%, or 199 people -- had not learned about the program from sources other than the newsletter. Even if this group contains the subset of 31 people who said they had read the newsletter, the implication is that the remaining 168 people (72% of all respondents) are not at all familiar with the program. Thus, anywhere from 72% to 86% of the parents have not learned about the program.

Science as a Career Choice. Most of the parents said they'd like to see their child go into a "science, engineering, or health" career. At Deady, 93% said "yes"; at Lanier, 82%; and at Pershing, 77%. Overall, 85% of the respondents said "yes"; only 5% said "no"; 10% expressed no preference.

V. Recommendations:

(a) Questionnaire Revisions

- Consider deleting Question #4, about science grades, from future questionnaires. The data it yields is probably not useful (as discussed in Section IV, "Science Grades," above).
- Revise Question #5 (especially if #4 is dropped).

(b) • Consider ways to improve communications with the parents about the program -- particularly with regard to the newsletter. Should the newsletter be continued? If so, how can it be more effectively distributed? How well-informed are the school administrators and teachers as to the role of the newsletter? (Consider a small informal survey of the pilot school administrators and maybe the teachers to find out what is happening to the newsletters they receive, how they are distributing them, what suggestions they have for content, as well as distribution, etc. Their feedback also could be useful in any planning for an expanded -- i.e., districtwide -- newsletter service.)

The value of expanding or encouraging other methods for communicating with parents (such as those mentioned in Section IV above) could also be examined.

PARENT INTERVIEW
7th Grade

Interviewer: ______________________________

School: __________ **Student:** ______________________________

Person Interviewed: Mother Father Guardian, Male

Guardian, Female Other: ______________

1 (a). Has __________ ever talked about his/her science classes this year? Y 1 N 2

(b) *If "yes"*: How often would you say he/she talks about it?

Every Day	Quite Often	Once-in-a-while	Hardly Ever	Never
1	2	3	4	5

(c) *If "no"*: Has _________ ever talked about his/her <u>other</u> subjects or classes? Y 1 N 2

If "yes": Which subject(s)? ______________________

2. How well do you think he/she likes science this year?

Very Much	Somewhat	Very Little	or	Not at All	Don't Know
1	2	3		4	5

3 (a) How do you think he/she likes science class compared to last year?

Much Better	A Little Better	About the Same	or	Not as Well as Last Yr.	Don't Know
1	2	3		4	5

(b) *If "much better," "a little better," or "not as well"*: Why do you think that is? __________

____

____

____

4. Do you recall what _____ _________'s science grade was on his/her last report card? (*Prompt, if necessary*: Would you say it was . . . .)

69 or Below (F)	70 to 74 (D)	75 to 79 (C)	80 to 89 (B)	90 to 100 (A)	Don't Know
1	2	3	4	5	6

5. How do you think his/her science grades this year are compared to last year?

Better	About the Same	Worse Than Last Year	Don't Know
1	2	3	4

The National Project on Scope, Sequence and Coordination of Secondary School Science

Linda W. Crow
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The national science education reform called Scope, Sequence and Coordination (SS&C), is based on the analysis of thirty years of learning research studies, human resource data, and career access programs. This research base has led to the largest single financial effort in precollege science education since the post-Sputnik era of the late 1950s. The SS&C project initiated by the National Science Teachers Association (NSTA) has launched a major reform effort to restructure science teaching at the secondary level.

The Current Status of Science Education

Since the early 1980s, numerous reports have drawn attention to the failure of schools to educate students for a technological and scientific society. Surveys show that the majority of students leave secondary school without a basic understanding of science, mathematics, or technology. Most students stop taking science as soon as their school systems allow. Over half the students never take another science course after tenth grade. Only 19 percent of high school students take a course in physics, and only about 40 percent take chemistry. In addition, few college students major in a scientific field. The demand for scientists and engineers is not being met; nor are schools preparing citizens with the science background necessary for their future success.

A quick solution to this dilemma might be to remove the element of choice and require students to take existing science courses. This is no solution however: research indicates that the very structure of the U.S. educational system contributes significantly to students' lack of interest and achievement. Only the United States employs the "layer cake" sequence and structure of biology, chemistry, and physics at the high school level. All other industrialized nations of the world provide students the opportunity to study all the sciences over several years. They do not compress all of biology, chemistry, earth science or physics into one-year units. Nor do they stack the disciplines in the illogical layer cake order. American high schools established this ill-conceived structure in the late 1890s. When the middle school or junior high appeared, the high school's layer cake approach was copied and has remained in place ever since.

On top of this structure, our educational system also places filters, supposedly to identify the most gifted students and track them into course work that would prepare them for math and science, however, an examination of these filters reveals that they are not able to accurately identify the most gifted and often are barriers to students who are not seen as the traditional achievers in science. It is not surprising that these filters prevent large numbers of underrepresented groups from choosing careers in science, math, and engineering.

With demographic changes and the demand for a more scientifically literate population, such exclusions have been devastating. In the past, the United States has been a world leader because of its human resources. One need only read the news today to realize what effect its outdated education

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system has had upon economic and social changes.

The Research and Development Basis

Research over the last 30 years provides clear implications for science education reform. Piaget (1973) showed that concrete experiences should precede terminology and theoretical presentations. The appropriate sequencing of concepts was said to be essential by such notable researchers as Bruner (1960), Arons (1976), and Karplus (1976). All of this research supports the idea that concepts should be derived from experiences, with students acquiring a concept from experiences in different contexts. In addition, research on the "spacing" effect (Dempster, 1988) demonstrated conclusively that each science discipline should be taught over a period of several years, not concentrated into one year. Dempster's studies indicated that both achievement and retention are increased when spacing is used.

The research clearly shows how science should be taught to increase student understanding and achievement, as well as appreciation for the subject. It is no mystery. Instruction must begin with concrete experiences, build to the theoretical understanding and allow an adequate amount of time between experiences. An examination of our practices in the secondary schools suggests we do just the opposite. We begin by teaching for theoretical understanding as quickly as possible and cover as many facts as possible. Erroneously, recall is set up as the highest form of achievement and the collection of unrelated facts is the goal, at least in the minds of most students (Postman & Weingartner, 1969). It is no wonder that students soon become disenchanted with science and choose not to pursue it.

The last component of the SS&C Project is the coordination of the disciplines taught. Students often see biology, chemistry, earth/space sciences, and physics as separate entities having no bearing on one another. The SS&C program shows that the sciences are interdependent and fit together to provide explanations for phenomena.

The National SS&C Model

With these research conclusions in mind, Aldridge (1989) set out to devise a realistic model for the restructuring of science. The following table illustrates the original configuration of four science subjects taught over a six-year period. Notice that SS&C exposes students in the middle level grades to intensive descriptive and phenomenological experiences in the sciences. In later years, abstractions and theory will be the focus.

Table 1

Example of a Revised Science Curriculum for Grades 7 Through 12 in the United States.

	Grade Level						Total Time Spent
	7	8	9	10	11	12	
	Hours Per Week By Subject						
Biology	1	2	2	3	1	1	360
Chemistry	1	1	2	2	3	2	396
Earth Science	3	2	2	1	1	1	360
Physics	3	2	2	1	1	1	360
Total Hours /Week	8	7	8	7	6	5	
Emphasis	descriptive phenomenological			empirical semi-quantitative			theoretical abstract

Aldridge presented this initial model in 1989 and it met with tremendous support and interest. California and Houston, with funding from the Department of Education, became the first two SS&C Centers. In addition, a Coordinating Center was established at NSTA. The following year, additional funding was obtained through the National Science Foundation (NSF) to establish five centers–California, Houston, Iowa, North Carolina and Puerto Rico. All of these centers have embedded the essential changes described by Aldridge (1989) in their restructuring efforts. Each center has a somewhat different approach dictated in part by that center's particular characteristics. For example, the California Project began as a state-wide initiative, while the Houston Project is a smaller, more focused effort. The more recent centers–Iowa, North Carolina, and Puerto Rico–have their own regional perspectives. Iowa has attempted to take an "STS" approach, for instance. North Carolina has begun its work in the sixth grade, rather than the seventh. Puerto Rico is producing Spanish language materials and also is integrating mathematics into its restructured science program.

For the first time, an educational reform project will also be documented and evaluated on a national level. The Coordinating Center has asked Iris Weiss at Horizon Research, Inc, Chapel Hill, North Carolina to serve as national documenter. Records will be maintained as to what occurs in the project and each center, how the project succeeds or fails and how the SS&C changes are implemented at the different centers.

Support at the National Level

Through the efforts of the Coordinating Center, the SS&C project has provided *The Content Core* as a foundation for each center's selection of appropriate instructional materials and approaches. The focus is on the use and adaptation of existing instructional materials. The production of student materials will be left to professional publishing houses. Recently the California and Texas State departments of education have joined in a collaborative effort concerning textbook standards. As the two largest "textbook states", they have traditionally exerted a disproportionate (and not always positive) influence on most publishers. It is hoped that this cooperation can provide publishers with incentives to make the sweeping changes that are needed in student textbooks.

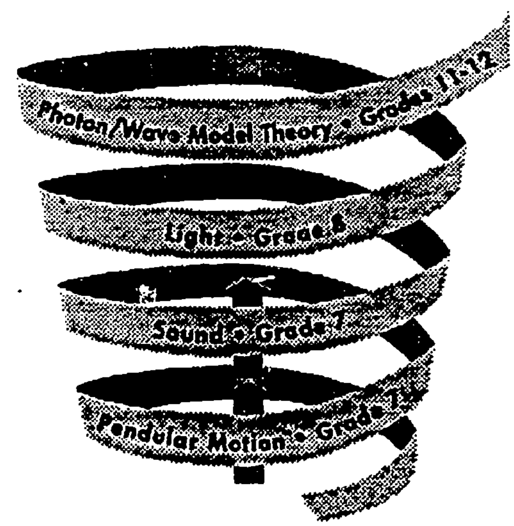
The Content Core is an evolving document that begins to answer the question of what in each scientific discipline is appropriately included at the various grade levels. This document was developed over a two-year period by content committees, following an analysis of existing materials. *The Content Core* is intended as a starting rather than ending point for instructional designers.

The Spiral Curriculum

In contrast to the current system, the SS&C program draws directly on the results of research. Concepts are sequenced and appropriately spaced out over time. They are included in the sixth through eighth-grade program only if they are handled in a phenomenological or descriptive manner. The spacing technique, which enables students to revisit concepts over a period of years, is carried out in the "Spiral Curriculum." The idea is not new, but has rarely been implemented in a school setting. For example, a study of harmonic (pendular) motion, could begin in the sixth through eighth grades, followed in later grades by a study of the phenomena of sound and light (see Figure 1). In grades 11 and 12, a study of wave theory which is more abstract, would be based upon the foundation of earlier experiences.

Figure 1

The Spiral Approach



Possibilities for using the spiraling approach abound in the other science disciplines, as well. In the middle grades, for example, students could begin a study of animal adaptations and behavior patterns. Later an investigation of fossils and geologic time could be added. The theory of evolution could ultimately be approached in a meaningful fashion. Again, the goal is not to have students memorize countless facts and definitions, a feat which has no relationship to true understanding. As Jules Poincare (1854-1912) pointed out,

> Science is built up with facts, as a house is with stone. But a collection of facts is no more a science than a heap of stones is a house.

The development of true conceptual understanding requires experiences first. Terms and definitions should be added later. This deeper understanding of science will allow students to answer fundamental questions on which SS&C is based: What do we mean? How do we know? What evidence do we have? Why do we believe? Later, students will be able to provide the evidence supporting important science models and theories. Remembering names and definitions should never be the ultimate focus in science. As stated in the California Framework:

> But a name should not become more important than the phenomenon being described, or than its empirical or logical relationships with other phenomena.

It is important not to believe that students can acquire a deep understanding of science by studying models or expositions of theories or models, no matter how well designed they are. Students learn through creating their own models and theories, not by reading descriptions. This means that students must be given opportunities to experience or observe a phenomenon, to revisit concepts over time and to develop answers to those four fundamental questions posed above.

Processes and Products of Science

SS&C points program designers toward sorting scientific knowledge in terms of the processes of science and the products of science. Both process and product are important. Each has many subcategories, some of which are more appropriate for certain grade levels.

The processes of science have long been defined but in many different ways. Since the names and numbers of processes vary considerably, a standard list and description was prepared as part of the national SS&C Project (Arons, 1989). Table 1 presents this list. Likewise, a description and ranking of products was developed (Aldridge, 1990), as shown in Table 2.

In the middle grade, SS&C classes, facts, terms, concepts, laws, models and theories are studied mainly in descriptive and qualitative, using words and visual models, but little mathematical symbols or equations. The processes of observing and inferring are emphasized, but gradually the students to use the higher order processes. At the ninth and tenth grades, the science program becomes more quantitative and symbolic, with greater emphasis on concepts and empirical laws.

Table 2

The Processes of Science

by Arnold Arons, University of Washington.

Observing–Examining a system (or monitoring its change) closely and intently through direct sense perception and noticing aspects not usually apparent on casual scrutiny.

Inferring–Reasoning, deducing, or drawing conclusions from given facts or from evidence such as that provided by observation.

Measuring–Using instruments to determine quantitative or properties of objects, systems, or phenomena under observation. This includes the monitoring of temporal changes of size, shape, position, and many other properties or manifestations.

Communicating–Conveying information, insight, explanation, results of observation or inference or measurement to others. This might include the use of verbal, pictorial, graphic, or symbolic modes of presentation, invoked separately or in combination as might prove most effective.

Classifying–Systematic grouping of objects or systems into categories based on shared characteristics established by observation.

Predicting–Foretelling or forecasting outcomes to be expected when changes are imposed on (or are occurring in) a system. Such forecasts are not made as random guesses or vague prophecies but involve, in scientific context, logical inferences and deductions based (1) on natural laws or principles or models or theories known to govern the behavior of the system under consideration or (2) on extensions of empirical data applicable to the system. (Such reasoning is usually described as "hypothetico-deductive.")

Controlling Variables–Holding all variables constant except one whose influence is being investigated in order to establish whether or not there exists an unambiguous cause and effect relationship.

Interpreting Data–Translating or elucidating in intelligible and familiar language the significance or meaning of data and observations.

Developing Models–Creating, from evidence drawn from observation and measurement, a mental picture of a phenomenon (e.g. current in an electric circuit), the mental picture being then used to help rationalize the observed effects and to predict effects and changes other than those that entered into construction of the model.

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Table 3

Products of Science

by Bill G. Aldridge,
National Science Teachers Association

Scientific Term–A word or words that scientists use to name an entity, object, event, time period, classification category, organism, or part of an organism. Terms are used for communication and would not normally include names given to concepts, laws, models or theories.

Scientific Fact–An observation, measurement, logical conclusion from other facts, or summary statement, which is concerned with some natural phenomenon, event, or property of a substance, which can, through an operationally defined process or procedure, be independently replicated, and through such replication has achieved consensus in the relevant scientific profession.

Scientific Concept–A regularly occurring natural phenomenon, property or characteristic of matter which is observable or detectable in many different contexts, and which is represented by a word, or words, and often by a mathematical symbol or symbols is called a scientific concept.

Scientific Principle–A generalization or summary in the form of a statement or mathematical expression which expresses a regular dependence of or measurements for a variable representing a concept on one or more other variables representing other concepts.

Empirical Law–An empirical law is a generalization of a relationship that has been established between two or more concepts through observation or measurement, but which relies on no theory or model for its expression or understanding.

Scientific Theory–An ordinary-language or mathematical statement created or designed by scientists to account for one or more kinds of observations, measurements, principles or empirical laws, when this statement makes one or more additional predictions not implied directly by any one of such components. When such prediction or predictions are subsequently observed, detected or measured, the theory begins to gain acceptance among scientists.

Scientific Model–A representation, usually visual but sometimes mathematical or in words, used to aid in the description or understanding of a scientific phenomenon, theory, law, physical entity, organism, or part of an organism.

Universal Law–A law of science that has been established through universal acceptance and which has applicability throughout the universe. There are few such laws, and they are basic to all of the sciences (e.g. Law of Universal Gravitation; Coulomb's Law; Law of Conservation of Energy; Law of Conservation of Momentum).

Application of Science–Utilization of the results of observations, measurements, empirical laws, or predictions from theories to design or explain the workings of some human-made functional device or phenomenon produced by living beings and not otherwise occurring in the natural world.

Finally, in the eleventh and twelfth grades, there is a heavier use of equations, models and theories, with substantial mathematics coming into play. All grade levels require students to make applications, beginning at the personal level in the middle grades and advancing to global applications in the higher grades.

Project Assessment

Through a grant from the U. S. Department of Education, NSTA has begun the design of a performance-based assessment. Using a new CD-I format, the goal is to assess depth of understanding and to provide a diagnostic overview of students' science knowledge. The prototype consists of multi-tiers or levels and tries to find out how students know something is true, what evidence they have for a given belief, and how they would go about learning something new. The focus is upon the questions that form the basis of the SS&C Content Core. The tiers increase in complexity, allowing students to stop at any point. All students can succeed at the first level. As the item gets more difficult, more students are exited from the system.

The model is intended as an inexpensive and powerful method of administering performance-based assessments. In addition, this assessment through a branching of questions will test for cognitive knowledge. Many groups and individuals have discussed this approach, but none have produced anything similar. This prototype will be field tested in various SS&C centers.

Conclusions

Will the SS&C reform movement solve problems of classroom size, drugs and lack of parental interest? Obviously not. The SS&C initiative seeks to change the scope, sequence, and coordination and to demonstrate how these changes can be brought about in a variety of school settings. Many reform advocates focus upon the direction of the reform (bottom-up or top-down) while others focus upon a single participant of the school culture. Others demand that reforms solve myriad peripheral problems such as malnutrition and absenteeism.

But we must not lose the sight of the fundamental reason for this massive reform: to have students more interested in science and choosing science as a career; to expand the cross section of citizens interested in science and able to function in a society that is based on a scientific world view. The United States must develop its human resources more effectively. Our individual security and national well-being depend on it.

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The Houston Project on Scope, Sequence and Coordination of Secondary School Science

FACT SHEET

The Project

- A science education reform program in which instruction in *all* the science disciplines is carefully coordinated, sequenced, and spaced out from grades six through 12.
- Administered by Baylor College of Medicine in partnership with the Houston Independent School District, the National Science Teachers Association, the U.S. Department of Education, and the National Science Foundation.
- Headquartered at Baylor College of Medicine, a private, nonprofit institution located in Houston's Texas Medical Center.
- Primary funding sources: the U.S. Department of Education and the National Science Foundation.

Project Timeline

- 6th-Grade Program — **Development** underway in 1992-93.
- 7th-Grade Program — **Implemented** in all middle schools of the Houston Independent School District in fall 1992; piloted in Deady, Lanier, and Pershing middle schools in 1990-91 and 1991-92.
- 8th-Grade Program — **Piloted** in Deady, Lanier, and Pershing middle schools in 1991-1992 and 1992-93; scheduled for implementation in all HISD middle schools in 1993-94.
- 9th-Grade Program — **Piloting** underway at the High School for Health Professions (HISD) and Lanier Middle School in 1992-93; more high schools to be added in 1993-94.
- 10th-Grade Program — **Development** underway in 1992-93.
- Plans for extension and expansion of project include development through the 12th grade.

Instructional Program Description

- Program is based on the concepts and areas of scientific knowledge as identified and sequenced in the *SS&C Content Core*, developed by scientists, school teachers, school administrators, and university educators on the discipline committees of the National Science Teachers Association.
- Middle school program is organized into series of "blocks," collections of activities that draw on all the scientific disciplines (biology, chemistry, physics, and the earth and space sciences), relate thematically to one or more scientific concepts, and support designated learning objectives. A similar approach, but with a syllabus format, is being developed for the high school program.
- Blocks are adapted from existing materials and developed by local SS&C staff, scientists, science teachers, and school educators; field tested and revised by project teachers.
- Not a technology or computer-based program: Requirements for supplies are minimal — essentially the same as for any lab class; additional materials are readily available.
- Existing textbooks are inappropriate, but may be useful as occasional references.

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