ADI NEWS

Volume 10, Number 4 | The Association for Direct Instruction | Summer, 1991

Now available: Theory of Instruction: Principles and Applications by Engelmann & Carnine!

See Page 47 for ordering information!

The **Direct Instruction News** is published Fall, Winter, Spring and Summer, and is distributed by mail to members of the Association for Direct Instruction. Membership and subscription information may be found on page 41 of this newsletter. Readers are invited to submit articles for publication relating to DI. Send contributions to: The Association for Direct Instruction, P.O. Box 10252, Eugene, Oregon, 97440.

Editor	Wes Becker
Associate Editors for Research	Craig Darch
	Russell Gersten
	Robert Horner
	Ed Kameenui
Departments	
Dear Ziggy	Zig Engelmann
Layout	Wes Becker
	Bryan Wickman
Typesetting	Bryan Wickman
Printing	Springfield News

Children's Alternative Frameworks: Should They be Directly Addressed in Science Instruction?*

by Anbanithi Muthukrishna
Doug Carnine
Bonnie Grossen
Sam Miller
University of Oregon

Over the past decade, there has been considerable international interest, within science education, in children's ideas about natural phenomena (Hills, 1989; Driver, Guesene, & Tiberghein, 1985; Osborne & Freyberg, 1985). The focus has been on exploring ways in which children seek to explain the world, and on the implications for science teaching. The findings of the numerous studies, as summarized by Osborne and Wittrock (1983), Driver and Erickson (1983) and Gilbert and Watts (1983) are the following:

1. From a young age and prior to the formal learning of science, children have ideas about a variety of scientific phenomena.
2. Children's views are often significantly different from the scientist's view, and these views are often not known to the teachers.
3. These ideas are part of a conceptual framework that provides a sensible and coherent understanding of the world from a child's point of view.

The ideas children hold have been described by a variety of terms, such as "misconceptions" (Novak, 1983), "children's science" (Gilbert, Osborne, & Fensham, 1982), "alternative frameworks" (Hewson, 1985), "preconceptions" (Osborne & Freyberg, 1985), "naive beliefs" (Caramazza, McClosky, & Green, 1981), "mini-theories" (Claxton, 1987), "untutored beliefs" (Hills, 1989), "intuitive notions" (Bar, 1989), and "informal knowledge" (Prawat, 1989). We will refer to these views as *alternative frameworks*.

Several studies have documented the finding that children's alternative frameworks are extremely resistant to change (Anderson & Smith, 1987; Gunstone, Champagne, & Klopfer, 1981; Linn, 1983; Linn & Burbules, 1988; Schneps, 1987). Although students may acquire the scientist's view, they do not modify their prior conceptions.

Because instruction has not been successful in removing alternative frameworks, many researchers have concluded that these alternative frameworks must be directly addressed in the instruction. Schneps (1987), for example, concluded that unless the misconceptions of students are directly addressed in instruction, they will not be free from their "private universe of half-understood ideas."

In recent years, the interest in how the learner constructs meaning has led researchers to neglect consideration of the role of curriculum design factors in promoting conceptual change. It is possible that one of the major causes of alternative frameworks is the failure of science curriculum to present the content coherently to the learner. According to Tyson and Woodward (1989), American textbooks are "encyclopedic" or "compendiums of topics," none of which are covered in much depth. These authors cite data to show that science textbooks from grades 6 to 9 contain as many as 2500 new and unfamiliar words—this figure is double that which is found in a foreign language text for the same grades. Yager (1983) conducted a study of 25 K-12 science textbooks and found that one sixth-grade text contained 3400 technical words, a junior high school text contained 4600 technical words, and a high school biology textbook contained 9900 technical words. Pauling (1983) found that first-year college and secondary school chemistry books contained a tremendous amount of information presented at an extremely advanced, theoretical level, but treated so superficially that it could never be understood by the student. Roth and Anderson (1988) state that, to cope with the barrage of ideas presented in textbooks, students rely on strategies that emphasize memorization of facts and definitions of lists of "big words," rather than on strategies that foster conceptual understanding.

The excerpt in Figure 1 is representative of typical science textbook information. It overloads the students with a large number of unrelated, abstract concepts. As Linn (1987) points out, when the conceptions being taught are too complicated to fit into the processing capacities of students, alternative conceptions may emerge.

Eylon and Linn (1988) emphasize the value of an integrated, in-depth coverage of science topics that shows students the value of coherent perspectives. In-depth coverage can elaborate incomplete ideas,

*Reprinted from *Journal of Research in Science Teaching* (in press).

Figure 1. Example of Textbook Information on the Formation of Mountains

Have you ever tried to keep a block of wood under water? It is a difficult job. As you push the wood downward, you can feel the force of the water pushing it up again. When wood is put into water, it doesn't sink completely. It sinks until a balance is reached between it and the water. The reason for this state of balance is the difference in their densities.

Thousands of years ago, Scandinavia was covered by a thick ice sheet. The mass of the ice forced the crust deeper into the denser mantle. Then the ice melted. The mantle has been slowly pushing the land upward since. This motion will continue until a state of balance between the crust and mantle is reached again. This state of balance is called **isostasy** (ie-soss-tuh-see).

Observing floating ships shows us how the crust behaves as it floats on the heavy mantle rock. See Fig. 12-21. When cargo is transferred from ship A to ship B, ship A rises in the water and ship B sinks. The crust, floating on the mantle, behaves in a similar way. For example, rock and soil move from one area on the crust to another when rock falls from the mountains to the land below. Because of *isostasy,* the area that loses the material rises. The area that gains the material sinks.

The rising and falling of parts of the crust take place very slowly and put a strain on the crustal rock over a long period of time. How do you suppose the rocks respond to this strain? Sometimes they crack, like a piece of glass. If there is no movement along such a crack, it is called a **joint**. A crack in which there is movement along either side is called a *fault.* Small *joints* can be seen in many rocks. Large systems of joints may cover many square kilometers.

Sometimes large blocks of rock may be tilted like a row of books that fell over. The result is a set of tilted blocks separated by faults. Mountains made in this way are called **fault-block mountains.** The Grand Tetons are *fault-block mountains.*

Some forces squeeze rock together. The faults caused by these forces are slanted. One slab of rock slides up over the next. This type of fault is a **thrust fault.** *Thrust faulting* causes the area of the crust to decreased. The Appalachian (app-ah-lay-shin) Mountains contain may large thrust faults.

Forces that squeeze rocks together do not always cause faults. Some rocks may yield to strain by **folding.** Slow, steady pressure can make some rocks bend without breaking. *Folds* in rocks may be small wrinkles. They also can be large enough to form the foundations of mountains. The Appalachian Mountains, for example, contain the remains of may great folds. During their long history the Appalachians have been worn down. Today we see long parallel ridges and valleys formed by the tilted rock layers of ancient folds. See Fig. 12-23.

Scattered all over the earth are very large regions of land that are elevated above the level of the surrounding crust. A region of land that is elevated is called a **plateau** (pla-toe). The Grand Canyon is found on the Colorado Plateau. *Plateaus* can be caused by the forces that cause faults and folds. In this case, large parts of the crust are bent upward. Plateaus can also be formed when lava pours out and covers a large part of the land surface. The Columbia Plateau of Washington State is an example of a lava plateau.

While large areas of land are being uplifted into plateaus, some small areas are sinking. Death Valley in California is an example of such a place. The large block that makes up the floor of Death Valley is slowly tilting as one end sinks. See Fig. 12-26.

Some of the forces that cause strain in the crust come from movement of the crustal plates. At the mid-ocean ridges, hot mantle material rises. When the mantle material cools, it forms new sea floor and pushes the crystal plates. The plates bend and twist as they are driven away from the mid-ocean ridges.

Magma may also push up and lift the crust at places within the interior of the plates. Sometimes such forces from below can raise a part of the crust to make **dome mountains.** An example of *dome mountains* are Black Hills of South Dakota. These mountains are like a blister in the midst of the Great Plains that surround them.

From: Ramsey, W.L., Gabriel, L. A., McGuirk, J. F., Phillips, C. R., & Watenpaugh, T. R. (1983). *General Science.* New York: Holt, Rinehart, & Winston.

provide enough cues to encourage the selection of a different view of phenomenon, and establish a well-understood alternative.

A curriculum that provided explicit, integrated, in-depth coverage of core concepts in science is the *Earth Science* videodisc program (Systems Impact, 1987). It emphasizes the importance of strong schema, based on connections or mappings (Hofmeister, Engelmann, & Carnine, 1989). Information is organized in terms of a conceptual network (see Figure 2). Seemingly unrelated phenomena are unified through a common set of rules. This feature avoids the fragmentation of knowledge. It is easier for students to learn a schema-based, small set of related relationships that make sense of other facts than to learn those same facts as unrelated bits of information. For example, *Earth Science* focuses on the underlying principle of convection. An understanding of convection can enable new students to explain many other terrestrial phenomena, such as ocean currents, air currents, and many phenomena in the solid earth.

To fully understand the concept of convection—the circulation of heat through a medium—one has to understand many other concepts: heating and cooling, the implications for expansion and contraction, which lead to rising and sinking, and finally areas of high and low atmospheric pressure. All these phenomena are causally related. Figure 2 illustrates how the various principles fit together. A portion of a substance is heated in position A. As it expands, it becomes less dense and rises, leaving behind the area of low pressure. An area of high pressure is created above the heated substance at point B. The substance then moves from the high-pressure area at B to the low-pressure area at C. That low pressure is created as a substance in front cools, contracts, and sinks. The sinking substance creates a high in front of it, as at point D. The substance then moves from the high-pressure area at point D to the low-pressure area at point A. The cycle repeats itself over and over, forming rotating cells, called convection cells, which appear at the top of point A (Carnine, 1989).

After this instruction, the concept of convection is used to make sense of other phenomena, such as ocean currents and air currents. Figure 3 shows convection cells in the solid earth and how they account for plate tectonics, which in turn can explain the formation of granite mountains, volcanoes, earthquakes, and so forth. The crust of the earth actually rides on the top of convection cells. At point E in Figure 3, the crusts come together at the subduction zone, where the oceanic crust goes under the continental crust, causing earthquakes, volcanoes, and rift valleys. At point F in Figure 3, the ocean crust is pulled apart by two convection cells, causing deep ocean trenches and volcanoes.

The *Earth Science* program does not deal with incorrect prior knowledge directly. Essential relationships, not misconceptions, are identified, evaluated, and linked to new knowledge. Misconceptions about the relationships may cause errors during learning. When these errors occur, students are reminded of the relationships that underlie the correct answer. Through explicit maps of concept networks, students link the prerequisite concepts to the underlying principle of convection, and use this principle to

Figure 2. Component concepts of a convection cell.

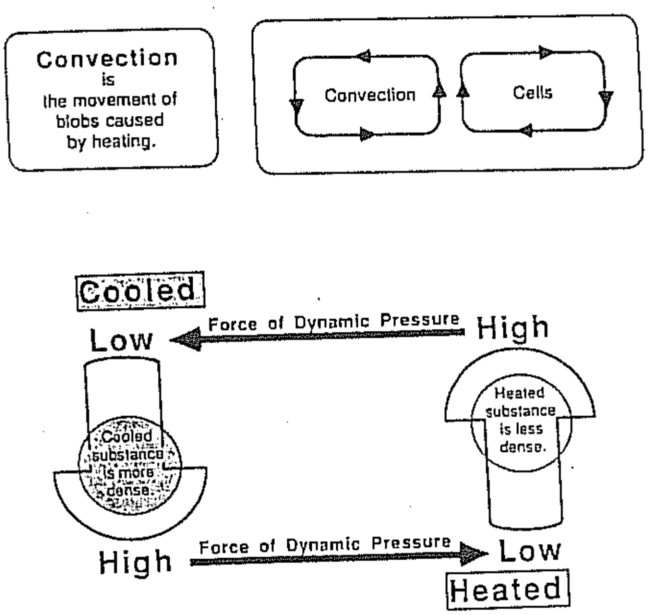
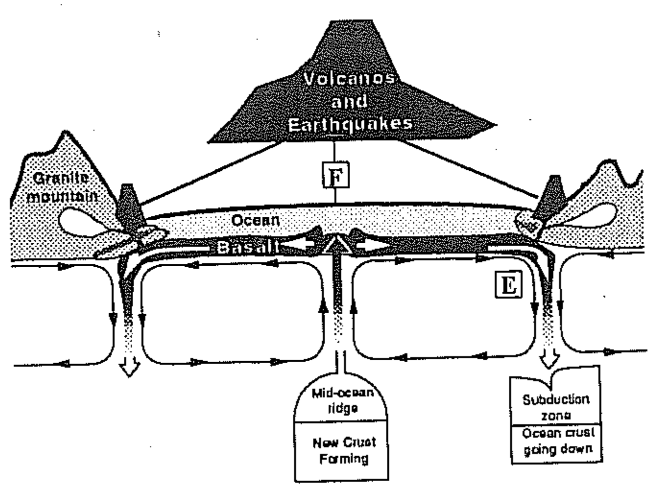


Figure 3. Role of Convection Cells in Accounting for Phenomena in the Solid Earth



explain many of the other natural phenomena found in the earth, oceans, and atmosphere. These phenomena from the diverse areas of geology, oceanography, and meteorology are not unrelated but form part of a unified, structured scheme (Carnine, 1989).

In addition, videodisc technology permits dynamic illustrations that are difficult to conduct in the classroom. Computer graphics, sound effects, highlights, and other techniques maintain student attention. The videodisc makes possible an interactive format, enabling students to explore the concepts being taught, decide what they know, and clarify their own views. They can test the validity of their own views, consider merits and defects, and compare their view with that in the dynamic presentation. These features encourage students to reflect on their own learning.

The present study was undertaken to evaluate the effect of the *Earth Science* curriculum design features on children's alternative frameworks. Our hypothesis was that the design features of the *Earth Science* program would effectively: (a) get students to abandon their alternative frameworks and adopt a clear scientific viewpoint, (b) provide students with a schema which facilitates the integration of new knowledge, and (c) develop in students a language with which they would be able to explain their views.

Method

Subjects

Forty-one eighth-grade students from two intact science classes participated in the study. All subjects had completed 30 lessons in the *Earth Science* videodisc program. One class of 25 higher ability students completed the *Earth Science* program first. The second class of 16 lower ability students, including three students from the resource room, completed the program later (after our testing). The mean raw score of the higher ability group on the math subtest of the California Test of Basic Skills was 66.3 ($SD = 9.5$); of the lower ability group, 51.6 ($SD = 15$). The average percentile equivalent for the higher ability group was 81.2, and of the lower ability group, 56.7.

Procedures

An interview technique was used to assess student conceptions. This technique has been described by Osborne and Freyberg (1985) as the "interview about events," and was used to explore children's views and ideas of everyday phenomena.

In the study, students were required to respond to the following two questions, both prior to and following their exposure to the videodisc program: (a) Why is it hotter in the summer? (b) What causes mountains to form? All interviews were conducted in an informal and non-threatening atmosphere. It was emphasized that students were required to give their own ideas and viewpoints, and that there would be no emphasis placed on whether responses were correct or incorrect. Interviews were not standardized in any way. The interviewer could interact actively with students by asking further probing questions, depending on the nature of their responses. Children were encouraged to draw pictures to illustrate their answers.

Measures

The taped interviews were transcribed word-by-word. These transcriptions comprised the data for analysis. From studying the data, it was possible to determine levels of student understanding for each phenomenon. The system of categorization used in other research (Simpson & Marek, 1988); Marek, 1986) was adapted and used to classify student responses in this study. An explanation of the five categories follows:

1. *A Sound Understanding (S).* Such responses indicate that students seem to have acquired an integrated scientific perspective. They are able to restructure their ideas and give a coherent explanation of the phenomena.

2. *Partial Understanding (PU).* Such responses seemed to indicate that students had merely a partial knowledge of the phenomena. Although ideas are not verbalized in an integrated or unified way, some understanding is evident.

3. *Clearly Evident Misconceptions (M).* Students sometimes give just one simplistic, incorrect viewpoint. Generally, students give linear explanations (e.g., mountains are caused 'by volcanoes') rather than see a number of forces as being responsible for the phenomenon. These responses indicate a lack of understanding about the phenomena and the presence of an alternative framework.

4. *Confused, Faulty Outcomes (CF).* In some instances, responses indicate a partial understanding, but evident in the response is a specific misconception. Students give rather confused, contradictory explanations, or they explain the phenomena as being caused by one act or event rather than by a number of forces or in evolutionary terms. A similar category was identified by Renner, Abraham, Grzybowski, and Marek (1990).

5. *No Conception (NC).* These students fail to formulate an answer. They sometimes admit that they had some exposure to the information, but cannot access it.

The following evaluation criterion were developed for categorizing answers to question 1 (Seasons):

1. *Sound Understanding (s).* Response includes two or more of the following:
   - Seasons are caused by the tilt of the Earth's axis.
   - The varying angle between the sun's rays and the earth's surface caused by the tilt of the axis results in varying heat between winter and summer.
   - Varying heat is also caused by the differing lengths of daylight.
   - It is hottest when the sun's rays fall at right angles to the earth's surface or when the sun appears directly overhead.
2. *Partial Understanding (PU).* Response includes at least one of the following:
   - Tilt of the earth's axis toward the sun.
   - Varying heat caused by differing lengths of daylight.
   - The varying angle between the sun's rays and the earth's surface caused by the tilt of the axis.
3. *Clearly Evident Misconception (M).*
   - Earth is closer to the sun during summer, and in winter the earth is further away from the sun.
4. *Confused Outcomes (CF).* Response includes at least one response from categories 2 and 3 above.
5. *No Conception (NC).*
   - "I don't know."
   - "I knew it once, but I cannot remember."

The following evaluation criteria were developed by categorizing answers to question 2 (Mountains):

1. *Sound Understanding (S).* Response includes two or more of the following:
   - Caused by rising blocks of rock that are pushed up by forces (convection) in the mantel.
   - Continental rocks, such as granite, are less dense than the basalt rocks which cover most of the ocean floors.
   - The granite and basalt come together in subduction zones—ocean crust goes under the continental crust, pushing the earth's crust up, causing mid-ocean ridges, volcanoes, and mountains.
2. *Partial Understanding (PU).* Response includes at least one of the following:
   - Convection in the mantle pushes the earth's crust at the subduction zones.
   - Two plates coming together.
   - Layers of earth getting pushed together.
3. *Clearly Evident Misconceptions (M).* Response includes:
   - By the oceans.
   - Sand piles up and becomes mountains.
   - Mountains grow.
   - By winds and weather erosion.
4. *Confused, Faulty Outcomes (CF).* Response include at least one response from categories 2 and 3.
5. *No Conception (NC).*
   - "I don't know."
   - "I knew it once, but I can't remember."

The transcripts were evaluated by two independent raters. Overall inter-rater agreement was 80%. Inter-rater agreement for categorizing a sound and a partial understanding (scientific understanding) versus confused, faulty conceptions and clearly evident misconceptions (alternative frameworks) was 95%.

Results

Quantitative Analysis

Table 1 gives an analysis of the responses of the high-ability students by categories of understanding on the pretest and posttest for the question on *Seasons.* In the pretest, 4% of the students had a sound understanding of the phenomenon, and 16% had a partial understanding. A number of alternative frameworks were evident which will be discussed in the section on qualitative analysis. On the posttest, 64% had a sound understanding, and 28% of the students displayed a partial understanding. Even these partial responses on the posttest showed evidence of correct scientific concepts. Following the intervention, 92% of the students displayed either a "sound" or a "partial" understanding with no evidence of the alternative frameworks that were recorded on the pretest. The categories "confused, faulty outcomes" and "clearly evident misconceptions" include all the alternative frameworks held by students. Only 4% of the high-ability group showed evidence of possessing alternative frameworks on the posttest compared to 72% on the pretest.

Table 2 summarizes the responses of the high-ability group for the question on *Mountains.* On the pretest, none of the students had a sound understanding prior to the intervention, and only 24% had a partial understanding. On the posttest, 44% of the students displayed a sound understanding, and 40% had a partial understanding. Following the intervention, 84% of the students displayed either a "sound

Table 1 Analysis of the Responses of the High Ability Group by Levels of Understanding on Pretest and Posttest for Seasons

Levels of Understanding	Pretest Frequency	Pretest %	Posttest Frequency	Posttest %
1. Sound Understanding	1	4	16	64
2. Partial Understanding	4	16	7	28
3. Clearly evident misconception	18	72	0	0
4. Confused, faulty outcomes	0	0	1	4
5. No Conception	2	8	1	4

understanding" or a "partial understanding," with no evidence of the alternative-frameworks students held prior to the intervention. Only 16% of the students possessed alternative frameworks on the posttest, compared to 64% on the pretest.

Table 3 summarizes the responses of the low ability group for the question on *Seasons*. On the pretest none of the students had either a sound or a partial understanding prior to the intervention. On the posttest 81% of the students displayed a sound understanding, and 13% had a partial understanding. Following the intervention, 94% of the students had displayed either a "sound understanding" or a "partial understanding," with no evidence of the alternative frameworks. Only 6% of the students showed evidence of alternative frameworks on the posttest, while 88% had alternative frameworks on the pretest. of the resource room students, none hadd alternative frameworkson the posttest, while two had alternative frameworks and one student had no conception on the pretest.

Table 4 reflects responses of the low ability group for the question on *Mountains*. On the pretest none of the students had either a sound or a partial understanding prior to the intervention. On the posttest 56% of the students displayed a sound understanding; and 44% had a partial understanding on the posttest. Following the intervention, 100% of the students had displayed either a "sound understanding" or a "partial understanding," with no evidence of the alternative frameworks. None of the students possessed alternative frameworks on the posttest, but on the pretest 81% of the students had them, including all of the resource room students.

The results support the hypotheses set at the beginning of the study. The *Earth Science* videodisc program succeeded in effecting conceptual change for the majority of students in the study. The categories of responses were quantified as follows: No conception = 0; clearly evident misconception = 1; confused, faulty outcomes = 2; partial understanding = 3; sound understanding = 4.

A repeated measures 2 x 2 ANOVA was performed on the pre- and posttest scores of the higher and lower ability groups on the question on *Seasons* showed no interaction and no group effect, indicating that the performance of the higher and lower ability groups was not significantly different across the pre- and posttests. A similar 2 x 2 ANOVA was performed on the results for the question on *Mountains*. The interaction was significant ($\underline{F}$ (1,39) =7.4, $\underline{p}$< .01), indicating that the performance of the group varied. The lower ability group performed significantly lower on the pretest ($\underline{t}$ (39) = 2.1, $\underline{p}$<.05), *but the performance of the two groups was not different on the posttest*, $t(39) = 1.5$.

The mean posttest score for both groups of 3.34 (*SD* = .79) for the question on *Mountains* was significantly higher than the pretest mean of 1.22 (*SD* = .88); t (40) = 11.8, p < .00005. The mean posttest score of 3.59 (*SD* = .87) for the question on *Seasons* was significantly higher than the mean pretest score of 1.32 (*SD* = .88); t(40) =

Table 2. Analysis of Responses of the High Ability Group by Levels of Understanding on Pretest and Posttest for Mountains

Levels of Understanding	Pretest Frequency	Pretest %	Posttest Frequency	Posttest %
1. Sound Understanding	0	0	11	44
2. Partial Understanding	6	24	10	40
3. Clearly evident misconception	14	56	2	8
4. Confused, faulty outcomes	2	8	2	8
5. No Conception	3	12	0	0

Table 3. Analysis of the Responses of the Low Ability Group by Levels of Understanding on Pretest and Posttest for Seasons

Levels of Understanding	Pretest Frequency	Pretest %	Posttest Frequency	Posttest %
1. Sound Understanding	0	0	13	81
2. Partial Understanding	0	0	2	13
3. Clearly evident misconception	8	50	1	6
4. Confused, faulty outcomes	6	38	0	0
5. No Conception	2	12	0	0

Table 4. Analysis of the Responses of the Low Ability Group by Levels of Understanding on Pretest and Posttest for Mountains

Levels of Understanding	Pretest Frequency	Pretest %	Posttest Frequency	Posttest %
1. Sound Understanding	0	0	9	56
2. Partial Understanding	0	0	7	44
3. Clearly evident misconception	12	75	0	0
4. Confused, faulty outcomes	1	6	0	0
5. No Conception	3	19	0	0

12.06, $p = .00005$. There is clear evidence that students' alternative frameworks failed to interfere with learning, even though the alternative frameworks were not directly invoked and assessed in the instruction.

Qualitative Analysis of Pretest Responses

There were students who had only a partial understanding of the phenomena. Some understanding was evident, but student ideas were not fully integrated or unified. The manner of developing explanations was not explicit. For example, in response to the question on *Seasons,* ideas such as "tilt of the earth's axis," "angle of the sun's rays," "length of time the sun is in the sky,"emerged, but students were not able to elaborate clearly. With respect to the question on mountains, arguments such as "something to do with plates," "layers of the earth getting pushed together," were given, but students were not able to elaborate in a clear manner. The following are examples of responses indicating *partial understanding:*

Question on *Seasons:* "It's hotter in the summer because the sun's rays are less—sort of right against the earth—in winter they are much more spread out because–it's rounder up there so they spread out against the side of the earth.

Question on *Mountains:* "Two plates coming together forms mountains." Some students seemed to have had some exposure to information but were not able to access it. For example,

Question on *Mountains:* "I don't know. Pressures maybe. That's the only thing I can think of." (Interviewer: What sort of pressures?) "I really don't know."

There were students who attempted to bring in all they knew in the hope that somehow they will arrive at the correct answer. For example,

Question on *Seasons:* "The earth is closer to the sun because it goes around in its axis so when it gets more sunlight, it get closer to the sun while it's turning around. So in the daytime, we're closest in the sun–so that's why we have day too–and if it's closer on its axis–it's just closer to the sun and it spins as it goes around."

Question on *Mountains:* "There's one (reason) by water–sand piles up and piles and becomes a mountain. Did you say a mountain?

(Draws a picture.) My picture is when a volcano erupts–lava and stuff goes down the hill and then it stops...more lava comes."

Some responses indicated that students believed mountains were formed by "single acts of creation" (for example, by volcanoes), rather than in "evolutionary terms." Similarly, seasons were explained as caused by one force or event, rather than a number of forces or events. Osborne and Freyberg (1985) also note this tendency in children to explain phenomena as having just one cause.

Some alternative frameworks revealed that students accept more than one explanation for a specific phenomena and are not concerned if explanations are self–contradictory or mutually inconsistent. For example,

Question on *Mountains:* "O.K. Well... let me see... any kind of mountain? I guess mountains start out maybe just as they were–when there wee mountains at first and like they got eroded down by sand and earth and then some sand and earth was pushed into mountains and now it's packed together over millions of years." (Interviewer: How are they pushed into mountains?) "Weather, just nature. . . sometimes lava would form mountains–or you could make them with rock but..." (Interviewer: How? Manmade?) "Yeah!"

In the question on *Seasons*, students were aware of a cause and effect relationship between the movement of the earth in relation to the sun, but their notions were vague, muddled, and imprecise. It seems that they had exposure to isolated bits of factual information, possibly through books, teachers, or television. For example:

"As the world goes around the sun, when it's summer here, it's winter elsewhere–hits it in more in one spot–might go slower in the summer. When it rotates, it might go more slowly so the sun hits in one spot. When it turns that might be winter. If it goes around then it might be winter for a while because the atmosphere changes. That would be winter."

"I just think of it as–well...the sun...I mean the earth turns in rotation to the sun and...I usually thought of it like being in a different spot in the sky at the same time as in summer and winter and then it's actually windier and things and storms are easier to be pushed around so in different places in the earth the storms come over. So for one thing it's gonna black out the sun, it's gonna be able to snow and..." (Interviewer: How does that affect being hotter in the summer?) "Well, it's gonna black out the sun, which blacks out the heat and then the water and the snow is gonna be able to fall."

Some responses depicted a kind of linear reasoning, influenced by experience of other phenomena. These were simplistic, *incorrect explanations.*

For example:

Questions on *Seasons:* "Because the earth is closer to the sun. . . well. . . since the sun is hotter and if the earth is closer to the sun then it will be hotter in the summer than in the winter because the earth will be farther away from the sun in the winter " (This was the most common misconception, evident in 15 of the 27 responses.)

Question on *Mountains:* "Let's see... I really don't know. I think it has something to do with the wind and dust and dirt and it's just a build up of the dirt on that specific area and then it gets packed with snow because of the elevation and it grows in size according to how tall it is."

Certain idiosyncratic ideas were evident. Again these seemed to be influenced by already–acquired information on other phenomena. They appear to be perceptually dominated. For example:

Question on *Mountains:* "I think mountains because atmospheric pressure kinda knocks it down." (Interviewer: Knocks?) "Yes. Kinda makes it tumble because of the atmospheric pressure at the peak and that would make it fall." (Interviewer: What would fall?) "Tumble. The peak." (Interviewer: And that would form a mountain?) "Right."

"The wind blows from... dirt and dust and stuff or something... and blows up against a hill and the hill continues to get bigger until finally it is a mountain."

A summary of some of the clearly evident misconceptions follows: Question on *Season:* "Maybe the earth gets closer to the sun during that part of the time."

"Environmental changes–like forests and stuff like that–during the summer."

"It's hotter in the summer because of how the earth rotates–it has its axis divided into four different seasons–which side is closer to the sun–gets summer." (The influence of a textbook diagram is evident here.)

"In different places in the earth storms comes over... so for one thing it's gonna black out the sun. .. it's gonna be able to snow."

"As the world goes around the sun, when it's summer here, it's winter somewhere else–it hits more in one spot–it might go slower in the summer. When it rotates it might be slowing so the sun hits one spot."

Question on *Mountains:* "Mountains form because atmospheric pressure kinda knocks it down."

"It's something to do with the wind and the dust and the dirt, and it just builds up in a specific area."

"Wind or weather or something like that–like build up–where water hits in one spot. When water gets lower you can see the top."

"By volcanic eruption." (The students consider the formation of a mountain as by a single event rather than in evolutionary term.)

Qualitative Analysis of Posttest Responses

Language was definitely more precise than evidenced in the pretest. There was virtually no use of phrases and words such as "maybe," "something like that," "kind of," "earthquakes or something," in posttest responses. It is clear that the *Earth Science* program made the subject matter comprehensible to the students. Voss(1987) and Eylon and Reif (1984) suggest that when key concepts and their connectedness are made explicit to learners, information is more accessible and comprehensible:

Responses that depicted a sound understanding reflected a clear and logical development of ideas. Most students were explicit in their explanations. For example,

"Granite mountains are formed at subduction zones where the convection cells in the mantle are pushed together and creates the less dense rock. The granite then gets to rise and the more dense rock gets to sink under. Just the action of pushing it together causes the granite to rise and creates mountains."

Twenty-six of the 82 responses for both questions displayed a partial understanding of the phenomena on the posttest. However, the responses seemed to indicate that their problem lay not so much in their understanding of the phenomena, but in their ability to verbalize their understanding. One student's response clearly indicated this: "I hate this (the interview), when I'm doing a test, I do fine. But when I'm saying it, I can't say it that well... Oh God, I don't know how to explain it. I just know the answer."

Discussion

The results of the study show that an explicit, conceptually integrated curriculum can virtually eliminate alternative frameworks without specifically eliciting or addressing the in the instruction. This finding contradicts the generally held assumption that because alternative frameworks are resistant to change, they must be directly addressed in the instruction. In contrast to the focus on the learner perspective in recent research, this study demonstrates that curriculum variables are also critical factors in effective learning.

The *Earth Science* program meets three of the four conditions of curriculum design important for conceptual change, that were set out by Posner, Strike, Hewson, and Gertzog (1982): a new conception must be: (a) intelligible, (b) plausible, and (c) fruitful. However, the fourth condition, that dissatisfaction with the existing conception can only be achieved by addressing the alternative framework,was not met.

In spite of ignoring students' alternative frameworks, the *Earth Science* program resulted in 92% of the students abandoning their alternative frameworks and adopting the teachers' science. The interventions reviewed in this paper, which addressed alternative frameworks, reported success rates ranging from 28% to 69%. The curriculum that did not address alternative frameworks, the *Earth Science* program, seems to be more effective than those that directly address alternative frameworks.

It is interesting to note that prior to instruction the most common misconception for the question on *Seasons* held by students in this study, was the same as the one led by Harvard graduates in the Schneps study (1987). The misconception was: "It is hotter in the summer because the earth is closer to the sun." Only 2 of the 41 students in this study retained this particular alternative framework after instruction. Yet with the Harvard graduates this misconception seemed to be the "conception" they carried through life.

The *Earth Science* program capitalized on students' ability to reason and use their own logic to assess and evaluate the plausibility of their own conceptions and alter them in response to explicit, dynamic instruction.

A science curriculum that is "intelligible" because it explicitly presents information, "plausible" because it presents dynamic, real-world examples of the phenomena, and "fruitful" because a few underlying principles can be used to integrate a large domain of information, can be effective in eliminating alternative frameworks without spending valuable instructional time invoking and addressing them. ◆

References

Anderson, C.W., & Smith, E.I. (1987). Teaching Science. In V. Richardson-Koehler (Ed.), *Educator's handbook: A research perspective* (pp. 84-111). New York: Longman.

Bar, V. (1989). Children's views about the water cycle. *Science Education*, 73 (4), 481-500.

Caramazza, A., McClosky, M., & Green, B. (1981). naive beliefs in sophisticated subjects: Misconceptions about the trajectories of objects. *Cognition* 9, 117-123.

Carnine, .D. (1989). Teaching complex content to learning disabled students: the role of technology. *Exceptional Children*, 55 (6), 524-533.

Claxton, G. (1987). *Mini-theories: A modular approach to learning applied to science.* Paper presented at the annual meeting of the American Educational Research Association, Washington, DC. (ERIC Document Reproduction Service No. ED 281741)

Driver, R., & Erickson, g. (1983). Theories-in-action, some theoretical and empirical issues in the study of student's conceptual frameworks in science.. *Studies in Science Education*, 10, 37-60.

Driver, R., Guesene, E., & Tiberghein, A. (1985). Some features of children's ideas and their implications for teaching. In R. Driver, E. Guesene, & A. Tiberghein, A. (Eds.), *Children's ideas in science* (pp.193-201). Milton Keynes: Open University Press.

Eylon, B. S., & Linn, M. C. (1988). Learning and instruction: An examination of four research perspectives in science education. *Review of Educational Research*, 58 (3), 251-301.

Eylon, B. S., & Reif, f. (1984). Effects of knowledge organization on task performance. *Cognition and Instruction*, 1 (1), 5-44.

Gilbert, J. K., Osborne, R. J., & Fensham, P.J. (1982). Children's science and it consequences for teaching. *Science Education*, 66 (4), 623-633.

Gilbert, J. K., & Watts, D. M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. *Studies in Science Education*, 10, 61-98.

Gunstone, R. F., Champagne, A. B., & Klopfer, L. E. (1981). Instruction for Understanding: A case study. *Australian Science Teachers Journal*, 27 (3), 27-32.

Hewson, M. G. (1985). The role of intellectual environment in the origin of conceptions. in L. H. T. West & A. L. Pines (Eds.), *Cognitive Structure and Conceptual Change.* Orlando, FL: Academic Press.

Hills, F. L. C. (1989). Students' "untutored beliefs" about natural phenomena: Primitive science or common sense? *Science Education*, 73 (2), 155-186.

Hofmeister, A. M., Engelmann, S., & Carnine, D. (1989). Developing and validating science education videodiscs. *Journal of Research in Science Teaching*, 26 (8), 665-677.

Linn, M. C. (1983). Content, context and process in adolescent reasoning. *Journal of Early Adolescence*, 3 (1), 63-82.

Linn, M. C. (1987). Establishing a research base for science education: Challenges, trends, and recommendations. *urnal of Research in Science Teaching*, 24 (3), 191-217.

Linn, M. C. & Burbules, N. C. (1988). Response to contradictions: Scientific reasoning during adolescence. *Journal of Educational Research*, 80 (1), 67-75.

Novak, J. D. (1983). Overview. In H. Helm & J. D. Novak (Eds.), *Proceedings of the International Seminar: Misconceptions in Science and Math* (pp. 1-5). Ithaca, NY: Cornell University. (ERIC Document Reproduction Service No. ED 242552)

Marek, E. A. (1986). They misunderstand, but they'll pass. *The Science Teacher*, 53 (9), 32-35.

Osborne, R., & Freyberg, P. (1985). Roles of the science teacher. In R. Osborne & P. Freyberg (Eds.), *Learning in science: The implications of children's science* (pp. 91-99). Birkenhead, Auckland: Heinemann Education.

Osborne, R., & Wittrock, M. (1985). The generative model and its implications for science education. *Studies in Science Education*, 12, 59-87.

Pauling, L. (1983). Throwing the book at elementary chemistry. *The Science Teacher*, 50 (1), 23-29.

Posner, G., Strike, K., Hewson P., & Gertzog, W. (1982). Accommodation of a scientific conception: Towards a theory of conceptual change. *Science Education*, 66 (2), 221-227.

Prawat, R. S. (1989). Promoting access to knowledge, strategy, and disposition in students: A research synthesis. *Review of Educational Research*, 59, 1-41.

Ramsey, W. L., Gabriel, L. A., McGuirk, J. F., Phillips, C. R., & Waterpaugh, T. R. (1983). *General Science.* New York: Holt, Rinehart, & Winston.

Renner, J. W., Abraham, M. R., Grzybowski, E. B., Marek, E. A. (1990). Understandings and misunderstandings of eighth-graders of four physics concepts found in textbooks. *Journal of Research in Science Teaching*, 27 (1), 35-54.

Roth, K., & Anderson, C. (1988). Promoting conceptual change learning from science textbooks. In P. Ramsden (Ed.), *Improving Learning: New perspectives* (pp. 109-141). London: Kogan Page Ltd.

Schneps, M. H. (Producer, Director). (1987). *A private universe* (Film). Boston, MA: Harvard University and Smithsonian Institute.

Simpson, W. D., & Marek, E. A. (1988). Understandings and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. *Journal of Research in Science Teaching*, 25 (5), 361-374.

Systems Impact, Inc. (1987). *Earth Science.* Washington, DC: Author.

Tyson, H., & Woodward, A. (1989, November). Why students aren't learning very much from textbooks. *Educational Leadership*, pp. 14-17.

Voss, J. F. (1987). Learning and transfer in subject matter learning: A problem solving model. *International Journal of Educational Research*, 11, 607-622.

Yager, R. E. (1983). The importance of terminology in teaching K-12 science, *Journal of Research in Science Teaching*, 29, 577-588.

The Application of DI Sameness Analysis to Spelling

by Robert C. Dixon

Much of the literature on Direct Instruction addresses questions related to the delivery of instruction, rather than focusing on the key unique feature of DI programs—the careful *analysis of content* for efficient communication to learners. We will examine this notion of "content analysis" as it applies specifically to spelling curricula for students with learning disabilities and regular classroom students alike.

In an exhaustive review of research on the spelling ability of students with learning disabilities, Gerber (1985) summarizes that research does not support the notion that spelling disabilities are the result of abnormal psychological processes, and further, that better organized spelling information does lead to improved spelling quality, as well as to quicker "decision speed" among students with learning disabilities. Although, as Gerber points out, other factors also influence spelling improvement, such as adequate practice for mastery and corrective feedback. However the effectiveness of these "other" factors is also influenced by content organization, i.e., the exemplars utilized during practice and the nature of the information conveyed during feedback.

This article focuses upon the application of sameness analysis to three options for presenting spelling content: whole word, phonemic, and morphemic. The potential of these approaches is discussed first in terms of the goal of generalization. Although spelling has been researched as much as any area of the language arts (Graham and Miller, 1979), much of that research appears to center upon instructional practices, such as the relationship between testing and studying, presenting words in lists versus sentences, very general correction procedures, and motivational methods. What follows will: (1) relate the sameness analysis of the three content approaches to the sometimes weak empirical evidence of the effectiveness of those approaches, (2) discuss implications of this analysis for retention and transfer, and (3) suggest implications for preliminary evaluations of spelling programs.

Whole Word and Phonemic Analyses of Spelling

The fundamental question of an initial DI "sameness analysis" is: What do examples of the desired outcome have in common that may prove to be the basis for accurate generalization? Because students make their expressive written vocabulary choices from throughout the range of their oral vocabularies, analysis of spelling necessarily entails an examination of a relatively large corpus of words. Thus, the objective of initial spelling analysis is to determine what features that corpus of words has in common.

The most familiar approaches to presenting spelling content are "whole word" and "phonemic." Within a whole word approach, students simply (but not easily) memorize the spellings of lists of words. Supporters of whole word approaches contend that students don't have to memorize very many words in order to learn most of the words they need in writing, but that argument is based upon *statistical slight- of-hand*. There is no potential for generalization in whole word approaches (other than the generalizations some students infer incidentally), and therefore, such approaches are not subject to DI sameness analysis.

Phonemic approaches to spelling, on the other hand, have *potential* for generalization, but that potential is limited. Hanna, Hodges, and Hanna (1971) conducted an analysis of over 17,000 that was quite similar to a DI analysis in that it looked for *phonemic* samenesses—or sound-symbol rules—across all the words analyzed. Hanna, et al., found that under ideal circumstances, about two hundred sound-symbol spelling rules could be used to spell about half of the 17,000 words studied. That is, if we taught children two hundred sound-symbol rules *and they learned them perfectly*—didn't forget a rule, didn't confuse two rules, etc.—the best they would be able to do is spell less than half of the 17,000 words analyzed by Hanna, et al.

Hanna's group surmised that a somewhat different analysis would have likely produced only slightly different results. They further qualified their results by pointing out that the computer study "did not encompass important morphological and contextual information needed for a comprehensive mastery of American-English orthography" (p. 94). This rather intriguing qualification hints at a dimension of sameness in spelling in addition to phonemic, namely, morphemic.

Morphological Analysis of Spelling

In addition to Hanna, et al., there is substantial theoretical support for incorporating morphology in both reading and spelling instruction (Chomsky, 1970; Chomsky & Halle, 1968; Hodges and Rudorf, 1966; Liberman, 1982; Simon & Simon, 1973; Templeton & Scarborough-Franks, 1985; Venezky, 1970). Basically, morphemes are *meaningful* units—prefixes, suffixes, and word bases (free or bound bases). It is accurate to say that all words comprise one or more morphographs—the written equivalent of morphemes—a notable sameness among spelling words with at least the appearance of some potential for generalization. That potential is realized through two fundamental characteristics of written morphemes:

1. a given morpheme is either always spelled exactly the same way in different environments, or
2. a given morpheme changes its spelling under certain specific, predictable circumstances or contingencies.

These characteristics are analogous to characteristics we might hope pertained more uniformly to phonemes; i.e., that a given phoneme is always spelled one way, or that alternative spellings were always predictable (and, therefore, generalizable, but not overgeneralizable).

The potential benefits of a morphemic analysis of spelling are, analogous to the use of phonemes in either decoding or encoding. A relatively small number of components can be combined in various ways to produce a large number of words. For instance, assume a student can spell only three morphographs: *re, cover, ed.* Few words are generated from just these three morphographs: *recover, covered, recovered.* Now assume an increase from three to seven morphographs: *re, dis, un, cover, pute, ed,* and *able.* The increase from three to seven morphographs yields: *recover, recoverable, recovered, unrecoverable, unrecovered, repute, reputable, reputed, disreputable, disrepute, coverable, covered, uncover, uncoverable, uncovered, discover, discoverable, discovered, undiscoverable, undiscovered, dispute, disputable, disputed, undisputable, undisputed,* etc.

These words result either from simply affixing morphographs in various combinations, or by applying a predictable rule for changing the spelling of a morphograph (a final-*e* rule). The ratio of high-frequency morphographs to words increases exponentially, until the higher-frequency morphographs are exhausted. We know, for example, that about 800 morphographs appear in 10 or more words and generate approximately 16,000 words (Becker, Dixon, Anderson-Inman; 1980).

Morphographs reveal regularities in English orthography not readily apparent in terms of sound alone. For example, the sound for the letter *e* in the prefix *re* changes across words like *reputed* (as in "They are reputed to be less than honest") and *reputable* (as in "This university is a reputable institution"), but the spelling remains the same. Similarly, a word like *sign* is morphemically regular in that both its spelling and meaning are preserved in derivatives such as *signal, resign, signify,* and so on.

However, when relying on sound alone, students with learning disabilities, as well as other students, seem unaware of the conservation of morphemically regular words, such as *magic.* Students will misspell a word like *magician* in numerous ways, as Carlisle (1987) discovered: *magition, magicion, magishion, magition,* etc. In a strategy combining both sound and meaning—morphophonemics—it becomes clear that the elements in *magic* are preserved in derivatives such as *magic + ian = magician,* in spite of the phonological changes undergone by *magic* after affixation. (The choice of *ian* over *ion* is based upon the morphemic generalization that *ian* usually refers to people.)

Neither a morphological nor phonological approach to spelling alone is enough to allow students to generalize to all the words in the corpus from which they may choose to draw in their expressive writing. The word *magic* itself can't be considered altogether regular phonemically, given some ambiguity in the spelling of /j/ in a medial word position. Students who can't spell *magic,* in turn, are preempted from utilizing the morphemic information that would normally lead to a correct spelling of *magician.* Taken together, however, a morphophonemically-based strategy has the potential for considerably reducing the more than 50% irregularity uncovered in the strictly phonemic approach by Hanna and associates.

Yet in spite of support spanning over two decades, there has been precious little empirical investigation into the possible benefits of morphology for learners with or without disabilities.

A Research Perspective

Graham and Miller (1979) cite several studies showing intense phonics instruction to be no more effective than non-phonics instruction, and other studies showing that intensive phonics results in superior achievement over non-phonics approaches. Our discussion thus far suggests one possible explanation for such contradictory findings: *Whole word versus phonics may not be an either/or question.* Our analysis implies it is a question of capitalizing upon phonemics to the extent that doing so results in reliable generalization, and building from a base of phonemic knowledge to capitalize upon morphemic generalization, and finally, "defaulting" to whole word approaches when neither phonemics nor morphemics provide a reasonable basis for accurate generalization.

Studies on morphemics are far from conclusive. Carlisle (1987) studied the patterns of misspellings among ninth grade students with learning disabilities, in comparison with nondisabled fourth, sixth, and eighth graders. She found that the ninth grade students with learning disabilities had a knowledge of derivational morphology comparable to that of the nondisabled sixth graders—knowledge of building word families orally by affixation. All the students studied failed to some extent to apply their morphological knowledge to spelling, but the biggest gap between knowledge and application to spelling was among the students with learning disabilities, who applied their morphological knowledge to spelling less than the nondisabled fourth graders.

Further, an analysis of the misspellings of all the students revealed that the vast majority of those misspellings were phonemically acceptable. This finding generally supports the Tovey's (1978) claim that many misspellings are phonemically feasible. Gerber (1985), however, indicates that there are subtle changes in the quality of students' spelling errors, ranging as a function of age from preliterate, to prephonetic, to phonetic, to transitional, and finally, to correct spellings. Nonetheless, Carlisle's (Carlisle, 1987) descriptive findings indicate that in general, the older students with learning disabilities had reached a point of overgeneralization with phonemics, but had not begun to effectively employ morphemic generalizations.

In a study assessing the effects of morphologically-based *instruction*, Robinson and Hesse (1981) evaluated the direct effects of teaching seventh grade students to spell using SRA's *Corrective Spelling through Morphographs* (Dixon & Engelmann, 1979). *Corrective Spelling* is a program designed in accordance with the sameness analysis principles discussed throughout this paper and employed by Hanna, et al., (1971) In *Corrective Spelling* specific bases for reliable generalization are identified analytically. Students are then taught approximately 750 high-frequency morphographs and the generalization principles outlined above (that the parts recur in different words with similar meanings, either spelled consistently or with minor, predictable spelling changes). The program pretests for knowledge of several basic, regular phonemic generalizations and does not recommend placement for those students who lack such generalizations. To the best of our knowledge, this is the only commercially available program that focuses students' attention intensely and almost exclusively on morphemic generalizations.

In the quasi-experimental Robinson and Hesse (1981) study, 180 seventh grade students received instruction from *Corrective Spelling* for about 20 minutes a day, for 140 school days. Students were pre- and posttested on two instruments: the Stanford Achievement Test, and a criterion-referenced test comprising 50 words derived from the spelling program and 50 words that did not appear in the program, but were derivable from the morphographs and the combining principles taught in the program.

Results on the Stanford Achievement Test were statistically significant, though not particularly impressive. However, the gain on the criterion-referenced test was substantial. The mean pretest score was 51.602 (SD 18.124) and the mean posttest score was 80.620 (SD 12.247). Performance on this test is indicative of generalization, given that half the test items were uninstructed. However, an analysis of the criterion test items, which could show the extent of generalization in the study, is not available.

In a follow-up study, Hesse, Robinson, and Rankin (1983) repeated the criterion-referenced test approximately one year later with 109 students still available from the original study. The most dramatic result of the follow-up study was in the area of retention. There was no significant difference between the original criterion-referenced posttest and the long-term posttest (a year later), in spite of the fact that students received no formal spelling instruction between tests (in the eighth grade). Although these studies point to the possibility that a focus on morphemics could lead to both generalization and retention, the lack of comparison groups makes it impossible to draw conclusions regarding the direct effects of the *Corrective Spelling* program.

In another study of *Corrective Spelling through Morphographs* (Earl, Wood, & Stennett, 1981), grade six students gained .9 grade equivalent on list 2 of the Morrison- McCall Spelling Scale, compared with a gain of .4 for an equivalent group in a traditional basal spelling program. Although this study did utilize a suitable control group, there was no assessment of the adequacy of implementation of either program, the control spelling program includes non-spelling language arts skills, and the number of students in the study was not large—27 experimental students and 36 control.

In a third study (Vreeland, 1982), a group of 20 fourth-grade students in *Corrective Spelling* (identified as Program A) was compared with two other groups of 20 fourth-grade students in two other programs (identified only as Program B and Program C). The students in *Corrective Spelling* gained 1.7 grade levels on *The Test of Written Spelling*, while students in Programs B and C gained .8 and .7 respectively. A weakness in this study was that the teacher of *Corrective Spelling* received six hours of training in the use of the program and was observed periodically throughout the seven months of the study, while teachers in Programs B and C received no special training.

In short, the few studies of the only intensely morphemically-based spelling program we could locate all tended to support use of a morphemic approach to spelling instruction, but they also contain methodological weaknesses. The empirical evidence does not support a jump onto a morphological bandwagon.

Slavin (1989) has discussed the propensity of American education toward curricular faddism. "Few educational innovations," he claims, "are designed to insure positive effects in a fair evaluation" (p. 756). Among his recommendations for stopping curricular pendulum swings from one fad to another is his recommendation that school districts pilot programs according to well-established evaluation criteria: (1) compare the group using the program with a comparable control group, (2) assess objectives pursued equally by control and experimental classes, and (3) evaluate the program under realistic conditions and over realistic periods of time.

In order to implement this recommendation, educators would have to decide which of the available curricular programs to pilot. One option is to review existing studies that meet the criteria for fair evaluation—if such studies exist and are available. Another option is to analyze curricular materials for features, which taken individually, have been shown through experimental research to be effective. Although that approach has intuitive appeal and is no doubt better than no appeal to research, "to say that a program is based on well-established psychological principles is not necessarily to say that it is effective in practice" (Slavin, 1986, p. 166). Be that as it may, there is no unequivocal empirical evidence supporting various combinations of whole word, phonemic, and morphemic approaches to spelling, whether incorporated into unified programs or not.

Faced with this vacuum of empiricism, practitioners have few objective options for evaluating the potential effectiveness of spelling programs. It is not surprising that some educators advocate dismissing formal spelling instruction from the language arts curriculum altogether, electing instead to advocate informal spelling instruction, centered around words of special interest to individual students for one reason or another (Glatthorn, 1988). An alternative option is to pilot programs in the manner suggested by Slavin. However, because it is impractical for most schools or districts to pilot *all* available programs, the type of sameness analysis described herein could serve some usefulness in helping select programs for empirical learner verification.

Sameness Analysis and Program Analysis

Our discussion of sameness analysis as it applies to spelling content has implications for evaluating spelling programs. Those implications, to be sure, are tentative, and the logical step following an analytical program evaluation is to test programs empirically, according to well-established research design principles, such as those advocated by Slavin (1989) above.

It is safe to say that every spelling program contains some elements of the three content approaches we have discussed, intentionally or not. Because some useful words in English are simply not generalizable, either phonemically or morphemically, the only choice is for students to memorize those words. Even programs *intentionally* designed around whole word instruction may unavoidably promote the induction of phonemic generalizations, since phonemic elements are present in words. Finally, every program has morphemic elements. Some attention could be given to prefixes and suffixes, and at least a few affixation rules, such as a rule for doubling consonants in words like *running* and *occurred*.

Analysis of Phonemic Generalization

The research we have looked at herein indicates that effectively capitalizing upon phonemic generalization might involve a delicate balance. Younger spellers—whose spelling can be characterized in Gerber's (1985) terms as preliterate, prephonetic, and phonetic—are probably the principle beneficiaries of instruction based principally upon phonemics generalizations. Once students have become relatively proficient phonemic spellers, however, further emphasis on phonemics appears to result in overgeneralization.

The implication for programs is that attention on phonemic generalizations should be focused in the earlier levels, and ideally, there should be placement tests to ensure that students who would benefit from phonemics generalizations get them, and students who have them don't waste their time on them.

Those levels of a program that do emphasize phonemic generalizations should focus on true generalizations (such as /k/ spelled *ck* at the ends of words), rather than on "phonemic patterns" that form the basis for no reliable generalization (such as the spelling of /e/ in the middle of single-syllable words). Words governed by such "nonrule" patterns (like *meal* and *feel*) are certain to be difficult discrimination problems for students. The implication is that these vowel patterns, in fact, must be remembered, which in turn implies the need for a great deal of discrimination practice in order to achieve a level of fluent mastery sufficient to promote the easiest possible transference to writing.

If it is the intention of a spelling program to teach phonemic generalizations at any levels, then the program should also provide frequent opportunities (and evidence) of such generalizations. The extremely common practice of testing on Friday the exact words that were targeted during the week (Rowell, 1972) provides no evidence of generalization. A test or probe of generalization must include words that: (1) are new or uninstructed, and (2) but can be derived from the component skills required for those tested. Furthermore, sensitive ongoing assessment requires attention to more than "number of words spelled right." As Gerber's (1985) analysis indicates, simple right/wrong data may not reflect improvements in the quality of students' thinking.

Analysis of Morphemic Generalizations

Once programs have provided students with sufficient reliable phonemic generalizations for proficiency, there should be a notable shift toward a focus on morphemic generalization. That is not to say that younger or less able students can not benefit from some instruction on morphemic generalization revolving around, for example, common prefixes and suffixes. However, the prerequisite for capitalizing upon the potential of morphemic generalization is fundamental knowledge of phonemic generalization. The students Carlisle (1987) described who used morphemic information to correctly spell *magician*, for example, first had to know how to spell *magic*.

If a program emphasizes morphemic generalization in more than a passing fashion, there should be ample evidence that students' attention is focused upon high utility morphographs, probably organizing instruction around such morphographs. A single, phonemically regular morphograph like *port*, for example, appears in many words, including *apportion, deportation, export, important, importune, portable, proportion, report*, and *supporting*. The other parts of these words—*ap, ion, ate, ex, im, able*, and so forth—are also highly productive and should therefore receive attention in the program.

In addition to a focus on particular morphographs, like those that Becker, Dixon, and Anderson-Inman (1980) found occurring in ten or more words each, a program emphasizing morphemic generalizations would also direct students' attention to numerous applications of morphology, many of which are quite troublesome in terms of sound alone. For example, a "recombining" strategy can often help students spell the "schwa" sound, like the vowel sound in the second syllable of *sedative* or *definite*. By either adding or removing prefixes and suffixes, primary stress shifts position and those schwa sounds become clear vowel sounds with fairly obvious spellings—the /a/ sound in *sedate* and the /i/ sound in *define*.

There are many such applications that a morphemic orientation would presumably address. A combination of morphemic strategies, for example, can considerably reduce the sheer memory burden usually associated with learning how to spell /ir/ in words like *inventor, grammar, amplifier, dancer*, and *tractor*. Similarly, morphemic strategies can make the discrimination of *ible* and *able* more a matter of strategic problem-solving than of rote recall, and can considerably simplify the problems frequently associated with spelling the ends of words like *magician, electrician, decision, instruction, impression*, and *suspicion*.

Summary

In spite of the necessity for students to memorize the spellings of some words, the discussion in this article has been governed by the assumption that given a choice, most educators would aspire for students to spell by generalization rather than by memorization. Gerber (1984; 1985) has hypothesized—backed up by considerable support—that the principle difference between expert and poor spellers is that the former display "flexible, strategic, and efficient problem-solving behavior" (p. 40) not demonstrated by the latter. We have indicated that such problem-solving behavior is most likely facilitated through an instructional focus on both phonemic and morphemic generalization, in judicious combination. Our converse assumption is that memorization of word lists does not much facilitate any such problem-solving behavior. We might add that memorizing lists of words intuitively seems a grim prospect for students with learning disabilities, is questionably effective, and could be insufficient for the adult needs of such students in any case.

We have not discussed at any length the role that variables other than content might have on achievement, such as the kinds of effective instructional functions identified by Rosenshine and Stevens (1984) and others. However, we have implied a level of primacy for content analysis. Just how effective are "effective" instructional functions, such as frequent review, immediate feedback, low errors in initial instruction, motivational techniques, and so on, when superimposed on an approach to content that, at least analytically, has as many inherent disadvantages as a whole word approach to spelling?

We have not, either, discussed the many factors that contribute to retention, or the extremely critical goal in spelling of transference to writing. We note, however, that meaningfulness seems to contribute to retention, and that generalization strategies are more meaningful than memorization strategies. Furthermore, the successful acquisition of strategic spelling skill is at the very least a crucial prerequisite for transfer to untaught words. If students demonstrate such skill, but transfer to writing is still not apparent, then various linkage and motivational variables probably warrant further analysis. ◆

References

Becker, W.C., Dixon, R., & Anderson-Inman, L. (1980). *Morphographic and root word analysis of 26,000 high frequency words* (Tech. Rep. No. 1980-1). Eugene, University of Oregon Follow Through Project.

Carlisle, J. F. (1987). The use of morphological knowledge in spelling derived forms by learning-disabled and normal students. *Annals of Dyslexia, 37*, 90-108.

Chomsky, C. (1970). Reading, writing, and phonology. *Harvard Educational Review, 40*, 247-309.

Chomsky, N. & Halle, D. (1968). *The Sound Pattern of English.* New York: Harper and Row.

Dixon, R., & Engelmann, S. (1979). *Corrective Spelling through Morphographs.* Chicago: Science Research Associates.

Earl, L. M., Wood, J., & Stennett, R. G. (1981) Morphographic spelling. A pilot study of its effectiveness with grade six students. *Special Education in Canada, 55*(4), 23-24.

Gerber, M. M. (1985). Spelling as concept-governed problem solving: Learning-disabled and normally achieving students. *Advances in Reading/Language Research, 3*, 39-75.

Gerber, M. M. (1984). Orthographic problem-solving ability of learning disabled and normally achieving students. *Learning Disability Quarterly, 17*, 157-164.

Glatthorn, A. A. (1988). What schools should teach in the English language arts. *Educational Leadership*, September, 44- 50.

Graham, S. & Miller, L. (1979). Spelling research and practice: A unified approach. *Focus on Exceptional Children, 12*(2), 1-16.

Hanna, P. R., Hodges, R. C., & Hanna, J. S. (1971). *Spelling: Structure and strategies.* New York: Houghton Mifflin.

Hesse, K. D., Robinson, J. W., & Rankin, R. (1983). Retention and transfer from a morphemically based direct instruction spelling program in junior high. *Journal of Educational Research, 76*(5), 276-279.

Hodges, R. E., & Rudorf, E. H. (1966). Searching linguistics for cues for the teaching of spelling. In T. D. Horn (Ed.), *Research in handwriting and spelling.* Champaign, IL: National Council of Teachers of English.

Liberman, I. Y. (1982). A language-oriented view of reading and its disabilities. In H. Myklebust (Ed.), *Progress in learning Disabilities.* New York: Grune and Stratton.

Robinson, J. W., & Hesse, K. D. (1981). A morphemically based spelling program's effect on spelling skills and spelling performance of seventh grade students. *Journal of Educational Research, 75*, 56-62.

Rosenshine, B., & Stevens, R. (1984) Classroom instruction in reading. In D. Pearson (Ed.), *Handbook of research on teaching* (pp. 745-798). New York: Longman.

Rowell, G. A. (1972). A prototype for an individualized spelling program. *Elementary English, 49*, 602-604.

Simon, D., & Simon, H. (1973). Alternative uses of phonemic information in spelling. *Review of Educational Research, 73*, 115-137.

Slavin, R. E. (1989). Pet and the pendulum: Faddism in education and how to stop it. *Phi Delta Kappan, 70*(10), 752- 758.

Slavin, R. E. (1986). The NAPA evaluation of Madeline Hunter's ITIP: Lessons learned. *The Elementary School Journal, 87*(2), 165-171.

Templeton, S., & Scarborough-Franks, L. (1985). The spelling's the thing: Knowledge of derivational morphology in orthography and phonology among older students. *Applied Psycholinguistics, 6*, 371-390.

Tovey, D. (1978). Sound-it-out: A reasonable approach to spelling? *Reading World, 17*, 220-233.

Venezky, R. L. (1970). *The Structure of English Orthography.* The Hague: Mouton.

Vreeland, M. (1982). *Corrective Spelling* program evaluated. *ADI News, 1*(2), 3.

The Search for a Unified Social Studies Curriculum: *Does History Really Repeat Itself?**

by Diane Kinder and William Bursuck
Educational Research and Services Center and Northern Illinois University

We are living at a time of dramatic political change world-wide; indeed, events in Eastern Europe are indicative of a major trend towards democratization. While these developments give some cause for celebration, the eventual success of this movement cannot be assumed. Its success will depend largely on the capability of people to make decisions that will influence their own lives as well as the lives of others in their communities, country, and the world. Individuals will need an understanding of history and how solutions to current problems can often be understood in terms of problems and events of the past (Crabtree, 1989; Rogers, 1984).

Over the years, the self-proclaimed leader of the movement towards democracy has been the United States; we pride ourselves on having one of the oldest and most effective democracies. Yet, recently there has been cause for concern regarding the ability of our own young people to effectively participate in democratic government. In order to determine if our young people are armed with the knowledge of democratic principles and history required by a democracy, the National Endowment for the Humanities funded the first National Assessment of Educational Progress (NAEP) of American history (Ravitch & Finn, 1987). With approximately 8,000, 17-year-olds enrolled in general education high school programs tested, the average student answered correctly only 54.5% of the items he or she attempted. These results were especially disturbing in view of the fact that most of these students had previously taken or were currently enrolled in American history, and that unanswered questions were not counted as wrong answers. Perhaps more telling than this figure is an accounting of the specific items that students missed. Twenty percent of the students did not know that George Washington was commander of the American army during the Revolutionary War. Forty percent did not understand the system of "checks and balances" among the branches of the federal government. Less than one third of the 17-year-olds knew that American foreign policy following World War I was isolationism, who Betty Friedan and Gloria Steinem are, or to what reconstruction refers. Ravitch and Finn (1987) in their report of the first NAEP results concluded that the current generation of Americans is "at risk of being gravely handicapped" (p. 200) by their ignorance. Lynne Cheney (cited in Ravitch & Finn, 1987), chair of the National Endowment of the Humanities that sponsored the NAEP, concluded that students not only do not know much about history but that they do not like it very much either.

While students' dismal performance in history can be attributed to many factors, both in and out of school, thisn article will focus on the influence of history instruction and textbooks. First, problems with currently used history and social studies textbooks and instruction will be discussed, including the effects on students with mild handicaps. Second, preliminary efforts to develop considerate history curriculum resulting from a "sameness analysis" (see Carnine, 1990) will be presented. Finally, research related to the effectiveness of this more considerate history curriculum will be described.

Social Studies and History Instruction

Textbooks

Perhaps the most predominant instructional tool in America is the textbook (Goodlad, 1976). American educators depend on the textbook as the basis for instruction. Textbooks, as a means of providing information, are used increasingly with each advancing grade (Armbruster, 1984) and seem particularly important in social studies and history instruction (Armento, 1986). Yet, there has been considerable criticism of textbooks in the literature. Armbruster and her colleagues (Anderson, Armbruster, & Kantor, 1980; Armbruster, 1984; Kantor, Anderson, & Armbruster, 1983) have found that textbooks are frequently "inconsiderate" of their readers; many are poorly written, incoherent, and use short, simple sentences. Further, Armbruster and Anderson (1985) found that the relationships between sentences, ideas, and concepts are often

*Reprinted from *Journal of Learning Disabilities* (in press) Copyrighted 1991 by Pro Ed Inc. Reprinted by permission.

*This paper was supported in part by a research grant (G0087C3034) from the U.S. Department of Education. However, the opinions expressed in this paper remain those of the authors.

vague, and the language is not precise. History textbooks, in particular, have come under intense scrutiny of late (Crabtree, 1989; White, 1988). They have been found to be superficial and to trivialize the content of history (Crabtree, 1989). All too often, the major concepts of history are not made obvious (White, 1988) because the textbooks provide a brief mention of everything and little if any analysis (Tyson & Woodward, 1989; Zakariya, 1988). This may be problematic for students with learning disabilities who tend to have difficulty memorizing and retaining isolated facts as well as organizing information into a conceptual framework (Lovitt, 1989; Smith, 1983).

An example of how the superficial treatment of a topic might make it difficult for the reader, particularly one with learning disabilities, to understand history's interrelated concepts, can be seen in a recently published junior high United States history text (Jacob, Wilder, Ludlum, & Brown, 1988). The chapter covering Lyndon Johnson's administration included short descriptions of the women's movement, *La Raza*, the black-power movement, and the protests by young people. The discussion of the protest by young people included little more than statements that young people proclaimed peace and love, listened to music by the Beatles and Bob Dylan, protested on campuses, and were against the war. These isolated facts did not specifically relate young peoples protests to the disappointing results of the Great Society, the activism of minorities including the increased use of violence, and, perhaps most importantly, the Vietnam War, a conflict that was deeply dividing the American People. The intensity, importance, and relationship of the events of the sixties can not be gleaned from this account of the young people living at the time. The superficial treatment of events and failure to clarify and integrate major concepts is not limited to this text or to junior high texts. Beck, McKoewn, and Gromoll (in press) recently concluded their in-depth evaluation of fourth and fifth-grade American history texts by stating that the texts did not present information in a way that facilitated the organization of facts into a coherent whole.

Instructional Approaches

Because social studies and history instruction are so dependent on the text, it is not surprising that history instruction also has been criticized. An in-depth review of the literature on social studies instruction is beyond the scope of this article; the interested reader is referred to Brophy's (1990) recent comprehensive review of the literature regarding the goals, content, and pedagogy of social studies instruction. For our purposes, the discussion of social studies instruction will be limited to three common approaches: the traditional content approach, the inquiry approach, and the balanced approach (Brophy, 1990; Kaltsounis, 1987; Savage & Armstrong, 1987). The traditional method is commonly delivered through lecture and recitation and considered predominantly analytic in nature (Ravitch & Finn, 1987). This approach involves identifying key concepts students are to learn, and then reducing these concepts to a list of specific statements (Kaltsounis, 1987; Savage & Armstrong, 1987). While breaking objectives down into component knowledge seems laudable, this approach may be problematic from the learners' point of view. For example, the causes of the American Revolution might be reduced to:

the Wool Act, the Hat Act, the Iron Act, the Navigation Acts, the Sugar Act, the Stamp Act, and so forth.

The learner could easily become caught up in learning the details of each regulation and taxation act and miss the bigger picture, namely that Britain wanted control of production, navigation, and taxation in order to benefit economically from the colonies. This listing and memorization of seemingly unrelated facts is particularly likely to occur when the traditional approach is combined with common administrative pressures to "cover" the curriculum; a situation that can result in the superficial treatment of issues for efficiency sake. Thus, good students may come to view their task as one of learning many details with little or no understanding of the higher-level structure and conceptual networks; less-able students may come to view their task as simply impossible. It is no wonder that all too many students neither know much about history nor like it.

Inquiry approaches tend to differ from traditional approaches mainly in the way instruction is delivered. Traditional history instruction is carried out through discussion, lecture, and student reports (Voss, 1986) in which the teacher directs learning. Inquiry approaches are more student centered; that is, teachers guide students in discovering information and act as a resource in helping the students induce generalizations (Kaltsounis, 1987). While the intention of this approach is to foster higher-level learning by teaching inductively, in practice, teachers using inquiry methods still tend to stress lower levels of learning such as recalling facts (Kaltsounis, 1987). Thus, as in the traditional approach, students come to perceive history as a matter of learning isolated facts.

The balanced approach (Kaltsounis, 1987) is an attempt to integrate the best elements of the traditional and inquiry approaches. A number of recently had been developed to facilitate general comprehension (Brophy, 1990), and not history content per se. For example, Brownlee (1988) and Walton and Hoblitt (1989) suggested teaching students to map the components of narrative grammar, such as the setting, characters, problem, goal or plan, actions, and outcome. Finally, some have suggested techniques for understanding history content through the identification of commonly used text structures, and the words or phrases that signal their usage. For example, Devine (1987) suggested students be taught to organize notes using Meyer's (1975) analysis of expository thought or text structures including collections, descriptions, causation, problem/solution, and comparison. While teaching students to identify these text structures in controlled passages has proven to facilitate students' comprehension and understanding (Horowitz, 1985a, 1985b), our experience tells us that it is difficult for trained graduate students to identify these structures in history textbooks and exceptionally difficult for students with mild handicaps (Kinder, Bursuck, & Epstein, in press).

Armbruster and Anderson (1985) suggested an analysis or strategy similar to Devine's (1987); however, they identified a single structure or frame that appeared to account for many of the events specific to history. Armbruster and Anderson termed their structure Goal-Action-Outcome (GAO) based on the presumption that the components of goal, action, and outcome constituted the heart of historical events. Armbruster and Anderson illustrated this framework with a GAO analysis of the formation of the Massachusetts state government following the Revolutionary War. The goal was to establish a government that derived its power from the people and that could be changed by the people. The action or process used to achieve this goal was a state Constitutional Convention. The outcome was the establishment of a three-branch government with most power reserved for the people.

While the use of one consistent analysis or frame has merit, it appears that the GAO frame does not consistently clarify historical events. For example, the GAO analysis implies that people or governments have a visionary, proactive approach to actions. Our analysis indicates, however, that the decisions and actions of people and governments tend to be more reactive in nature. We propose that people and governments are reacting to problems, that the causes of these problems are small in number and that there are a few, common *solutions* to these problems. The outcomes or *effects* of these solutions, though not always clearly stated in textbooks, might, in fact, result in other problems. This problem-solution-effect analysis seems to provide a frame or schema for many historical events.

Examples may help the reader to see how this problem-solution-effect analysis can facilitate understanding the relationship between events, facts, and concepts. As noted previously in this article, the traditional approach to teaching the causes of the Revolutionary War relates a series of acts imposed on the colonies by the British (e.g., the Wool Act, the Hat Act, the Iron Act, the Navigation Acts, the Sugar Act, the Stamp Act, etc.). By using the problem-solution-effect analysis, linkages between these regulations can be established, making them easier to learn. The problem-solution-effect analysis would illustrate that prior to the Revolutionary War, England needed to import raw materials for industries that often did not show a profit; moreover the English government had debts from the French and Indian War—both problems based in economics. England's solution to the problems was to pass a number of revenue-producing laws that required the colonists to buy manufactured goods from England, sell raw materials only to England, and tax many items brought into the colonies. The effects of these laws were that the colonists became angry, smuggled goods in and out of the country, and boycotted the purchase of some English goods.

This problem-solution-effect analysis seems to "fit" many other historical events as well. Consider the invention of the cotton gin. Generally, the isolated fact that Eli Whitney invented the cotton gin is taught; however, the need for the cotton gin at that time and the historical effects of this invention usually are not made clear. The problem-solution-effect analysis shows these causal connections. Unlike the cotton grown in Egypt, most of the cotton grown in the southern United States was short-staple cotton. The short fibers made it difficult and expensive to remove the seeds©™another economically-based problem. The solution was Eli Whitney's invention of a machine to remove the seeds. The effect was that much more cotton could be cleaned in a day. Thus, farmers could sell more cotton, and were in turn motivated to grow more cotton, which ultimately increased the need for slaves.

Our final example demonstrates another recurrent source of problems in history; namely, human rights. In the early 1800s the Mormons had a problem with people from the majority culture who did not approve of their practice of polygamy or their belief that Mormons were the chosen people. The problem escalated to the point that two Mormon leaders were killed. The Mormons' solution was to move west to Salt Lake where no one would interfere with their religious practices. The result of this migration was that the Salt Lake settlement became a successful farm community with representative government and religious freedom.

It appears that the problem-solution-effect analysis not only consistently "fits" historical events and demonstrates what Brophy (1990) has termed a network of information, but captures a sameness in the types of problems and solutions found in social studies as well. Frequently problems involve economics, though occasionally religious freedom or human rights are issues. The solutions are more variable, yet limited to several categories: fighting, moving, inventing, accommodating, or tolerating the problem.

Given the apparent potency of problem-solution-effect analysis in interpreting history, students taught to identify the problems, solutions, and effects in historical events might then look for these features when reading history, thereby providing them with a framework for organizing and understanding information. Nonetheless, while the incorporation of this analysis into a curricular form appears promising, it will certainly need to meet what Gersten and Woodward (1990) have called the "reality principle." That is, the curriculum must be concrete, manageable, and workable in order to be implemented. The following section describes our initial attempts to incorporate the problem-solution-effect analysis into a complete, workable history program.

History Instruction Model

The program (Kinder, 1989) consists of a scripted teachers' guide designed to accompany the Holt, Rinehart, and Winston's United States history text (Reich & Biller, 1988). This textbook was considered to be relatively "considerate" of the reader in a review of ten commonly used American history texts (Kinder et al., in press). That is, the text employed features considered to be reader friendly (Dreher & Singer, 1988) such as introductions that reviewed previous content and previewed the upcoming content, summaries, and a higher than average use of the problem-solution text structure. The repeated use of explicit problem-solution structures was particularly attractive given our previously espoused views regarding the benefits of problem-solution-effect analysis.

The complete program includes preskills instruction, problem-solution-effect analysis and note-taking, vocabulary and time-line note-taking, and a reciprocal questioning component. As stated previously, the analysis of historical events showed that economics was the cause of many problems. Therefore, prior to teaching students the problem-solution-effect analysis, basic economic principles were taught as preskills. Students learned that countries, companies, farms, and individuals have a balance of "money in" and "money out". Farms, for example, have "money in" from the sale of crops, but "money out" for salaries for farm workers, purchasing seed, fertilizer, and machines, transportation for crops to market, and so forth. Students learn that the preferred balance is greater "money in" than "money out".

The problem-solution-effect analysis and note-taking procedure was also taught in isolation, prior to using it with the textbook. During preskills instruction, students read a number of unrelated passages that each included explicitly stated problems. For example, students read about farming in New England. Like many other problems, the problem in New England related to economics. With thin, rocky top soil and a short growing season New England farmers could not produce enough crops to sell; therefore, more money went out than came in. The solutions were to farm on the coastal plains, grow crops that did not need a long growing season, and raise animals. The effect was that farmers could grow enough to meet their "money out" but little more; hence, we have the presence of subsistence farming. Initially, the teacher modeled the procedure of identifying the problem, solution, and effect and students wrote the notes. The teacher's model demonstrated that for many events in history, four questions can be asked and answered: What is the problem? Why was it a problem? (often economic), What was the solution? (move, fight, invent, tolerate) and What was the effect? Later, students read explicit passages; this was followed by the teacher asking probing questions, and then leading a discussion of the problem. Students took notes by dividing the notebook paper into three columns, one each for problems, solutions, and effects.

After preskills instruction, active teacher-led instruction using the textbook continued to illustrate the connection among facts utilizing the problem-solution-effect analysis. Initially, students recited the four problem-solution-effect questions and read a "chunk" of text as identified in the scripted teachers' guide. After the students had finished reading, the class discussed the problem, why it was a *problem*, the *solution*, and the *effect*. Students then wrote the answers to these questions using a structured note-taking system and repeated the problem-solution-effect analysis on the next "chunk" of information.

Figure 1 shows one student's *problem-solution-effect* notes on the topic of colonial trade (the student's spelling and sentence structure were not corrected). This figure not only illustrates the student's analysis of an economic problem but also the understanding that a solution such as the Navigation Acts can result in another problem (colonists had more "money out" than "money in"). The *problem-solution-effect* notes illustrate the linkage of information and facts as opposed to the more common practice of presenting facts in isolation. The expectation was that through repeated exposure to the problem-solution-effect analysis students would be able to identify important information, incorporate that information into a network, and retain this network of information more easily than isolated facts.

While the problem-solution-effect analysis was a key component to the history curriculum, it was not the complete model. Ravitch and Finn (1987) have made a strong case for including chronology in history instruction. Therefore, in addition to problem-solution-effect notes, students also developed a time-line to accompany each chapter showing the sequence of events. Further, in view of the evidence that vocabulary instruction can enhance reading comprehension (McKeown, Beck, Omanson, & Perfetti, 1983) a strategy to decipher key vocabulary words was included in the program. Like most middle or junior high school American history texts (Kinder, et al., in press) the Holt, Rinehart, and Winston (Reich & Biller, 1988) text printed key vocabulary in bold-face type. Students were taught to identify these vocabulary words, determine the meaning from the text, and record the word and its meaning in their notes. Thus, to summarize the textbook-reading strategy, the students read a passage; with the teacher's assistance analyzed the problem, solution, and effect; and wrote structure notes. After completing their problem-solution-effect notes for the entire chapter, the students reviewed the chapter, developed their time-lines, and wrote the definition of each text-identified vocabulary word.

In addition to writing cohesive content notes, vocabulary notes, and time-lines, students were taught a strategy for studying their notes (Armbruster & Anderson, 1981). This involved a reciprocal questioning strategy; for each event, students were taught to ask each other why certain actions were taken. For example, one question about the cotton gin might be, "Why did Eli Whitney invent the cotton gin?" and the answer was a statement of the problem ("Southern cotton was short-staple cotton and it was difficult and expensive to remove the seeds.") A second type of question asked the results of the actions; "What was the effect of the invention of the cotton gin?" The answer to this type of question is the effect—in this case more cotton could be cleaned, more cotton could be grown, and there was an increased need for slaves.

Students were also asked to review the definition of terms and to put two or three events in chronological order. To avoid the meaningless memorization of dates in the chronology questions, students were asked to state why it made sense that one event would happen before another. For example, "Why does it make sense that the Constitution was written before George Washington was elected president?" This review component could be organized in a variety of ways—teacher directed, cooperative learning groups, or individualized. Reciprocal questioning was utilized to encourage students to develop

Figure 1. Structured Notes for Problem-Solution-Effect as Prepared by One Student.

Chapter 4 Making a Living
Section 2 Colonial Trade

Problem	Solution	Effect
England was unhappy cause Dutch was getting all the money.	The Navigation Acts They started a thing called the Navigation acts they said. 1. The English ships had to carry all good 2. They had to sell goods only to England 3. They put tax on some good shipped from foreign colonies	The shipbuilding grew. They had to sell their goods for lower prices. Had to pay more for foreign goods.
The colonists had to pay more than what they got back.	They smuggled goods in and out of the USA.	Englands to far away to stop them.

self-questioning strategies. This required students to not only be able to answer questions, but also to be able to ask questions similar to those that might be on a test.

In summary, the complete program consisted of teacher directed discussion to analyze the problem-solution-effects for each "chunk" of information, recording notes regarding this analysis, developing a time-line, and defining vocabulary. This note-taking process was followed by studying the network of information, time-line, and definitions using reciprocal questioning.

Preliminary Findings

The effectiveness of the American history program described above has been examined in two studies, one of which has been completed (Kinder & Bursuck, 1990) and the other is in progress. The first was a multiple baseline study across three junior high school special education classrooms of 4 to 10 school-identified students with behavior disorders, learning disabilities, and mild retardation. During baseline, the Holt, Rinehart and Winston (Reich & Biller, 1988) text was used along with a "traditional" approach. Students read and discussed the text, answered textbook and workbook questions, and took tests. The baseline and intervention tests included vocabulary items and time line questions in addition to short answer and multiple choice questions that were designed to determine if students had integrated information gleaned from larger sections of the text. The average baseline scores for the three classrooms ranged from 45% to 57%. The three special education teachers then introduced the American history program sequentially under the requirements of the multiple baseline design. In all cases, test scores immediately and dramatically improved; the average scores for the three classrooms while using the program ranged from 78% to 85%. In addition, consumer satisfaction surveys indicated that both the students and the teachers were pleased with the program.

Although the study appears to indicate that the strategy is successful in teaching American history content to students with mild handicaps, whether or not the students could independently apply the strategy to the program textbook or other texts was not investigated. A study in progress is examining this issue. Certainly it is hoped that the independent usage of the strategy would help students with learning disabilities be more successful in general education history classes

Conclusion

Recent findings on the outcomes of history instruction in the United States indicate a crucial need for social studies curricula that go beyond current practices that frequently stress the memorization of isolated facts. The social studies curriculum described in this article is only the first step in the development of what Carnine (this series) has termed "intelligently organized curricula." While preliminary indications are that this curriculum can be effective, it is not without its limitations. Social studies is a very diverse field including many disciplines: history, civics, geography, psychology, and so forth. The curriculum described here is specific to the discipline of history. Other disciplines will require an analysis specific to their content. The curriculum described in this paper attempts to teach a "meaningful understanding of coherent networks of information" (Brophy, 1990, p. 369). However, other higher-order applications commonly included in the literature such as critical thinking, decision making, and citizen-participation activities are not included in this curriculum.

In spite of these limitations, we believe that the work described here represents the beginning of an empirical base in support of a unified curriculum that integrates facts and concepts into a network of knowledge. It is our hope that future research will reveal instructional approaches that teach higher-order thinking skills in all social studies disciplines. Translation of this research into easily comprehensible teaching procedures (Gersten & Woodward, 1990) and effective staff development (Joyce & Showers, 1988) then will be required to ensure more successful instructional outcomes for handicapped and nonhandicapped learners as well. ◆

References

Anderson, T. H., Armbruster, B. B., & Kantor, R. N. (1980). *How clearly written are children's textbooks? or, of bladderwarts and alfa* (Report No. CS 005 649). Urbana-Champaign: University of Illinois. (ERIC Document Reproduction Service No. ED 192 275)

Armbruster, B. B. (1984). The problem of "inconsiderate text." In G. G. Duffy, L. R. Roehler, & J. Masson (Eds.), *Comprehension instruction* (pp. 202-217). New York: Longman.

Armbruster, B. B., & Anderson, T. H. (1981). Research synthesis on study skills. *Educational Leadership*, 39, 154-156.

Armbruster, B. B., & Anderson, T. H. (1985). Producing 'considerate' expository text: Or easy reading is damned hard writing. *Journal of Curriculum Studies*, 17, 247-253.

Armento, B. (1986). Research on teaching social studies. In M. Witrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 942-951). New York: Macmillan.

Beck, I. L., McKeown, M. G., & Gromoll, E. W. (in press). Learning from social studies texts. *Cognition and Instruction*.

Brophy, J. (1990). Teaching social studies for understanding and higher-order applications. *The Elementary School Journal, 90*, 351-417.

Brownlee, W. A. (1988). History and the learning disabled student. *History and Social Science Teacher, 24*(1), 28-29.

Carnine, D. (1990). Beyond technique—Direct Instruction techniques and higher-order thinking skills. Eugene, OR.: *ADI News, 9(3), pp.* 1-22.

Carnine, D., Silbert, J., & Cameenui, E. (1990). *Direct instruction reading*. Columbus, OH: Merrill Company.

Crabtree, C. (1989). Improving history in the schools. Educational Leadership, 47(3), 25-28.

Devine, T. (1987). *Teaching study skills: A guide for teachers* (2nd ed.). Boston: Allyn & Bacon.

Dreher, M. J., & Singer, H. (1988). Friendly texts and text-friendly teachers. *Theory Into Practice, 28*(2), 98-104.

Foley, R. (1989). *Correlates of academic achievement of adolescents with behavior disorders*. Unpublished doctoral dissertation, Northern Illinois University, DeKalb.

Gersten, R., & Woodward, J. (1990). Rethinking the regular education initiative: Focus on the classroom teacher. *Remedial and Special Education, 11*(3), 7-14.

Goodlad, J. I. (1976). *Facing the future: Issues in education and schooling*. New York: McGraw-Hill.

Hoge, J. D. (1987). What What Works says to social studies teachers. *The Social Studies, 78*, 114-117.

Horowitz, R. (1985a). Text patterns: Part 1. *Journal of Reading, 28*, 448-454.

Horowitz, R. (1985b). Text patterns: Part 2. *Journal of Reading, 28*, 536-541.

Jacobs, W. J. Wilder, H. B., Ludlum, R. P., & Brown, H. M. (1988). *America's story*. Boston: Houghton Mifflin Co.

Joyce, B., & Showers, B. (1988). *Student achievement through staff development*. New York: Longman.

Kaltsounis, T. (1987). *Teaching social studies in the elementary school* (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Kantor, R. N., Anderson, T. H., & Armbruster, B. B. (1983). How considerate are children's textbooks? *Journal of Curriculum Studies, 15*(1), 61-72.

Kinder, D. (1989). *Teachers' guide*. Unpublished manuscript.

Kinder, D., & Bursuck, W. (1990). *Social studies strategy instruction*. (Research Report No. 1990-1). DeKalb, IL: Educational Research and Services Center.

Kinder, D., Bursuck, B., & Epstein, M. (in press). An evaluation of history textbooks. *Journal of Special Education*.

Lovitt, T. C. (1989). *Introduction to learning disabilities*. Boston: Allyn and Bacon.

McKeown, M., Beck, I., Omanson, R., & Perfetti, C. (1983). The effects of long-term vocabulary instruction on reading comprehension: A replication. *Journal of Reading Behavior, 15*(1), 3-18.

Meyer, B. J. F. (1975). *The organization of prose and its effects on memory*. Amsterdam: North Holland Publishing Co.

Patton, J. R., Polloway, E. A., & Cronin, M. E. (1987). Social studies instruction for handicapped students: A review of current practices. *The Social Studies, 78*, 131-135.

Prawat, R. S. (1989). Promoting access to knowledge, strategy, and disposition in students: A research synthesis. *Review of Educational Research*, 59(1), 1-42.

Ravitch, D., & Finn, C. E. (1987). *What do our 17-year-olds know?* New York: Harper & Row.

Reich, J. R., & Biller, E. L. (1988). *United States history*. Austin, TX: Holt, Rinehart and Winston.

Rogers, P. J. (1984). Why teach history. In A. K. Dickinson, P. J. Lee, & P. J. Rogers (Eds.), *Learning history* (pp. 52-70). London: Heinemann Educational Books.

Savage, T. V., & Armstrong, D. G. (1987). *Effective teaching in elementary social studies* New York: Macmillan.

Smith, C. R. (1983). *Learning disabilities: The interaction of learner, task and setting*. Boston: Little, Brown and Company.

Tyson, H., & Woodward, A. (1989). Why students aren't learning very much from textbooks. *Educational Leadership*, 47(3), 14-17.

Voss, J. F. (1986). Social studies. In R. F. Dillon & R. J. Sternberg (Eds.), *Cognition and instruction* (pp. 205-239). Orlando: Academic Press.

Walton, S., & Hoblitt, R. (1989). Using story frames in content-area classes. *The Social Studies, 80*, 103-106.

White, J. J. (1988). Searching for substantial knowledge in social studies text. *Theory and Research in Social Education, 14*, 115-140.

Zakariya, S. B. (1988). Students who are ignorant of the past are endangering our future. *The American School Board Journal, 17*, 20, 37.

Making Connections in Mathematics*

by Siegfried Engelmann
Douglas Carnine
Don Steely

Poor performance in mathematics extends beyond students with learning disabilities and from impoverished backgrounds. In the National Assessment of Educational Progress (Carpenter, Coburn, Reys, & Wilson, 1976), only 25% of the 4th-graders and 62% of the 8th-graders could solve five story-problems (one using each basic operation, and one requiring two operations). Their performance dropped even further during the next five years (Carpenter, Corbitt, Kepner, Lindquist, & Reyes, 1981). At that time, only 1/3 of 7th-graders could add fractions such as 1/3 and 1/2 (Peck & Jencks, 1981). Improvement since then has been slight. During the 1989–1990 school year, the estimate is that only 50% of the high school juniors and seniors will master 8th grade mathematics. Fifty percent represents quite an improvement from 8th grade where the estimate is that only 16% of the students will have mastered the content of typical 8th-grade math textbooks (Anrig & LaPointe, 1989).

International comparisons reveal similar problems. *The Underachieving Curriculum* (1987) compared 8th-grade students from 20 countries (ranging from Swaziland and Nigeria, to Sweden, Thailand, and Luxembourg). U.S. students ranked 10th out of 20 in arithmetic, 12th of 20 in algebra, 16th of 20 in geometry, and 17th of 20 in measurement. Although 40% of U.S. 13-year-olds could regularly solve two-step problems, close to 70% of their Canadian counterparts could do so. About 95% of U.S. students are "below average" in comparison to Japanese students.

Yet the new standards from the National Council of Teachers of Mathematics (1989) don't directly address these problems, but go on to more far-reaching goals:

To value mathematics.
To reason mathematically.
To communicate mathematics.
To solve problems.
To develop confidence.

It seems, at least, that the U.S. is well on its way to reaching the fifth broad goal of the National Council of Teachers of Mathematics—to instill confidence. A study reported that American 13-year-olds placed last in math and next to last in science when compared with students in four other countries and four Canadian provinces. Although U.S. students were last in mathematics knowledge, 58% said they were good at math. Conversely, although Korean students ranked highest in math, only 23% of that nation's students reported that they were good at math (LaPointe, Mead, & Phillips, 1989).

The Conventional Mathematics Curriculum

Developing competence in U.S. students will not be as easy as building their confidence, in part, because of the ways in which mathematics instruction occurs and the structure of the textbooks that define the curriculum. For example, Porter's research (1989) identified four weaknesses that directly affect the development of students' problem solving skills: (1) an inordinate amount of time is spent teaching computational skills, at the expense of concept understanding and problem solving [further corroborated by Perkins and Simmons (1988) and Hamann and Ashcraft (1986)]; (2) 70% or more of the topics covered received less than 30 minutes of instruction time (these were "taught for exposure"); and (3) there are large differences among teachers in the actual amount of time spent teaching mathematics.

The fourth weakness, the "low-intensity curriculum," was also cited by the 1987 Second International Mathematics Study, which lays the major blame of poor student performance on the spiral curriculum. "Content and goals linger from year to year so that curricula are driven by still unmastered mathematics content begun years before" (p. 9). The National Council of Teachers of Mathematics (1989) also noted the need to change the "repetition of topics, approach, and level of presentation in grade after grade" (p. 66). This comment is directed at the spiral curriculum, in which each concept is revisited year after year.

The intent of the spiral curriculum is to add depth each year, but the practical result is the rapid, superficial coverage of a large number of topics each year. As an example, the topic of fractions is introduced in the kindergarten level of a 1991 edition of a major math series and continues through grade 8. According to the suggested pacing guidelines, by the end of 8th grade students will have spent more than 120 days on fractions, most of it review and reteaching tasks from previous years. The analysis of another currently popular math series shows that 76% of the material in grade 6 is review, 80% in grade 7 and 82% in grade 8. Despite this enormous amount of instruc-

*Reprinted from *Journal of Learning Disabilities* (in press) Copyrighted 1991 by Pro Ed Inc. Reprinted by permission.

tion and review, other factors must be involved because, as noted earlier, by 7th grade only 1/3 of the students can add fractions, such as 1/2 and 1/3 (Peck & Jencks, 1981).

In contrast to the United States, where fraction instruction begins in grade one and repeats annually amidst numerous other mathematics objectives, France introduces fractions in a single grade (i.e., 7th grade). At the end of 7th grade, French students are more proficient in fractions than students in the United States. The "low intensity" math curriculum in the U.S. is believed to be a major cause of the U.S. students' poor performance (International Association for the Evaluation of Educational Achievement, 1987).

Research underway at the University of Oregon has identified a number of additional factors that might be contributing to the poor performance of U.S. students (Carnine, in press). These factors, which are based on an extensive review of math and concept teaching research (Dixon, 1990), are being used as criteria in evaluating math basals published both before (the 1980s) and after (the 1990s) the publication of the NCTM standards.

The preliminary findings are basically the same for both the 1980's and the 1990's versions of the programs (e.g., Silbert & Carnine, 1990a; 1990b) can be summarized as follows:

1. Provisions to ensure that the students have the relevant prior knowledge are often marginal. For example, one lesson from a sixth-grade basal used five geometry terms (pentagon, scalene triangle, equilateral triangle, octagon, hexagon) that were not taught earlier in the book and may or may not have been remembered from fifth grade.

2. The rate for introducing many concepts is too fast. For example, three new types of multi-step problems were introduced in one lesson of a fourth-grade text: (a) three numbers where the sum of two quantities is subtracted from a third number, (b) three numbers where a third number is subtracted from the sum of two quantities, and (c) four numbers where two sets of quantities are added and the sum of one set is subtracted from the sum of the other set.

3. The presentation of strategies often lacks logical coherence. The majority of strategies in a fourth-grade text were too general to be of any real value to lower-performing students. Examples of these general strategies included the following: (a) "Ask the question another way," (b) "Undo key actions," (c) "Find a related problem," and (d) "Look for a pattern." In addition, explanations for how these strategies worked were not given.

4. Many instructional activities do not communicate in a clear, concise manner. For example, in one first-grade lesson, students were to answer the question, "How much do 3 lizards cost?" The teacher's question, "How will you know what to draw for 3 lizards?" was largely unrelated to the operation required (e.g., multiplication as repeated addition). The lesson provided a table with the necessary data about lizards and cost. However, there was no strategy taught to determine the operation needed to solve the problem.

5. The transition, in the form of guided practice, between the initial teaching stage and the stage where students work independently is usually inadequate. For example, in one first-grade lesson, students are expected to independently work a difficult type of word problem in the lesson *in which that type is first introduced*. "The girls made birdhouses. 4 houses are yellow. There is 1 less red house than yellow, and 1 less green house than red. How many houses in all?"

6. The review provided to ensure that students will remember what they've learned is at times sparse (e.g., once every month-and-a-half) or absent entirely.

These six deficiencies with math basals are particularly serious because fundamentally, all math basals are quite similar. This homogeneity reflects the influence of the size of the state-wide adoptions in California, Texas, and Florida. To conform to the guidelines in these states, publishers end up acting as if all students "require or benefit from the same instructional goals and sequences," but to the extent that curriculum uniformity is achieved, "the ability to meet the diverse needs of students is reduced" (Tulley & Farr, 1985, p. 1). This observation is confirmed by the finding that pedagogy and educational research are seldom mentioned as factors influencing the judgments of selection committee members (Courtland et al., 1983; Powell, 1986).

Although some studies, such as Hamann and Ashcraft (1986), indict all areas of instruction in mathematics, the most prominent focus of poor performance has been on problem solving. The National Council of Teachers of Mathematics (1980) claimed that "problem solving must be the focus of school mathematics in the 1980's" (p. 2) and again emphasized it in their 1989 Standards, "The development of each student's ability to solve problems is essential..." (p. 5).

Despite the concern about problem solving over the last ten years, educators have not yet even agreed on its definition. Some have decided that problem solving involves written problems that "require students to read several sentences, decide how to organize the problem, and to solve or compute the problem they have created" (Wheeler & McNutt, 1983, p. 309). Some think that problem solving "should involve a child in gathering, organizing, and interpreting information so that he can use mathematical symbols to describe real world relationships" (Ashlock, Johnson, Wilson, & Jones, 1983, p. 239). Still others see it as a "selected sequence of activities, situations, contexts, and so on, from which students will, it is hoped, construct a particular way of thinking" (Thompson, 1985, p. 191).

Heller and Hungate (1985) have noted that the goal of the current general-strategies approach to problem solving is to promote "competent novice" performance, rather than expert performance that relies heavily on domain-specific knowledge. After finding that general mathematics problem-solving ability did not improve after instruction in a program designed to teach general problem-solving strategies, Derry (1989) questioned the goal of promoting competent novice performance. Derry recommends that mathematics instructional research take a new direction, i. e., that of identifying strategies and training methods that foster expert use of those specific strategies, rather than competent novice use of general strategies. According to Derry, such instruction must begin with an analysis of the core set of strategies that are recognized and employed by domain experts and be driven by that analysis rather than by attempts to teach general strategies. The present article illustrates such a curricular analysis for effectively teaching a group of related "problem solving" skills that are often not learned well by students.

The curricular techniques that are presented do not identify various details of instruction that would have to be orchestrated to make the instruction effective. Rather, it attempts to provide an illustration of a *curricular sequence* that has the potential to work well (much better than traditional approaches) for teaching the concepts.

The teaching approach to be outlined derives from the quality-sameness analysis formulated by Engelmann and Carnine in *Theory of Instruction* (1982). The analysis provides a fairly rigorous viewpoint for dealing with the ideas and skills that are to be taught. It further provides tests for designing material in a way that will focus teaching on demonstrating how related concepts are the same and minimize the need to teach a variety of different strategies. When applied to some skills, such as "problem solving," the analysis results in a wholesale reorganization of content.

Quality-Sameness Analysis

A fundamental assumption of teaching is that the stimuli the teacher presents (explanations, examples, reinforcement) cause changes in the learner. Ideally, they cause the learner to learn the ideas, relationships, or concepts the teacher intends to teach. The learner, however, is naive. Even if the learner understands that the teacher is trying to communicate information about something the learner is expected to master, the naive learner has no preknowledge of the concepts. Whatever learning is induced will be a function of the teacher's efforts. When instruction is viewed in this manner, the nature of what the teacher does to communicate concepts and relationships becomes extremely important. The learner is trying to extract qualities from what the teacher says. The teacher may be trying to teach the learner about fractions, for example. From what the teacher does, the learner will abstract qualities. The learner will formulate a concept of what fractions are. This formulation can be inferred largely by the learner's performance on tasks. If we present some of the tasks that teacher presents, we'll be able to see whether the teacher has communicated effectively with those examples. If we test the learner on additional examples—those that fall outside the range of what the teacher did—we'll be able to learn more about the learner's notions of what the concepts are. A third way of assessing the learner's knowledge is to take the next steps in instruction, introducing new fraction concepts.

Range of Examples

Possible problems that the learner exhibits may reveal "misconceptions" in the learner's conceptualizations. For instance, following the initial teaching of traditional fraction activities, we discover that the children can "generalize" to examples that have a numerator of 1 (such as 1/5), even though those examples were not presented in initial instruction. (The only examples presented were 1/2, 1/3, and 1/4.) We discover, however, that none of the children can generalize to an example that does not have 1 as a numerator, such as 2/3 or 2/4. If all the examples presented show fractions that are less than one whole, some learners understandably will assume that fractions must be less than one whole. If fractions are illustrated only with parts of "equal size" on two-dimensional figures, some children understandably will fix on the idea that fractions must be associated with "geometry" or "figures."

A curriculum with these types of examples will cause a serious problem for some of the children, because it is teaching them a distorted notion of what fractions are, how to decode them, and how they relate to whole numbers. (This is not to say that it will necessarily fail with all learners, simply those learners who don't achieve mastery.) The quality-sameness analysis assumes that all learner generalizations are based on perceived sameness of quality in the examples used in instruction. Inability to generalize implies that the quality-sameness basis for the generalization has not been communicated, and the cause should be looked for in the teaching examples.

The solution to such problems is to design curricula in a way that such misconcepts are eliminated or virtually eliminated. Learners could not assume that fractions always have a numerator of 1 if initial teaching presented fractions that have a numerator that is not one. Learners could not assume that fractions are less than one whole if the instruction presents fractions that are more than one whole quite early in the sequence. Learners could not assume that fractions apply only to geometry if the examples include non-geometric problems and applications.

Explicit Instruction about Important Samenesses

The quality-sameness analysis further assumes that children will appreciate how fractions are the same if they are provided with instruction that clearly shows the qualities that are the same. There are many sameness qualities in fractions. The most basic, however, is the idea that the numerator and denominator give information about how to translate the fraction into something the learner already understands—a number line or parts of a whole.

Therefore, quality sameness instruction would not start with 1/2 or 1/3, but would start with the generalizable quality of fractions and would frame instruction so it presented one-and-only-one interpretation about what fractions are and how they relate to things.

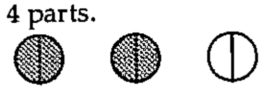
Learners would be taught these two rules for analyzing fractions:

The bottom number tells the number of parts in each group.
The top number tells the number of parts you use.

The initial range of examples would include fractions with various numerators and denominators: 5/3, 2/5, 4/4, etc. The activities would include making "pictures" for different fractions and writing the fraction for different pictures. Note that both activities derive from the rule about fractions. The rule tells how all fractions are the same.

To construct a picture for 4/2, children apply the rule. The bottom number tells the number of parts in each group. Children divide each group into 2 parts:

The top number tells the number of parts to use, so children shade 4 parts.



The same operational steps are used to process every fraction. All have the same qualities—the same number of parts in each group as the bottom number of the fraction; the same number of parts shaded as the top number of the fraction. To construct fractions from pictures, children examine the "picture" for the number of parts shown in each group, e.g.,

They write that number as the bottom number of the fraction: $\overline{4}$. They then determine the number of parts that are shaded. They write that number as the top number of the fraction: $\frac{5}{4}$

The amount of teaching required to teach the basic fraction analysis is relatively small compared to the number of fractions children learn. Children predictably generalize to the full range of fractions that have not been directly taught. (For instance, they would be able to write the fraction for a display that showed 20/14.)

Research

Curricular practices based on the analysis of quality sameness have generated six research studies involving math concepts. These studies deal with multiplication, division, fractions, ratios, proportions, and their associated word problems. In these studies, all treatments included active teaching techniques, but each compared different curricula. All studies, which are summarized in Table 1, included low-performing students. The subjects in five of the six studies included students with learning disabilities. In all studies, the quality-sameness assumptions tend to be confirmed. The curricular treatments based on a quality sameness analysis result in better learning.

For example, in the Kelly, Carnine, Gersten, and Grossen (1986) study, more than half the subjects were students with learning disabilities. The students who received instruction based on a sameness analysis were explicitly taught how to interpret the top and bottom numbers of fractions. Moreover, the students worked with a full range of fractions, with values greater than one as well as less than one. Only 8% of these students made errors in writing a fraction to represent shaded regions. In contrast, 75% of the students who received traditional basal instruction made mistakes. Principles of the quality-sameness analysis, such as making important samenesses explicit and providing a full range of examples, seem to more clearly communicate concepts to students, especially those with learning disabilities.

Solving Difficult Math Problems

The details of the quality-sameness analysis for math problem-solving skills did not emerge full-blown or perfect. It was shaped over time by work with students as part of the authors' development of instructional programs such as *Connecting Math Con-*

Table 1. Established Research Base in Mathematics

Authors	Topic	Results
Gleason, Carnine, & Boriero (in press)	Teaching multiplication and division word problems to mildly handicapped middle-school students.	Students receiving a curriculum based on the sameness analysis, whether from a teacher or computer, progressed from a chance level to a 90% accuracy level.
Moore & Carnine (1989)	Teaching ratio and proportion word problems to handicapped and remedial secondary students.	Students receiving active teaching and curriculum based on the sameness analysis had higher posttest scores than students receiving active teaching with a traditional curriculum.
Kelly, Gersten, & Carnine (1990)	Teaching fraction concepts to handicapped and remedial secondary students.	Students receiving a curriculum based on the sameness analysis made fewer conceptual errors than students receiving traditional instruction.
Kelly, Carnine, Gersten, & Grossen (1986)	Teaching fractions to handicapped and remedial secondary students.	Students receiving active teaching in a curriculum based on the sameness analysis scored higher on post and maintenance tests than students receiving active teaching with a traditional curriculum.
Darch, Carnine, & Gersten (1984)	Teaching multiplication and division word problems to skill-deficient middle-school students.	Students receiving active teaching in a curriculum based on the sameness analysis scored higher on post and maintenance tests than students receiving traditional curriculum and instruction.
Gersten & Carnine (1982)	Longitudinal field research on skill-deficient and handicapped students in 12 school districts.	Students at the end of third grade receiving four years of Direct Instruction scored higher on concepts, application, and problem solving than students receiving developmental, discovery, Piagetian, and other popular instructional approaches.

cepts (Engelmann & Carnine, 1991). In its final form, the analysis groups the following problems as "siblings," in that they are the same in important ways. The quality sameness may not be immediately obvious.

There are 168 workers at a plant.
144 of them are in the union.
If you approached a worker in that plant, what is the probability that the worker is not in the union?

Rita went on a trip.
In the morning, Rita drove a steady 60 mph.
In the afternoon, she drove for three hours and traveled 120 miles.
The entire trip was 300 miles.
What was her average speed for the whole trip?
How many miles did she travel in the morning?
How many hours did she drive in the morning?

There are perch and bass in a pond.
The ratio of perch to bass is 4 to 7.
If there are 308 fish in the pond, how many are bass?
How many are perch?

Linda had a stamp collection.
She sold 146 stamps.
She ended up with 152 stamps.
How many were in her original collection?

The problems are the same in that part of their solution involves "adding" or "subtracting." The addition-subtraction component interfaces with multiplication in all but the last problem. Furthermore, there are many other "subtypes" of problems that have the same logical characteristics as the sample presented above.

The logic is that if a value is the "whole" or "all" or "total" or "more than" the only other compared value, the value can be expressed as the sum of other values. The values can be shown as:

$$\xrightarrow{a \quad b} c$$

C is the "total" or "all." A, B, and C can be expressed by adding or subtracting.

$$a = c - b$$
$$b = c - a$$
$$c = a + b$$
$$c = b + a$$

This is the fundamental logic of sets. The universe is "all." It is composed of the set and the complement.

$$\xrightarrow{\text{set} \quad \text{complement}} \text{universe}$$

The same "addition" and "subtraction" relationships apply to these entities. The set equals the universe minus the complement. The complement equals the universe minus the set, etc.

The first three examples of story problems also involve a multiplication relationship. Multiplication can be expressed as a unique ordering of 2 values:

$$a\left(\frac{b}{a}\right) = b$$

This ordering is particularly important when one deals with problems involving fractions. The values for ratios, for instance, are related by multiplication.

While the description of the addition relationship and the multiplication relationship may seem both very "abstract" and only peripherally related to any effective teaching of problem solving, the abstract analysis provides the basis for developing routines that convey the relevant *quality-samenesses* to the learner. Although the analysis may be abstract, the teaching for the students is not. Rather, the teaching focuses on sameness. The basic technique for conveying sameness is to design problem-solving routines that treat critical details the same. (The message conveyed to the learner is that if they are treated the same, they are the same in some way. If they are not treated in the same way, they are probably not the same.)

Number Families

Number families are introduced for teaching facts. The general orientation of a number family is related to the number line:

$$\xrightarrow{1 \; 2 \; 3 \; 4 \; 5 \; 6}$$

If you start at the circled number and go right, you go to bigger numbers.
(The big number in a number family is to the right.)

If you start at the circled number and go left, you go to smaller numbers. (Small numbers in a number family are always left of the big number.)

Children are taught these rules about number families: The big number is at the end of the arrow. The small numbers are on top of the arrow. If the big number is missing, you add the small numbers. For

$$\xrightarrow{4 \quad 6} \_\_$$

students write $4 + 6 = \square$. If a small number is missing, you start with the big number and subtract the other small number shown. For

$$\xrightarrow{\_\_ \quad 7} 12$$

students write $12 - 7 = \square$.

Children are presented with a number-family table that presents the relevant addition-subtraction relationships. (See Figure 1.)

Figure 1. Addition and Subtraction Number Family Table

$1 \xrightarrow{1} 2$	$1 \xrightarrow{2} 3$	$1 \xrightarrow{3} 4$	$1 \xrightarrow{4} 5$	$1 \xrightarrow{5} 6$	$1 \xrightarrow{6} 7$	$1 \xrightarrow{7} 8$	$1 \xrightarrow{8} 9$	$1 \xrightarrow{9} 10$	$1 \xrightarrow{10} 11$
	$2 \xrightarrow{2} 4$	$2 \xrightarrow{3} 5$	$2 \xrightarrow{4} 6$	$2 \xrightarrow{5} 7$	$2 \xrightarrow{6} 8$	$2 \xrightarrow{7} 9$	$2 \xrightarrow{8} 10$	$2 \xrightarrow{9} 11$	$2 \xrightarrow{10} 12$
		$3 \xrightarrow{3} 6$	$3 \xrightarrow{4} 7$	$3 \xrightarrow{5} 8$	$3 \xrightarrow{6} 9$	$3 \xrightarrow{7} 10$	$3 \xrightarrow{8} 11$	$3 \xrightarrow{9} 12$	$3 \xrightarrow{10} 13$
			$4 \xrightarrow{4} 8$	$4 \xrightarrow{5} 9$	$4 \xrightarrow{6} 10$	$4 \xrightarrow{7} 11$	$4 \xrightarrow{8} 12$	$4 \xrightarrow{9} 13$	$4 \xrightarrow{10} 14$
				$5 \xrightarrow{5} 10$	$5 \xrightarrow{6} 11$	$5 \xrightarrow{7} 12$	$5 \xrightarrow{8} 13$	$5 \xrightarrow{9} 14$	$5 \xrightarrow{10} 15$
					$6 \xrightarrow{6} 12$	$6 \xrightarrow{7} 13$	$6 \xrightarrow{8} 14$	$6 \xrightarrow{9} 15$	$6 \xrightarrow{10} 16$
						$7 \xrightarrow{7} 14$	$7 \xrightarrow{8} 15$	$7 \xrightarrow{9} 16$	$7 \xrightarrow{10} 17$
							$8 \xrightarrow{8} 16$	$8 \xrightarrow{9} 17$	$8 \xrightarrow{10} 18$
								$9 \xrightarrow{9} 18$	$9 \xrightarrow{10} 19$
									$10 \xrightarrow{10} 20$

The most immediate value of presenting the number families is an economy in the amount of material that is to be presented. Only 55 families express all the basic fact relationships (200 facts). Furthermore, since both addition and subtraction are generated from these families, the quality sameness of the families is learned. (Children learn that a "new" family is just like familiar families. It has a big number and two small numbers. If one of them is missing, it is computed according to the practices used for familiar families.)

Children are introduced early to a wide range of variation. As soon as they have been introduced to strategies for addition and subtraction facts, they are presented with families that have 2-digit values:

$\xrightarrow{31} 46$ translates into $\begin{array}{r} 46 \\ \underline{-\ 31} \end{array}$

Comparison Problems

Children also learn a variety of linguistic applications. Jane had more than Frank. This sentence describes values in a number family:

$$\xrightarrow{\text{Frank}} \text{Jane}$$

They then combine the skills to work basic comparative problems:

Jane had <u>16</u> more stamps than Frank had.

Jane had 28 stamps. How many did Frank have?

The first sentence tells about the number family. The underlined number tells about the difference. The difference is always a small number. (The 16 in the sentence would represent a small number: Frank had *16* fewer stamps than Jane had.) When the sentence is read without reading the underlined part, it tells about the big number and a small number. "Jane had more stamps than Frank had." Here's the family based on the first sentence:

$$\xrightarrow{\;16 \qquad \text{Frank}\;} \text{Jane}$$

The next sentence tells how to replace one of the names with the appropriate number. Jane had 28 stamps:

$$\xrightarrow{\;16 \qquad \text{Frank}\;} \overset{28}{\cancel{\text{Jane}}}$$

Now the problem becomes an extension of the same strategy used to write number problems for number families. A number is missing. That's Frank's number. It is a small number. To write a problem with a missing small number, you start with the big number and subtract:

$$\begin{array}{r} 28 \\ -\ 16 \\ \hline 12 \end{array}$$

Frank's number is 12.

The comparison problem type is often difficult for children who have not been provided with an explicit, logical strategy for dealing with it. Note that the strategy is not based on spurious word properties. The rule they learn about sentences that compare values apply to virtually all statements that express comparative numerical values (e.g.,the pole is 311 feet shorter than the tower).

Sequence-of-events Problems

Children are also taught to process problems that may sound like subtraction but that actually require addition:

Tina had some berries.
She gave away 40 berries.
She ended up with 312 berries.
How many did she start out with?

This is a problem that tells about a sequence of events, what happened first and next. Therefore, the strategy involves putting the values in the number family in the same order they are named in the problem. The first thing named in the problem is:

Tina had some berries.

That's the first value placed in the family. To determine where it goes, students determine whether Tina will end up with more berries than she started with or fewer berries than she started with.

She ended up with fewer. To go to fewer, you go to smaller numbers on the number line. (Go left.) So the values in the family start with the big number and progress left.

Tina had some. That's a box for the big number:

$$\longrightarrow \square$$

She gave away 40 and ended with 312:

$$\xrightarrow{\;312 \qquad 40\;} \square$$

The big number is missing. The solution is to add the small numbers.

Although many children would be stumped by the problem because it talks about getting less but actually turns out to be an addition problem, the analysis of the number family makes the problem quite workable.

Classification Problems

In addition to the "comparison" problem and the "sequence of events" problem types, there is a third fundamental addition-subtraction problem—the subclass problem. If there are red cars and cars that are not red, the family shows this relationship:

$$\xrightarrow[\text{cars}]{\;\text{red} \qquad \text{not red}\;} \text{all}$$

Again, this relationship is the fundamental set notion.

Children receive practice in making number families for the classes. Later, children work problems like this one:

There were 86 cars on a lot.
12 of the cars were dirty.
How many cars were clean?

Here's the number family with names:

$$\xrightarrow[\text{cars}]{\;\text{dirty} \qquad \text{clean}\;} \text{all}$$

The problem gives information about all the cars and about those that are dirty:

$$\xrightarrow[\text{cars}]{\;\overset{12}{\cancel{\text{dirty}}} \qquad \text{clean}\;} \overset{86}{\cancel{\text{all}}}$$

The number of clean cars is a small number. To find it, start with 86 and subtract 12.

Data Table Problems

The articulation of logical rules that relate "real life" situations to number operations is further developed by the number family. These are 3-by-3 tables that can be used to show "cross classification" of classes and sub-class relationships.

The basic rules for the table are that each row is a number family. Also, each column is a number family. The column number families work the same way the rows do. The big number is at the bottom. The small numbers are above.

Children (who are now becoming students) first work on tables that involve only numbers.

			Total
	38		226
Total	119	276	

By applying number-family logic, students are able to fill in all the missing numbers. The basic procedure derives from the fact that if there are 2 numbers shown for a row or for a column, you can find the missing number in that row or column by adding or subtracting.

The top row has 2 numbers. The missing number is a small number and can be found by subtracting: $226 - 38 = 188$.

The bottom row has 2 numbers. The missing number is the big number and can be found by adding: $119 + 276 = 395$.

When the missing row numbers are filled in, students work the columns.

			Total
	38	188	226
Total	119	276	395

The first column has two numbers. The missing number is a small number. It is found by subtracting: $119 - 38$. The missing number in the middle column and last column are also found by subtracting: $276 - 188$ and $395 - 226$.

Students next combine knowledge of classification and the structure of the cross-classification table to work problems that are more conceptually difficult. The following table shows the vehicles for the morning ferry and the afternoon ferry on Tuesday:

	Cars	Other Vehicles	Total
Morning ferry	25		70
Afternoon ferry	36		82
Total for both ferries			

By filling in the missing numbers, the students can identify the number of other vehicles in the morning, in the afternoon, and the total for both times. They can identify the total number of vehicles transported, and the total number of cars. They are also able to answer a variety of "comparative" or non-numerical questions:

Which ferry carried the larger number of cars?

In the afternoon, were there more cars or other vehicles?

An extension of the table problems involves a blank table. Students are to put values in the appropriate cells, then fill in the missing numbers and answer the questions.

Here is a sample. The table is supposed to show the number of pine trees and other trees that are going to be planted in two parks: River Park and Hill Park.

	Pines	Others	Total Trees
River Park			
Hill Park			
Total for both parks			

Facts:
In River Park, 476 of the trees will not be pines.
The total number of pines in both parks will be 449.
There will be a total of 1323 trees in both parks.
In River Park, there will be 151 fewer pines than other trees.

The last fact requires the students to compare the number of pines and other trees in River Park. The fact indicates that there will be more "others" than pines:

151 Pines → Others

To make this comparison, students must refer to the numbers they would have already put in the table based on the other facts.

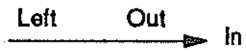
Specifically, 476 comes from the first fact:

151 Pines → 476 ~~Others~~

With all the facts placed in the table, students can figure out all the missing numbers and answer a variety of questions.

Multi-step, Sequence-of-Events Problems

Another extension of the number family logic involves applications in which there is an influx and outgo of values. The basic number family shows in as the big number, **out** and **left** as small numbers.

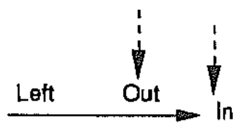


The family can accommodate a variety of basic problems:

> A tank is empty.
> 235 gallons are pumped in and 149 gallons are removed.
> How many gallons are left in the tank?

More complicated variations involve "stacking."

The **In** and **Out** categories on the family can be shown as vertical number families in a table:

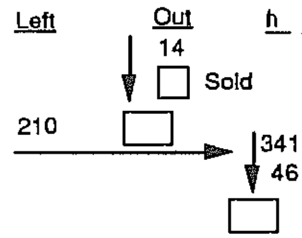


The rule for the stacks is that if more than one value is named for **In** or for **Out**, there are 3 values (just as there are 3 with a number family). The big number for these vertical families is the total for the name shown on the main arrow. Consider this example:

> On Monday morning, a store had 341 pairs of shoes in stock.
> During the day, the store sold some pairs of shoes.
> In the afternoon, the store received a shipment of 46 shoes.
> The store sent 14 pairs of defective shoes back to the factory.
> At the end of the day, the store had 210 pairs of shoes.
> How many shoes did the store sell?

The rules for the <u>in</u> values are (1) anything on hand at the beginning is an <u>In</u> value; i.e., the stock the store began with (341 pairs) is an **In** value; and (2) anything the store receives is an **In** value. The store received a shipment of 46 shoes. The total for **In** is the total of these values. The total for **Out** is the total for the pairs of shoes sold and the shoes sent back to the factory.

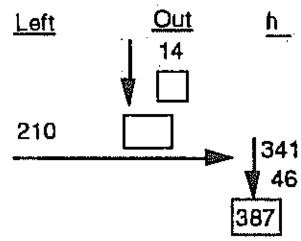
The solution for each part of the problem is based on the logic that if you know 2 values on an arrow, you can figure out the third or missing value. The missing value the problem asks about is the small number on the **Out** arrow—the number of shoes sold.



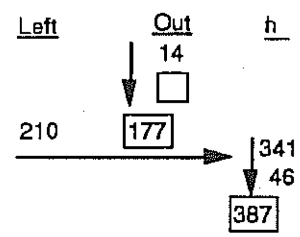
There's only one value (210) on the main arrow, so nothing can be done with the main arrow.

The vertical arrow for **Out** has only one value, so nothing can be done with that arrow.

The arrow for **In** has 2 small numbers. So the big number can be computed: 341 + 46 = 387.



Now there are 2 values on the main arrow (210 and 387). Therefore, the total for **Out** can be computed: 387 – 210 = 177.

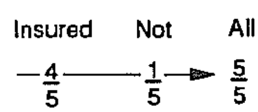


The question asks about the number of pairs sold, which is the missing small number in the **Out** number family. There are 2 values on that arrow. The missing value can be computed: 177 – 14 = 163. 163 pairs of shoes were sold.

Fraction Problems

Some of the less obvious applications of the number-family logic involve fractions. Here's a basic (and obvious) application.

4/5 of the cars were insured. This is a classification family:



The whole is 5/5.

The fraction for the non-insured is 1/5.

After learning about the properties of fraction number families, students work less obvious problems such as:

There were 4 aces in the deck and a total of 52 cards.
What fraction of the cards are aces?
What fraction are not aces?

Aces	Not	All
$-\frac{4}{52}$ ———	$\frac{48}{52}$ →	$\frac{52}{52}$

Other problem types include comparative information. For all these statements, the value at the end of the sentence is the reference value and is therefore one whole. One of the entries on the arrow is the difference.

She had 3/4 less than he did.
3/4 is the difference.
He is the reference value, $\frac{4}{4}$

Difference	She	He
$-\frac{3}{4}$ ———	——— →	$\frac{4}{4}$

The value for she must be $\frac{1}{4}$: $\frac{4}{4} - \frac{3}{4} = \frac{1}{4}$

Difference	She	He
$-\frac{3}{4}$ ———	$\frac{1}{4}$ →	$\frac{4}{4}$

In the next example, he is still the reference value of one, but she has more. She is more than one.

She had 3/8 more than he did.
In fact, the value for she is $\frac{11}{8}$: $\frac{3}{8} + \frac{8}{8} = \frac{11}{8}$

Difference	He	She
$-\frac{3}{8}$ ———	$\frac{8}{8}$ →	$\frac{11}{8}$

In the last fraction example, the sentence tells the value for <u>she</u>, not the difference. He is still the reference value of one:

She had 4/7 as much as he did.

Difference	She	He
———	$\frac{4}{7}$ →	$\frac{7}{7}$

The difference is $\frac{3}{7}$: $\frac{7}{7} - \frac{4}{7} = \frac{3}{7}$

Difference	She	He
$-\frac{3}{7}$ ———	$\frac{4}{7}$ →	$\frac{7}{7}$

Percentage Problems

Variations of all these fraction sentences can tell about percents, which are simply fractions with a denominator of 100:

The train was 14 % shorter in the morning than it was in the afternoon.
(The reference is the afternoon—that's 100%.)

Difference	Morning	Afternoon
$-\frac{14}{100}$ ———	$\frac{86}{100}$ →	$\frac{100}{100}$

In the morning, the train was 126% of its afternoon's length. The reference is still the afternoon's length.

Difference	Afternoon	Morning
$-\frac{26}{26}$ ———	$\frac{100}{100}$ →	$\frac{126}{100}$

A variety of problems are generated by these conventions:

After the game, Arnie weighed 12 pounds less than he weighed before the game.
After the game he weighed 140 pounds.
What percentage of weight did he lose during the game?

Difference	After	Before
$-\frac{12}{152}$ ———	$\frac{140}{152}$ →	$\frac{152}{152}$

The difference indicates the weight lost during the game. To convert that difference into a percent, the students divide:

$$152\,\overline{)12.00}\quad .075$$

The decimal .078 equals 7.8% or about 8%.

Multiplication Problems

Some problems combine addition and subtraction with multiplication. To work these problems, students combine what they learn about the logic of addition with the logic of multiplication.

According to that logic, there are only two numbers involved in multiplication: the one at the beginning of the problem and the other at the end.

$$a \times \square = b$$

The missing value is a ratio of b to a:

$$a \times \frac{b}{a} = b$$

The relationship is verified with familiar facts:

$$2 \times \square = 10$$

The missing value is equal to 5. The fraction 10/2 is equal to 5.

$$2 \times \frac{10}{2} = 10$$

The logic of this relationship suggests that it is possible to start with any value and through multiplication create any value. Through an extension of "dimensional analysis," it follows that hours times some value equals miles.

$$\text{hours} \times \square = \text{miles}$$

The missing value is miles over hours or *miles per hour* (rate of travel).

$$h \times \frac{m}{h} = h$$

Ratio problems. The most immediate application of the multiplication relationship involves ratios. The game is to complete the equivalent fraction:

$$\frac{4}{9} \times \frac{\square}{\square} = \frac{\square}{189}$$

The problem is the same as an addition-subtraction problem in an important way. If two numbers are shown, the third can be computed.

On the bottom, two numbers are shown: 9 and 189.

The missing value on the bottom is 189/9. That equals 21.

Because 4/9 and the fraction with a denominator of 189 are equivalent, the fraction that is multiplied by 4/9 must equal 1.

The denominator is 21, so the numerator must also be 21. Here's the problem:

$$\frac{4}{9} \times \frac{21}{21} = \frac{\square}{189}$$

The answer is 84.

The value of the multiplication analysis is heightened when students work with problems that give a larger fraction and ask about the missing part of a smaller fraction:

$$\frac{72}{144} \times \boxed{\frac{}{}} = \frac{12}{\square}$$

The fraction that equals one is 12/72 over 12/72.

$$\frac{72}{144} \times \boxed{\frac{\frac{12}{72}}{\frac{12}{72}}} = \frac{12}{\square}$$

The answer on the bottom is 24. Note that this problem involves values that "reduce." However, operation works with all values, whether or not they are whole numbers.

Many, many word problems can be worked with ratios. There is a variety of semantic forms for expressing ratios including: Four boxes contain 19 pounds. The ratio of boxes to pounds is 4 to 19. There are 6 bottles in each carton. The names tell about the names for the numerator and denominator of the ratio. Here's a problem:

> If every four boxes contain 19 pounds, how many pounds are in 34 boxes?

The units are boxes and pounds. The first fraction is 4 for boxes over 19 for pounds. The second fraction has a number for boxes.

$$\frac{\text{boxes}}{\text{pounds}} \quad \frac{4}{19} = \frac{34}{\square}$$

Ratios and number family problems. Here's a problem that involves ratios and addition:

> The truck dumped 2/5 of its load of coal.
> The coal that remained on the truck weighed 1680 pounds.
> How much was dumped?
> How much was the full load?

Here's the number family for the first sentence:

$$\overset{\text{Left}}{\frac{3}{5}} \longrightarrow \overset{\text{Dumped}}{\frac{2}{5}} \longrightarrow \overset{\text{All}}{\frac{5}{5}}$$

The ratio numbers (numerators) can be put in a ratio table. They go in the first column. Pounds go in the second column.

Left	3	1680
Dumped	2	□
All	5	□

The columns work just like those in other tables. If two values are given, the third can be computed. To get a second value in the column for pounds, we can work a ratio problem involving the amount left and the amount dumped.

$$\frac{\text{left}}{\text{dumped}} \quad \frac{3}{2} = \frac{1680}{\square}$$

The fraction that equals one is $\frac{560}{560}$. $\frac{3}{2}\left(\frac{560}{560}\right) = \frac{1680}{\square}$

Multiplying on the bottom gives 1120 pounds.

Left	3	1680
Dumped	2	1120
All	5	

The total load is computed by adding 1680 and 1120.

Ratio and number family problems with percents. A variety of similar problems can be created with percents.

> The iceberg was 17 percent heavier in March than it was in April.
> In March, it weighed 4569 tons.
> What was its weight in March?
> How many tons of ice melted between March and April?

The first sentence indicates that April is the 100 percent reference.

Here's the number family:

$$\begin{array}{ccc} \text{Difference} & \text{April} & \text{March} \\ -\frac{17}{100} \text{ ——} & \frac{100}{100} \rightarrow & \frac{117}{100} \end{array}$$

Here's the table:

Difference	17	☐
April	100	☐
March	117	4569

The solution is standard—work the ratio, then add or subtract.

Rate problems in data tables. The final version is the rate table. The rate term is the part that refers to "ratio." Miles per hour, cartons per ton, the spots on each bug, and similar terms describe a rate equation. For example, cookies each hour is:

$$\frac{\text{cookies}}{\text{hour}}$$

It further implies this equation:

$$\text{hour} \times \frac{\text{cookies}}{\text{hour}} = \text{cookies}$$

Here's a rate problem that involves cookies per hour:

> The red machine produces cookies at the rate of 34 cookies per hour.
> How many hours would it take for the machine to produce 450 cookies?

This problem could be handled as a simple ratio problem:

$$\frac{\text{cookies}}{\text{hour}} \quad \frac{34}{1} = \frac{450}{\square}$$

More complicated problems imply the use of the rate equation.

> On Monday, the red machine produced cookies at the rate of 34 per hour.
> On Tuesday, the machine worked for 8 hours and produced 272 cookies.
> The total cookies produced for both days was 447.
> How long did the machine work on Monday?
> How many cookies did it produce on Monday?
> What was the machine's rate on Tuesday?
> What was the average rate for both days?

The table for this type of problem is similar to that for the ratios. The column values that **do not** involve rates can be added.

Here's the problem in a "rate" table:

	Hours	x $\frac{\text{Cookies}}{\text{Hrs.}}$	= Cookies
Monday		34	
Tuesday	8		272
Total			447

The rate equation is implied by the rate term (cookies per hour). The equation, hours x cookies per hour, is used for Monday, Tuesday, and Total. Because the number of hours can be added and the number of cookies can be added, it is possible to get additional numbers in the table. For example, the missing number in the cookie column is obtained by subtracting: 447 − 272 = 175. After students write 175 in the table, two rows each have two values. The third value in each row can therefore be computed.

$$\text{Monday: } \square \times 34 = 175$$
$$\text{Tuesday: } 8 \times \square = 272$$

The solution to the first problem yields a second number for the first column. The remaining number in that column can then be computed by subtraction. At that point, all the cells in the table have a value and the questions can be answered.

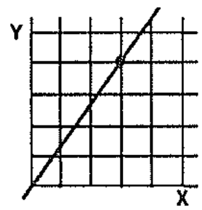
Conclusions

This paper has attempted to show some of the relationships and connections between problem types that are often treated as disparate entities. Some of the subtle differences between types suggests subtle discriminations the learners must master. The most articulate manner of achieving mastery of different types, however, is to *frame the discriminations in a context that involves known skills and that highlights the difference.* This goal is far more easily achieved if students learn the broad qualities and the sameness properties that are shared by various problem types, that is, they learn component skills that can be transfered or generalized to related problems.

The connections that were shown are not exhaustive. Ratios and ratio solutions can be mapped elegantly on the coordinate system. This type of mapping is particularly efficient for identifying sets of values that are related.

For every 4 bats you buy, you get 3 free balls.

We can treat bats as the **Y** value and balls as the **X** value:



$\frac{\text{Bats bought}}{\text{Free balls}} \quad \frac{4}{3}$

By working from a graph, students can read off the answer to a variety of questions; for example, "How many free balls would you get if you bought 44 bats? . . . What if you bought 36 bats?" A question could also be asked about bats: "How many bats would you have to buy to get 12 free balls?"

The same relationship can be treated as a series of equivalent fractions:

$$\frac{\text{Bats bought}}{\text{Free balls}} \quad \frac{4}{3} = \frac{44}{\square} = \frac{36}{\square} = \frac{\square}{12}$$

Or the ratio can be expressed as the rate of bats to balls: This is a "function table" of $\frac{Y}{X}$. The rate is the same for all Y or X values:

Balls	x $\frac{\text{Bats}}{\text{Balls}}$	= Bats
	$\frac{4}{3}$	44
	$\frac{4}{3}$	36
12	$\frac{4}{3}$	

In the '60s, much was written about "concept analysis." The distinction between "concept analysis" and "task analysis" was described and sometimes debated. The preceding description is a somewhat general concept analysis
of various skills that are lumped together under their central sharing of the number-family logic ($a \xrightarrow{b} c$) and the logic of multiplication (a x a = b).

When the entities are fractions and when they are operated on as ratios, some rather unexpected relationships emerge. They are not intuitive, inexplicable, or random. Rather, they are orderly and related.

A prediction of this analysis is that if the teaching for the various skills is developed adequately (which implies field-testing and shaping many details of the presentation), students going through the sequence will learn the concepts more consistently than students going through an approach that focuses on problem solving, discovery, or other "immersion" practice. The reason is that many teachers do not understand many of the relationships and samenesses articulated in this paper; yet, students are expected to discover them. Based on an extrapolation of student success with discovery in the '70s and '80s, the probability of discovering these relationships seems relatively low. ◆

References

Anrig, G. R., & LaPointe, A. E. (1989). What we know about what students don't know. *Educational Leadership*, 47(3), 4-9.

Ashlock, R. B., Johnson, M. L., Wilson, J. W., & Jones, W. L. (1983). *Guiding each child's learning of mathematics: A diagnostic approach to instruction.* Columbus, OH: Merrill.

Carnine, D. (in press). Reforming the mathematics curriculum. *Journal of Behavioral Education.*

Carpenter, T. P., Coburn, T. G., Reyes, R. E., & Wilson, J. W. (1976). Notes from the national assessment: Problem solving. *Mathematics Teacher*, 32, 389-393.

Carpenter, T. P., Corbitt, M. K., Kepner, H. S. Jr., Lindquist, M. M., & Reyes, R. E. (1981). *Results from the second mathematics assessment of the national assessment of educational progress.* Reston, VA: National Council of Teachers of Mathematics.

Courtland, M. C., Farr, R., Harris, P., Tarr, J., & Treece, L. (1983). *A case study of the Indiana state reading textbook adoption process.* Bloomington, IN: Center for Reading and Language Studies.

Darch, C., Carnine, D., & Gersten, R. (1984). Explicit instruction in mathematics problem solving. *Journal of Educational Research*, 77, 350-359.

Derry, S. J. (1989). Strategy and expertise in solving word problems. In C. B. McCormick, G. E. Miller, & M. Pressley (Eds.), *Cognitive strategy research: From basic research to educational applications* (pp. 269-302). New York: Springer Verlag.

Dixon, R. (1990). Research on improving mathematics instruction for low-performing students. Eugene: University of Oregon, Center for the Study of Improving Math Instruction.

Engelmann, S., & Carnine, D. (1982). *Theory of instruction: Principles and applications.* New York: Irvington Press.

Engelmann, S., & Carnine, D. (1991). *Connecting Math Concepts.* Chicago, IL: SRA.

Gersten, R., & Carnine, D. (1982). Effective mathematics instruction for low-income students: Results of longitudinal field research in 12 school districts. *Journal for Research in Mathematics Education*, 13(2), 145-152.

Gleason, M., Carnine, D., & Boriero, D. (in press). Improving CAI effectiveness with attention to instructional design in teaching story problems to mildly handicapped students. *Journal of Special Education Technology.*

Hamann, M. S., & Ashcraft, M. H. (1986). Textbook presentation of basic addition facts. *Journal of Cognition and Instruction*, 3(3), 173-192.

Heller, J. I., & Hungate, H. N. (1985). Implications for mathematics instruction of research on scientific problem solving. In E. A. Silver (Ed.), *Teaching and learning mathematical problem solving: Multiple research perspectives* (pp. 83-112). Hillsdale, NJ: Erlbaum & Associates.

Kelly, B., Carnine, D., Gersten, R., & Grossen, B. (1986). The effectiveness of videodisc instruction in teaching fractions to learning-handicapped and remedial high school students. *Journal of Special Education Technology*, *8*(2), 5-17.

Kelly, B., Gersten, R., & Carnine D. (1990). Student error patterns as a function of instructional design: Teaching fractions to remedial high school students and high school students with learning disabilities. *Journal of Learning Disabilities*, 23(1), 23-29.

LaPointe, A. E., Mead, N. A., & Phillips, G. W. (1989). *A world of difference: An international assessment of mathematics and science.* Princeton, NJ: Educational Testing Service.

Moore, L., & Carnine, D. (1989). Evaluating curriculum design in the context of active teaching. *Remedial and Special Education*, *10*(4), 28-37.

National Council of Teachers of Mathematics (1980). *An agenda for action: Recommendations for school mathematics of the 1980's.* Reston, VA: Author.

Peck, D. M., & Jencks, S. M. (1981). Conceptual issues in the teaching and learning of fractions. *Journal for Research on Mathematics Education*, *12*(15), 339-348.

Perkins, D. N., & Simmons, R. (1988). Patterns of misunderstanding: An integrative model for science, math, and programming. *Review of Educational Research*, *58*(3), 303-326.

Porter, A. (1989). A curriculum out of balance: The case of elementary school mathematics. *Educational Researcher*, *18*(5), 9-15.

Powell, D. (1985). Selection of reading textbooks at the district level: Is this a rational process? *Book Research Quarterly*, 24-35.

Silbert, J., & Carnine, D. (1990a). The mathematics curriculum—standards, textbooks, and pedagogy: A case study of fifth-grade division. Eugene: University of Oregon, Center for the Study of Improving Math Instruction.

Silbert, J., & Carnine, D. (1990b). Effective instruction in mathematics—the role of basal programs: A case study of fifth-grade fractions. Eugene: University of Oregon, Center for the Study of Improving Math Instruction.

Thompson, P. W. (1985). Experience, problem solving, and learning mathematics: Considerations in developing mathematics curriculum. In E. A. Silver (Ed.), *Teaching and learning mathematical problem solving: Multiple research perspective* (pp. 189-235). Hillsdale, NJ: Erlbaum.

Tulley, M., & Farr, R. (1985). The purpose of state level textbook adoption: What does the legislation reveal? *Journal of Research and Development in Education*, *18*(2), 1-6.

Wheeler, L. J., & McNutt, G. (1983). The effect of syntax on low-achieving students' abilities to solve mathematical word problems. *Journal of Special Education*, *17*(3), 309-315.

Linking Special and General Education Services Through Direct Instruction

Moss Point School District
Moss Point, Mississippi

Certainly one of the more common themes in special education is the potential linkage of special and general education services. Consultation models, peer collaboration between teachers, a common curricula, and adaptive teaching strategies are but a few of the proposed solutions to what is, at times, a marriage of inconvenience. Too often, where there is the promise of a meaningful dialogue between special and general education there is also a relentless and mundane exchange of paperwork — referrals, reports from school psychologists, IEPs, letters to parents, and so forth.

But there are occasions when special and general education services are unified, and the two do work in concert. There are even instances where the district's *special education program* dramatically influences its general education practices. Such is the case in the Moss Point School District.

You have to look closely to find Moss Point on the map. This Mississippi gulf coast town, about 30 miles east of Biloxi on the Alabama border, has a handful of elementary schools, two junior highs, and one high school. Of the 6,000 students, almost ten percent of them receive some kind of special education services.

Direct Instruction has been used in Moss Point for over a decade in special education. The reasons for this — and the levels of success — have been fairly typical. Special educators chose an array of DI programs to remedy deficiencies in reading, mathematics, and language. The *Reading Mastery* series, *Corrective Reading* (Decoding and Comprehension), *Spelling Mastery, DISTAR® Arithmetic* and the *Corrective Mathematics* modules, and the *DISTAR Language* programs have been used throughout the day in special education classrooms.

Easing Transfer to the Mainstreamed Classroom

Special educators in Moss Point always have been pleased with the Direct Instruction programs. In a few cases, however, they were perplexed with the performance of a few students. According to Ginger Hollimon, the district's special education director, "Every once in a while one of our special education students was reading just fine in the *Reading Mastery* programs, but had a harder time than the others adjusting to the mainstreamed classroom. The kinds of interactions expected of these few students in the regular classroom made transfer [of reading skills] difficult."

In pull-out classes, the special education students had been taught in very small groups, with ample feedback and direct contact. Naturally, this teacher-student ratio could not be maintained in the mainstreamed class. Deborah Millender, a special education teacher at the time, noted, "They didn't volunteer; they felt intimidated at asking questions; and when they didn't know a word, they just froze."

Special educators addressed this problem by working directly in mainstreamed classrooms as assistants to the regular teacher. They spend most of their time with mainstreamed students and others who were having academic difficulties.

Millender felt that this cooperative assistance helped in many ways. Obviously, the teachers appreciated the assistance during their reading period. But they also began to see how much progress the special education students had made in their Direct Instruction pull-out classes. The recurrent message was that Direct Instruction was effective in teaching low achieving students. Eventually, many saw that the DI curricula addressed *their* needs. As a result, several elementary schools in Moss Point have shifted to a Direct Instruction emphasis in their *regular* primary grades.

Enhancing the Mainstreamed Classroom Through Direct Instruction

In 1978, the general success of the Direct Instruction programs in special education caught the attention of Mary Alfred, principal of East Park Elementary School. Most of her students, although mainstreamed, were academically at-risk. She instituted *DISTAR Reading I, II,* and *III* (the precursors of SRA's *Reading Mastery* series) in the primary grades. Teachers were reluctant to use the new program at first, but the systematic phonics and the obvious student growth by the middle of the year convinced teachers at East Park that Direct Instruction was the best program for their students.

Success in the primary grades carried over into the upper grades. Fifth grade teachers were impressed with the change in the younger students. They too had many students who couldn't read, or whose reading was borderline. Mary Alfred suggested that the fifth grade teachers use the *Corrective Reading Program*. However, she offered it only under the condition that, if the teachers liked it, they needed to make a commitment to it. In requesting financial support from the superintendent, Alfred told him, "If you give me the funds for the DI programs, I'll guarantee success."

The chart below shows the dramatic change in student performance at East Park for fourth and sixth graders in reading, mathematics, and language. The school once had the lowest level of achievement in the district. Now, Alfred notes, "the majority of the high school honor students come from East Park. We feel that the programs build success, and that students *know* what they can do. It changes their self-esteem. Part of this has to do with the way the programs have taught teachers how to give praise."

In 1985, Moss Point changed its standardized tests to the Stanford Achievement Test. Taking the change in measures into consideration, performance levels have remained the same, or slightly higher.

In the last few years, East Park has implemented even more Direct Instruction. *DISTAR Arithmetic* is used in the first grade and SRA's *Corrective Math* modules are used selectively through the end of the third grade.

Last year another Moss Point school—Kreole Elementary School—followed East Park's model. Most of the students at Kreole, while not as low academically as East Park, still qualified for Chapter I services. *Reading Mastery* was chosen as the core reading program for the first three grades. In the combination third and fourth grade classroom, teachers also use *Spelling Mastery* and *Corrective Math*.

Mary Alfred has good reason to be pleased with the influence she—and in no small way, the district's special education program—has had in the Moss Point Schools. The PTA at East Park has grown from virtually nothing to a vital community organization. Alfred attributes this change to the SRA programs.

"Through the student achievement, we showed parents that school wasn't a place to fear, a place to avoid. Parents are proud in sending their children to East Park. Before, they used to send them to other schools in Moss Point. I think all of this came about through our commitment to kids and changing their self-esteem through better academic abilities."

As a fitting touch to these many accomplishments, Mary Alfred was nominated by her fellow principals for the National Distinguished Principal Award for the State of Mississippi, an honor which she won in 1989. This award was in recognition of her decade of service and accomplishments at East Park. ◆

Percentile Growth on the California Achievement Test

	Reading		Mathematics		Language	
	4th	6th	4th	6th	4th	6th
1978	12	9	15	1	18	12
1984	45	42	63	51	.53	40

Rock Hill School District
Rock Hill, South Carolina

"When we are just standing around, there is a pressure on us. It's air pressure. We don't feel it because we're used to it. But when divers go down in the ocean, they feel changes in pressure the deeper they go. If you could put a balloon in the ocean and push it down, it would get smaller and smaller because the air pressure inside the ballon stays the same while the water pressure outside becomes greater.

That's why divers have to come up slowly when they are way under the surface. If they come up too fast, the water pressure drops too quickly and they get bubbles in their blood, and they could die. Knowing about water pressure is very important."

Imagine that this is a junior high school teacher explaining water pressure to her class. The concepts are clear and simple enough for her students to understand. The class also learns an important principle — changes in depth are directly related to changes in pressure. Going deeper means greater pressure, and, more importantly, going toward the surface means a decrease in water pressure. Deep sea divers must know this principle intimately for survival.

Now imagine that this is a learning disabled student explaining water pressure. This *was* roughly the kind of explanation a student gave in a Rock Hill junior high school classroom last year. The teacher was so impressed that she asked the school special education teacher how the student knew about these concepts and was able to explain them so clearly. The answer was simple — Level IV of *Reading Mastery*. It's the reading program that Rock Hill special educators have found to be the most successful for their students.

The Rock Hill School District

Rock Hill is a small district of 13,000 students just across the North Carolina state line. The community is slowly transforming from an old industrial town of textile manufacturing to a part of the high technology world that has reshaped the Charlotte metropolitan area. The newly arriving white collar professionals sharply contrast with the older residents, many of whom have not graduated from high school. All of this is reflected in an exceedingly diverse student population. It is a daily challenge for Dr. Gwen Kodad, director of special education services for nearly 1200 students.

Rock Hill's special education program began using SRA's Direct Instruction programs in the early 1980s. The reasons were fairly typical. Too many students were reading the same basal reading texts again and again. Even when students were placed in special education, they continued to fall further and further behind their peers.

Distar Reading I and II, earlier versions of Reading Mastery I and II, were the first programs used. Rock Hill special education teachers committed to the programs for two years, and Kodad assured them that, if they didn't like them after that time, the district would switch to another remedial series. Though the teachers were a bit reluctant at first, they soon found that their students liked the SRA materials very much. The students felt successful. And the teachers who were unsure of its structured format quickly found that it didn't limit their creativity. Most of all, the Rock Hill students learned to read as they never had before.

Over time, the program has expanded to include the *Corrective Reading Series*. The SRA programs are taught in resource rooms for learning disabled students and self-contained classes for the educably mentally handicapped. Kodad remarks, "There are a lot a reasons why we like the programs. Certainly, the improved achievement is a large part of it. But using them throughout the district has immense advantages. Our kids move a lot. When they arrive at another school, they don't have to start in a new reading program. We feel that this kind of consistency is very important."

The evidence for improved performance came from various quarters. Junior high school teachers were the first to notice the effects of Direct Instruction. Many remarked that their mainstreamed students were much more capable of completing their work. These students turned in better assignments, their reading levels were much higher, and, like the student mentioned in the beginning, they knew more social studies and science than previous special education students.

As further evidence of Reading Mastery's effectiveness, Kodad selected a small group of learning disabled students for a controlled program evaluation. Thirty-two second graders just placed in special education were tested on the Woodcock-Johnson at the end of January 1989. The average score was just over one year below grade level. When the same students were tested on the Woodcock-Johnson at the beginning of May of that year, they had improved, on average, five months in their reading scores. Special education students were not only able to keep up with their peers, but they surpassed them over this period of time. This was one of many reasons why district special educators recently renewed their commitment to the *Reading Mastery* and *Corrective Reading* programs by choosing them from the state textbook adoption list.

Dr. Kodad's commitment to SRA's reading programs comes from their track record in maintaining growth patterns that prevent special education children from falling further and further behind their peers. She fully expects that the progress of these 32 second graders can be sustained. "Getting these kids into Reading Mastery early on is essential. I know that with other reading programs they'll be recycled through the same texts again and again. There won't be any progress, and they'll eventually end up in special education *much* further behind than if they had started with *Reading Mastery*. I can't say enough about the success we've had with the SRA programs." ◆

A Successful Beginning

The Learning Lab at Baylor University Waco, Texas

Not long ago, the chairman of the National Endowment for the Humanities took time to address the problems of our current educational system. What many expected to be a rather prosaic list of issues and challenges turned out to be an extended tirade on textbooks, teachers, and higher education training programs. Summar-izing the countless stories of weak or irrelevant training, the chairman recounted how teachers repeatedly described their professional training as worthless and "more likely to confuse and mislead rather than enlighten." Similar criticisms, though not as extreme in tone, have been voiced by business leaders, politicians, and even critics within the teacher education establishment.

> *"I feel confident to go into my class and be able to motivate my students. I find it easy to keep them on-task and listening."*
>
> *"My special education consultant made the comment to me that the first year special education teachers from Baylor were a lot more positive and reinforcing towards their students than other first year teachers and most of her experienced teachers!"*

Where it is fashionable to talk of change or claim that a four year undergraduate, liberal arts degree will improve the state of our public school systems, most solutions are short on the detailed "how tos" of change. Preparing the future teacher for today's classroom and for the extraordinarily diverse makeup of its students is no small challenge. It goes beyond some minimal level of competence. Ideally, it also means preparing teachers for a *successful beginning* in the classroom, where they feel in control of events and satisfied with their day-to-day accomplishments.

Teacher Training at Baylor University

Dr. Thomas Proctor has been teaching special education classes in the School of Education at Baylor University since 1978. Like so many professionals who are involved in teacher training and preservice education, Proctor exposed students to a variety of teaching curricula in his methods classes. Ways to teach reading, for example, were grounded in several widely-used commercial programs, and students learned how to supplement these basals where necessary. In 1982, all of this changed.

Pat Arredondo, a practicum supervisor, introduced SRA's *Corrective Reading Program* into the Baylor's Learning Lab. The intent of the lab was to give undergraduates an experience working with learning disabled students in one-on-one and small group settings. It quickly became apparent — within a matter of weeks — that this group of undergraduates was making the best progress with their learning disabled students.

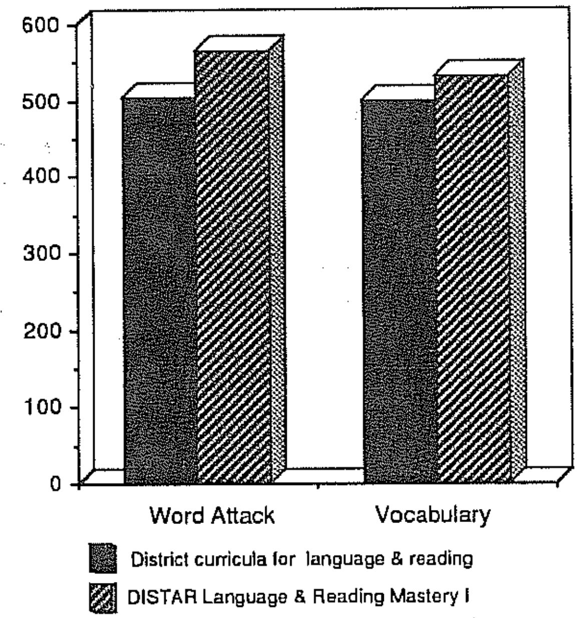
Proctor noticed the improvement immediately, and switched all of the lab training to Direct Instruction materials. By the next year, Proctor added *Reading Mastery* and *Language I, II,* and *III* to his strand of the teacher training program. Over time, SRA's *Corrective Mathematics, Expressive Writing,* and *Spelling Mastery* were incorporated into a comprehensive approach to preservice training.

The current program, now averaging 25 to 30 undergraduate special education majors each year, uses Direct Instruction as the core for most activities. It is the generic tutoring model that students learn in their beginning coursework. Later courses use Direct Instruction texts for reading and math. Finally, supervised practicum in the schools enable the students to apply what they've learned and to adapt their skills to a range of young learners. Proctor feels that with the emphasis on Direct Instruction, "students learn that what they do as a teacher is critical. With these programs, you can give them feedback [on their teaching] that makes a night and day difference."

More Than Another Practicum

Baylor student teachers were recently able to to experimentally evaluate the effects of the *DISTAR®* *Language* and *Reading Mastery* programs. Three first grade classrooms in the South Waco Elementary School participated in the project. In two of the classrooms, teachers continued to use the district's reading and language program. Direct Instruction practicum students in the third class taught *DISTAR Language I* and *II* (depending on placement) and *Reading Mastery I*. To account for the academic disparities between classes, the TOBE test was administered early in the fall term before the instruction began.

Adjusted Standard Scores on the CTBS—Spring, 1989



The graph above shows the comparative growth in achievement for the two approaches. Mean performance for the district's traditional curricula is significantly below that of the Direct Instruction class. It is even more interesting that these gains were made in spite of the fact that Direct Instruction was taught only two-thirds of the year. The traditional curriculum was used during the winter term when there were no practicum placements in the Direct Instruction classroom.

Student Attitudes Toward the Baylor Program

Proctor's concern for high quality instruction even extends to his own program. In fact, few teacher

Table 1. Student Attitude Survey

Reactions to the Program	Percent Who Agree or Strongly Agree
Direct Instruction aids learning.	97
I feel well prepared to use Direct Instruction.	94
Student improvement is worth the extra effort of using Direct Instruction.	91
Regular use of Direct Instruction with students has increased my appreciation of it.	89
Direct Instruction creates a positive attitude in the classroom.	89
There would be more support for Direct Instruction if people knew more about it.	87
I am glad Direct Instruction is emphasized at Baylor.	84
Direct Instruction helps students cope with academics.	84

training institutions evaluate their programs the way he has at Baylor. Over the last few years, Proctor has surveyed current students, recent graduates of the program, and perhaps most importantly, their supervisors in the public schools. Table 1 is a sample from a survey conducted two years ago involving 41 undergraduate students enrolled in the Baylor special education program and 19 recent graduates. For the graduates, the sentences were changed to reflect current practice. A consistently positive attitude toward the Direct Instruction training is reflected by well over a majority of those surveyed.

A follow-up evaluation in the spring of 1990 again reflected the value of the Direct Instruction preparation. This time, graduates and their supervisors were surveyed. Table 2 reflects two important findings: uniformly high ratings across a range of teaching concerns and a remarkable agreement between graduates and their supervisors. The Student Attitude Survey above indicates the level of assurance these students have in their training.

Exceptional Teaching

One of the finest compliments for a teacher training program is when school supervisors and consultants recognize a graduate of the program just by watching them teach. Carolyn Schneider, a consultant for schools in the Houston area, kept noticing Proctor's graduates in her daily classroom observations. Well before she was introduced to the new teacher, she found herself saying, "This teacher is exceptional. She's enthusiastic and very knowledgeable. More than anything, she can take the teaching skills used in the DI programs and use them in other contexts like science."

Schneider sees an incredible difference between the kind of preparation students get at Baylor and other programs. At Baylor, students don't get a "smattering of whatever." She feels that they know much more about what teaching is on a day-to-day basis. They come prepared and they know what it takes to have an impact on kids. Her recommendation to the Houston area schools is simple, "If there's *any way* you can get these people to work for your district, do it!"

Table 2. Mean Rating of Baylor Special Education Program Graduates and Their Supervisors

Competencies	Graduates Rating*	Supervisor Rating*
Motivates students to perform by using positive reinforcement.	6.0	5.8
Presents instruction effectively using techniques that include modeling, pacing, monitoring and correcting, simplifying, and teaching to mastery.	5.8	5.2
Manages the off-task and disruptive behavior of students by teaching rules, rewarding appropriate behavior, and quickly intervening to stop misbehavior.	5.7	4.8
Copes successfully and positively with the wide range of potential stressors frequently encountered by special education teachers.	5.5	5.2
Understands the learning and behavioral characteristics of students in various handicapping conditions.	5.1	5.2
Organizes and manages instruction through grouping, establishing routines, assessing and recording progress.	5.0	5.3

*6 = strongly agree 5 = agree 4 = slightly agree 3 = slightly disagree 2 = disagree 1 = strongly disagree

ADI

Join the Association for Direct Instruction Now and Save!

Due to incresed printing and overhead cost, the Association for Direct Instruction is forced to rise memberships and subscription costs. If you act now you can avoid these increased costs and extend your membership or subscription.

Membership Options:

A) Regular Membership: $15.00 per year (includes one year of *DI NEWS* and a 20% discount on ADI sponsored items and events).

B) Student Membership: $7.00 per year (includes one year of *DI NEWS* and a 40% discount on ADI sponsored items and events).

C) Sustaining Membership: $30.00 or more per year (includes regular membership privileges and recognition of your support in the *DI NEWS*).

D) Institutional Membership: $50.00 per year (includes 5 subscriptions to the *DI NEWS* and membership privileges for 5 staff people).

E) *DI NEWS* Subscription only: $7.00 per year (outside North America and Hawaii $10.00 per year).

ADI sponsored products and events include books and other materials published or marketed by the Association for Direct Instruction. The ADI NEWS is published 4 times a year (Fall, Winter, Spring and Summer).

To join the Association, complete the bottom portion of this form and mail it, with your check or Purchase Order (in U.S. funds) to the Association for Direct Instruction.

Check one:

I wish to become an Association member. Please enroll me as a:

_____ Regular Member ($15.00 annually)

_____ Student Member ($7.00 annually)

_____ Sustaining Member ($30.00 or more annually)

_____ Institutional Membership ($50.00 annually)

_____ I wish to subscribe to the DI NEWS only ($7.00 annually; $10.00 outside North America & Hawaii)

Name: ______________________________

Address: ______________________________

City, State, Zip: ______________________________

Phone: ______________________________

School District or Agency: ______________________________

Position: ______________________________

ADI MATERIALS PRICE LIST

Theory of Instruction

Siegfried Engelmann & Douglas Carnine

Membership Price $32.00 List Price $40.00

Direct Instruction Reading (Revised)

Douglas Carnine, Jerry Silbert & Edward J. Kameenui

Membership Price $32.00 List Price $40.00

Direct Instruction Mathematics (Revised)

Jerry Silbert, Douglas Carnine & Marcy Stein

Membership Price $32.00 List Price $40.00

Teach Your Child To Read in 100 Easy Lessons

Siegfried Engelmann, P. Haddox & E. Brunner

Membership Price $15.00 List Price $19.00

Structuring Classrooms for Academic Success

S. Paine, J. Radicchi, L. Rosellini, L. Deutchman, C. Darch

Membership Price $11.00 List Price $14.00

Members of the Association for Direct Instruction may purchase copies of the materials listed above at the Membership price. Shipping charges are $1.50 per book for 1-5 books and $1.00 per book for orders of 6 or more. Orders are to be paid in U.S. Funds, in advance. Purchase orders are also accepted. Please allow 4 weeks for delivery.

ADI cannot provide copies for entire classes nor can we provide desk copies. All such requests must be made to the publisher of the specific book.

SEND YOUR CHECK OR PURCHASE ORDER TO:

Association for Direct Instruction
P.O. Box 10252
Eugene, OR. 97440
(503) 485-1293
Fax (503) 683-7543

New

Now Available—Connecting Math Concepts, Levels A, B, C (1991 Edition)

- Grades 1-3
- Emphasizes the connections among math concepts
- Organizes lessons by related strands, not single topics
- Gives both guided and independent practice
- Places strong emphasis on problem solving

Important benefits for students and teachers

Connecting Math Concepts is designed to ensure that *all* students (not just some) will learn higher-order thinking and mathematics. What's more, they will apply what they know in a variety of meaningful activities as they learn to think and problem solve.

Develops important relationships among math concepts

The program establishes relationships among concepts and their application. Connecting Math Concepts introduces concepts at a reasonable rate and provides systematic, continuous review so that students learn, remember, and integrate the concepts they are taught.

Lots of ideas for applications extensions, and manipulatives

Suggested Application/Extension Activities are provided in every lesson. These include problem-solving activities, games, and cooperative learning activities. The program incorporates suggestions for manipulative materials to introduce, reinforce, or expand the concepts taught.

Tested materials that really work

Connecting Math Concepts was field-tested in a variety of classrooms across the United States. The authors carefully reviewed teacher critiques and student performance on every lesson and based extensive revisions on this feedback.

Connecting Math Concepts, Level A

Level A builds on the aspect of mathematics that is most familiar to children—counting. The lessons extend counting to a small set of facts and uses these to teach the basics of mathematics: addition and subtraction, their relationship to each other, and the concepts of more and less, place value, problem solving, estimation, money, and measurement.

Connecting Math Concepts, Level B

Level B teaches place value, relationships and facts of addition and subtraction, mental arithmetic, problem solving, measurement, money, column addition and column subtraction, geometry, multiplication, and data collection and analysis.

Connecting Math Concepts, Level C

In Level C, students learn a variety of problem-solving strategies for situations involving classification, comparison, addition and subtraction actions, multiplication and division, and even multistep problems. Key relationships are developed, such as multiplication and division, division and fractions, multiplication and addition, area and volume. Instruction covers place value, geometry, estimation, calculator use, measurement, money, and statistics. Concepts and computation skills are also taught for borrowing, multiplication, division, and fractions.

Authors

Siegfried Engelmann and Douglas Carnine

Components

Complete Set of Teacher Materials for each level contains 1 Teacher's Guide, 1 Teacher Presentation Book, and a separate Answer Key. Student Materials for Levels A and B consist of 2 Student Workbooks. Student Materials for Level C consist of 1 Student Workbook and 1 Student Textbook. Student materials must be ordered separately.

Connecting Math Concepts, Level A

Grade 1		Net Price
7-15628	Level A Connecting Math Concepts Complete Set of Teacher Materials	$150.00
7-15623	Level A Student Workbook 1 (pkg. 5)	24.75
7-15625	Level A Student Workbook 2 (pkg. 5)	24.75
7-15626	Additional Level A Teacher Guide	12.00

Connecting Math Concepts, Level B

Grade 2		
7-15638	Level B Connecting Math Concepts Complete Set of Teacher Materials	150.00
7-15633	Level B Student Workbook 1 (pkg. 5)	24.75
7-15635	Level B Student Workbook 2 (pkg. 5)	24.75
7-15636	Additional Level B Teacher Guide	12.00

Connecting Math Concepts, Level C

Grade 3		
7-15657	Level C Connecting Math Concepts Complete Set of Teacher Materials	150.00
7-15653	Level C Student Workbook (pkg. 5)	24.75
7-15654	Level C Student Text	15.00
7-15655	Additional Level C Teacher Guide	12.00

155 North Wacker Drive
Chicago, IL 60606
To order, call 1-800-621-0476.

Association for Direct Instruction
P.O. Box 10252
Eugene, OR. 97440

Non-Profit Organization
U.S. Postage Paid
Permit No. 122
Eugene, OR