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AUTHOR	Curtis, Ruth V.; Reigeluth, Charles M.
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ABSTRACT

Focusing on the achievement and motivational effects of analogies of varying enrichment levels when used with abstract, unfamiliar, and difficult content, this study examined their effects on instruction at the recall and application levels using content consisting of both concepts and principles. The subjects were 123 eighth-grade science students who were assigned to one of three treatment groups for each of six topics: (1) no analogy, (2) simple analogy, and (3) enriched analogy. An instructional booklet and a posttest booklet were distributed to each student, and both immediate and delayed posttests were administered. Analysis of variance revealed no significant main effects on any of the immediate posttests, i.e., recall, application, or total. In contrast, significance was approached or reached on 5 of the 12 delayed achievement test measures, 1 on the recall level and 4 on the application level. The results of this study suggest that, although analogies may not be very useful for either rote remember-level learning or application-level learning, they may often be very useful for creating linkages within memory that would have an important influence on meaningful understanding, long-term retention, far transfer, problem solving, and the skill of analogical reasoning. A 31-item reference list is provided. (RP)

INSTRUCTIONAL DESIGN, DEVELOPMENT, AND EVALUATION

WORKING PAPERS

THE EFFECTS OF ANALOGIES ON STUDENT MOTIVATION AND PERFORMANCE IN AN EIGHTH GRADE SCIENCE CONTEXT

by

Ruth V. Curtis
Charles M. Reigeluth

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SCHOOL OF EDUCATION, SYRACUSE UNIVERSITY

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Charles M. Reigeluth, Editor
Sheila Thompson, Production Editor
330 Huntington Hall
Syracuse University
Syracuse, NY 13210

INTRODUCTION

Instructional developers are often required to select instructional design components from a wide variety of elements and combine them in ways that maximize their benefit to the learner. The basis of that selection depends on several factors -- the type of learner, the nature of the learning task, the appropriateness of the subject matter, and its interestingness. One such instructional design component is the analogy.

An analogy compares similarities between something concrete and something abstract, when the two things are otherwise unrelated (Souder, 1981). It has the ability to make the unfamiliar familiar (Gabel & Sherwood, 1980; Dreistadt, 1969). This permits the learner to relate his or her own reality to an abstract or otherwise unknown phenomenon.

An analogy is often expressed as an explicit comparison (as opposed to the more implicit metaphor) between one area of knowledge and another area of knowledge that is completely outside the first (Ortony, 1979). A critical attribute of an instructionally useful analogous relationship is that one element is within the prior knowledge of the learner, while the other is distinctly unfamiliar (Reigeluth, 1980).

A simple analogy is structured into three main parts---the topic (the new content), the vehicle (the familiar content), and the words "is like" (Verbugge & McCarrell, 1977; Ortony, 1979). Although different in composition, the topic and the vehicle share a relational structure (Gentner, 1980). In the analogy, "An atom is like the solar system," "an atom" is the topic, while "the solar system" is the vehicle (Gentner, 1980).

A simple analogy can be enriched for the learner by adding grounds and limitations. The grounds are the shared attributes of the topic and vehicle and supply the rationale for them (Verbrugge & McCarrell, 1977; Ortony, 1979). Grounds for the analogy above may specify that the sun has planets that revolve around it, much like the nucleus has electrons revolving around it; and the revolving objects of both are attracted to the central object by a force (Gentner, 1980).

The second way of enriching an analogy is to describe the limitations to the analogous relationship (Reigeluth & Stein, 1983; Hayes & Tierney, 1980). If these limitations are not presented, the student may push the analogy too far and overgeneralize as to other "grounds" in the relationship that do not exist (Reigeluth, 1980; Smith & Wilson, 1974). An example of a limitation related to the above analogy might be that electrons repel each other while planets do not (Gentner, 1980).

Gabel and Sherwood (1980), however, disagree with the presentation of grounds and limitations when using analogies to enhance learning at the recall level. They assert that this causes the learner to assume a passive role and advocate, instead, presenting the analogy only and allowing the learner to extend the analogy him/herself.

One barrier to the effective use of analogies occurs when the learner does not understand or lacks the background knowledge of the vehicle (Hayes & Tierney, 1980). This may cause the learner to confuse the vehicle and topic, thereby harming, rather than helping, the learning process.

Gabel and Sherwood (1980) investigated the use of analogies in chemistry instruction. Their results showed no significance between groups with passages containing and not containing analogies when asked to recall information. However, they later discovered that almost half of the students in their study did not understand 90% of the analogies presented. They found that students who did understand the analogies scored significantly higher than those who did not. Although that part of the sample was too small to confirm generalizability, it appears to be important that analogous material be familiar to the learner.

Another hindrance to the effectiveness of analogies in instruction occurs when the number of limitations to the relationship is so great that the grounds are minimal and remote. An inappropriate analogy can mislead the learner and actually cause a decrease in learning (Pylyshyn, 1973).

Analogy as an Instructional Strategy

There are several reasons why analogies are hypothesized to be important instructional strategies. They relate new knowledge to a closely related body of previous knowledge, while building on that prior knowledge (Sari & Reigeluth, 1982; Reigeluth, 1980). They are excellent conceptualization devices which, while helping to concretize thinking, also may greatly impact upon the development of visual imagery, an important part of the learner's cognitive process (Jorgensen, 1980; Pylyshyn, 1973).

When used effectively in a message, analogies may provide a concrete understanding of highly abstract content, thereby instructing in a clearer, more meaningful manner than had they not been included (Souder, 1981; McCroskey & Combs, 1969). Analogies help the learner to build a cognitive schema or framework (Rumelhart & Norman, in press; Hayes & Tierney, 1980) when encountering complex content for which the learner may not be cognitively prepared (Royer & Cable, 1975).

Although analogies have been used in a variety of content areas, many of the studies related to their effectiveness have been in the area of science instruction (Bielinski, 1980; Rigney & Lutz, 1976; Smith & Wilson, 1974; Gabel & Sherwood, 1980). Science content contains many complex, abstract ideas, often remote from the learner's experience. Scientific concepts often require formal thinking, and the use of analogies makes formal concepts more concrete (Gabel & Sherwood, 1980).

Bielinski (1973) studied the effects of using verbal analogies to teach ninth-grade physical science for different ability levels in various content areas within science. His results showed no significant difference between teaching with and without analogies. However, in this study, analogies were presented as a separate exercise; i.e., the solving of twenty-five analogies weekly over a nine month period. It would appear that the students were given no context in which to apply the analogy.

Reigeluth (1980) suggests that the analogy be used, instead, as an embedded cognitive strategy activator (Rigney, 1978), which requires the learner to use a particular cognitive strategy that facilitates learning. The embedded activator is incorporated into the instruction in such a way that the learner is forced to use it and is unaware that he or she is using it.

In investigating the relationship of intelligence level to the benefits of analogies, several contradictions have appeared. Sternberg (1977) found that high ability students benefitted most from analogies in learning complex material. On the other hand, Bell and Gagne (1979), in a study of the effects of verbal analogies and quantitative and verbal aptitudes on the recall and comprehension of a technical text, found that high ability students performed significantly better in the no analogy condition when learning complex material. However, several conflicting results occurred, and a difference in processing strategy was proposed as a possible cause. Similarly, Gabel & Sherwood (1980) found that analogies helped lower ability, concrete thinkers to learn abstract chemistry concepts more than higher ability learners. They reasoned that high ability students were already able to think at the formal, abstract level; therefore, it was unnecessary to make formal concepts concrete for them.

All of the studies cited above looked at the use of analogies in the <u>recall</u> of specific facts only. Few studies have dealt with the use of analogies at the application, or use-a-generality level of instruction (Merrill, Reigeluth & Faust, 1979). The use-a-generality level requires the student to implement or apply a generality to new cases.

Curtis (Note 1) conducted a study using analogies with varying levels of enrichment to teach computer flowcharting to sixth graders. The results of this study failed to support the hypotheses that the richest analogies would result in the most learning and that all treatment groups would do better on the application-level posttest than the no analogy control group. There were, however, several methodological problems in this study. The content of the instruction was, in fact, concrete procedures for which analogies were unnecessary. In addition, the analogies were different for each of the procedures being taught, which may have diluted their power. Finally, the test lacked sufficient power to indicate any significance, since it consisted of only eight questions. Hence, there is a clear need for more research on the effects of analogies for use-a-generality level learning.

Analogy as a Motivational Strategy

When a learner is faced with complex materials on which s/he must intensely concentrate, strong motivation is usually a necessity (Dreistadt, 1969). Although subject matter is often intrinsically motivating, the way in which it is presented may be unappealing and uninteresting. The use of good instructional strategies, such as analogies, helps instruction to be both effective and efficient, while at the same time influencing student motivation (Reigeluth & Merrill, 1979). In turn, motivation influences both effort and performance (Keller, 1979). Reminding students of related knowledge that they have already acquired allows them to more easily comprehend that which they are about to learn, informs them of its relevance, and serves as a bridge to the new knowledge (Dick & Carey, 1978).

Keller (1983) advocates the use of analogies in his ARCS (Attention, Relevance, Confidence, Satisfaction) motivational design model to provide relevance and interestingness. The model identifies analogies as an important motivational tool for providing both concreteness and a linkage to past experiences. Analogies may help provide a motivational strategy which arouses interest by furnishing a bridge from new, unfamiliar or remote material, which can often be difficult and boring, to concrete, familiar material (Nelson, 1975; Dodge, 1980). McConnell (1978) suggests using analogies to help the learner become more personally involved with the content, thereby making it more important, useful and relevant. Although studies report higher enthusiasm for instruction that includes analogies (Smith et. al., 1980; Hayes & Tierney, 1980), evidence was collected strictly through informal observation.

In summary, there is a need for instructional design components which help students, particularly those of low ability, to learn abstract concepts and principles commonly used in science instruction. There is an equally important need to design and develop effective and appealing instructional materials for high ability students. Most studies investigating the use of analogies as instructional strategies use them on a recall rather than application level. In addition, few offer support for both their instructional and motivational value (Hayes & Tierney, 1980).

The present study sought to determine the effects of analogies of varying enrichment levels when used with abstract, unfamiliar and difficult content. Both the achievement and motivational effects were studied. In addition, it attempted to learn their effects on instruction at both the recall and application levels, using content consisting of both concepts and principles. On the basis of previous research, the following hypotheses were proposed:

1. The use of analogies will make difficult and abstract content more interesting and relevant to all students.
2. When given materials containing no analogy, a simple analogy, and an "enriched" (containing ground and limitation) analogy, all students will find the enriched analogy treatment more motivating than the other two treatments.
3. Average and lower ability students will achieve higher posttest and retention test scores on both the recall and application levels with the enriched analogy treatment than with the other two treatments; whereas, higher ability students will achieve higher posttest and retention test scores on both the recall and application levels with the simple or no analogy treatments than with the enriched analogy treatment.

METHODS

Subjects

The subjects of this study were 123 eighth-grade science students at a suburban middle school near Syracuse, New York. The school district is predominately white, middle to upper-middle class. Students consistently score above the national average on standardized reading and math achievement tests.

The students comprised five heterogeneous eighth-grade classes in the school. There were 71 females and 52 males. The general ability level of each student was rated by the science teacher who worked in a team-teaching situation which gave him sufficient knowledge of overall ability. Eighth grade students were selected because their science subject matter was considered to be at a complex enough level to lend itself well to the use of analogies.

Design

A posttest-only experimental design was used, with an immediate test and a delayed test. The delayed test was administered two weeks subsequent to the treatments. The statistical design was a 3 x 3 ANOVA on each dependent variable.

Instructional Task and Materials

An instructional booklet and a posttest booklet were distributed to each student. The instructional booklet contained one page of directions, six pages containing a different scientific topic of instruction followed by a motivational rating scale comparing all six topics.

The six instructional topics were alloys, cryogenics, isotopes, half-life, Ohm's Law, and the Doppler Effect. Since there were six topics, each student received two of them containing no analogies, two containing the analogies only, and two containing enriched analogies. All six topics were administered to each student, four on scientific concepts and two on scientific principles. Each contained a written expository passage.

The basic passage for each topic was identical in all treatments. The passages ranged in length from 89 words to 154 words, with an average of 119 words. They contained no examples or illustrations. Two of the passages are shown in Figure 1.

INSERT FIGURE 1 ABOUT HERE

<u>Treatments</u>

All materials were pilot tested for difficulty level and amount of time required to complete. There were three treatment groups for each of the six topics: no analogy, simple analogy, and enriched analogy. The basic passage remained identical for all three treaments. The no-analogy group contained only the basic passage. The simple-analogy treatment also contained a one-sentence statement of the analogy, while the enriched-analogy treatment contained the simple-analogy statement plus the grounds and limitations. The analogy was presented before the passage. The two enriched analogies for the passages in Figure 1 may be seen in Figure 2.

INSERT FIGURE 2 ABOUT HERE

Within each booklet, two topics contained no analogy; two topics contained a simple analogy; and two topics contained an enriched analogy. The way in which the treatments were assigned to topics and the sequence of the topics were both systematically varied as shown in Figure 3. One booklet was then randomly assigned to each student. Because all students received all treatments, there was no sampling bias overall.

INSERT FIGURE 3 ABOUT HERE

ALLOYS

An alloy is a solid mixture consisting of at least two metals. One of those metals makes up the chief part of the alloy. It is called its basic component. When these metals are mixed with each other in a molten form and then allowed to harden into a solid mass, they do not form distinct layers. They form a whole new substance.

Alloying metals produces changes in density, strength, hardness and melting point. Most alloys are more flexible than the pure metals from which they are made. Alloying may also produce changes in the conductivity of heat.

DOPPLER EFFECT

The pitch of a sound is determined by the length of its sound waves. The greater the wave length, the higher the pitch. A change in pitch can be caused by the Doppler Effect, named for its discoverer, Christian Doppler, a 19th century Austrian physicist.

The Doppler Effect is a change in wave length caused by the motion of a wave source. As a sound source approaches you, its movement crowds its sound waves together, causing a higher wave length or frequency and higher pitch. As a sound source passes you and moves away, the pitch of the sound you hear decreases. The sound waves are now farther apart. Both the frequency and pitch of the waves decrease.

The Doppler Effect may also be produced if you move toward the source of the sound. The pitch of the sound increases as you move toward the source and decreases as you move away from it.

Figure 1. Basic passages for topics 1 and 3.

An alloy is much like a cake you have baked. You take a bunch of different ingredients, mix them together and when finished a whole new substance is formed that is bigger, heavier and tastier (hopefully!) than any of the individual ingredients.

The Doppler Effect is much like what happens when you go out in a small boat. When you travel against the waves, they strike the boat with a relatively high frequency, resulting in quite a choppy ride. However when you travel with the waves, they catch up to the boat more slowly, hitting the boat with a relatively low frequency. However, the Doppler Effect involves sound waves rather than water waves.

Figure 2. Enriched analogies for topics 1 and 3.

	TOPIC 1	2	3	4	5	6
Student 1	N	S	E	N	S	E
Student 2	S	E	N	S	E	N
Student 3	E	N	S	E	N	S

	TOPICS					
Student 1	1	2	3	4	5	6
Student 2	2	3	1	5	6	4
Student 3	3	1	2	6	4	5

Figure 3. Systematic variation of topics and treatments for students
N = no analogy, S = simple analogy, E = enriched analogy

Tests and Measures

Following each passage, students completed motivation subscales 1-4 for rating the passage for interestingness and relevance using an Osgood differential scale (see Figure 4). Following all six passages, students were asked to rate the interestingness of each passage as it compared to the other passages.

INSERT FIGURE 4 ABOUT HERE

A posttest was administered directly following completion of the treatments. It consisted of 60 multiple-choice questions. There were five recall-level and five appication-level questions for each passage. Questions related to the basic passage only. Examples of recall-level and application-level test items for the passages in Figure 1 appear in Figure 5.

INSERT FIGURE 5 ABOUT HERE

A delayed (retention) test was administered two weeks after the treatment and posttest. It contained 30 multiple-choice questions. There were three recall-level and three application-level questions for each passage, similar but not identical to the posttest questions.

After completion of all treatments, the science teacher put an ability level rating for each student (1=high, 2=average, 3=low) on each posttest.

Procedures

Before conducting the study, a series of meetings was held between the researcher and the eighth grade science teacher in order to select appropriate content and design materials that contained concrete, familiar analogies for abstract, unfamiliar concepts and principles. In addition, to maintain a natural classroom context for the students, the science teacher administered all treatments without the researcher present.

When the students arrived for their regular science class, each was given an instruction booklet and a posttest. The order of the topics in each booklet, was randomized by groups of three; i.e., the first group contained passages on alloys, cryogenics, and Ohm's Law, while the second group contained passages on half-life, isotopes, and the Doppler Effect.

Students were instructed to read each passage and complete each motivation scale. After completing the instruction booklet they closed it and turned it upside down on their desks. Then

Please circle the number that best describes the way you feel about what you have just read.

I found the subject of this passage to be:

1	2	3	4
Very boring	Somewhat boring	Somewhat interesting	Very interesting

I thought that the way this passage was written made it:

1	2	3	4
Very interesting	Somewhat interesting	Somewhat boring	Very boring

When something is relevant, it means that it is related to something else you have learned or know. This reading was:

1	2	3	4
Extremely relevant	Somewhat relevant	Not very relevant	Not at all relevant

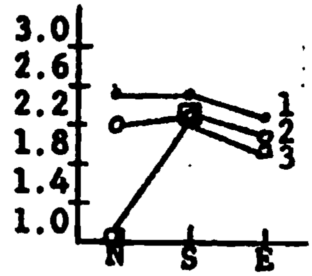
After reading this passage, I would like to learn more about ALLOYS:

1	2	3	4
Not at all	Very little	Somewhat	Very much

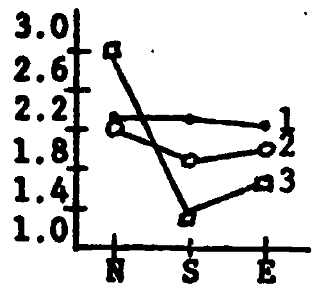
Figure 4. Motivation subscales 1-4 for topic 1.

Figure 5
Significant Interactions for Achievement Measures

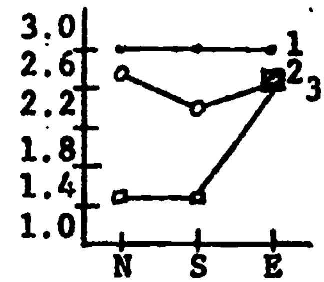
Analogy 5; Half-life Delayed Test
Recall



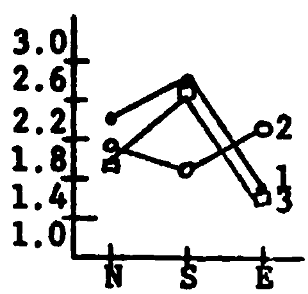
Analogy 1; Alloys Delayed Test
Application



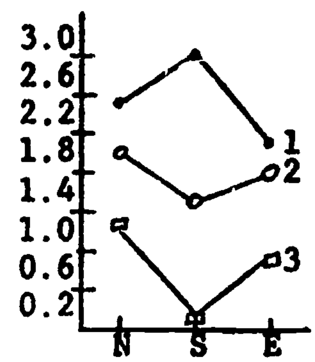
Analogy 5; Half-Life Delayed Test
Application



Analogy 4; Ohm's Law Delayed Test
Application



Analogy 6; Isotopes Delayed Test
Application



Key:
- N = No analogy treatment
- S = Simple analogy treatment
- E = Enriched analogy treatment
- 1 = High ability students
- 2 = Average ability students
- 3 = Low ability students

they were directed to open the test booklet and complete the questions in the remainder of the forty minute period. They were not allowed to refer to the instruction booklet after beginning the test.

Two weeks later, the science teacher administered the delayed test. Students were given about half a class period in which to finish.

RESULTS

The following are the results on the two sets of dependent variables---motivation and achievement.

Motivation Measures

All 123 students completed the motivation rating scale for each of the six topics. It consisted of five subscales: Interest In Topic, Interest In Format, Relevance, Interest In Learning More About Topic, and Interest Level Compared To Other Topics. In addition, a total motivation score consisting of the sum of the five subscales was determined for each topic. The F ratios and significance levels for all six motivation measures are summarized in Table 1, and the means are reported in Table 2. Whenever a significance level of .05 was reached, Duncan's Multiple Range Tests was used to identify which of the three means differed significantly (see Table 3). The topics are listed in order of difficulty (from least to most) in all tables. Since ability main effects were not of interest in this study, they are not reported.

INSERT TABLES 1, 2 & 3 ABOUT HERE

It was stated in hypotheses 1 and 2 that the use of analogies would make difficult and abstract content more interesting and that the enriched analogy would provide the most motivating instruction. For the subscale, Interest In Topic, three of the six topics had significant or near significant results. For Topic 1, the simple analogy was rated higher than both other treatments, while in Topic 5, the enriched analogy treatment scored significantly higher than the other two groups. In Topic 2, the enriched analogy treatment approached significance over the no analogy group.

For Interest In Format, three of the six topics also had significant or near-significant results. For topic 2, the enriched analogy approached significance over no analogy, but for topic 3 the no analogy treatment approached significance over the simple analogy. For topic 5, the enriched analogy treatment scored significantly higher at the .0005 level than either of the

Table 1
Significance Levels on All Motivation Measures for All Topics

	Topic 1 Alloys		Topic 2 Cryogenics		Topic 3 Doppler Effect		Topic 4 Ohm's Law		Topic 5 Half-life		Topic 6 Isotopes	
	F	p	F	p	F	p	F	p	F	p	F	p
Interest in topic:												
Analogy	4.50	.01**	2.58	.08	1.13	--	1.48	--	4.88	.009**	0.64	--
Analogy x Ability	0.22	--	1.10	--	0.23	--	0.32	--	1.52	---	0.53	--
Interest in format:												
Analogy	2.07	--	2.85	.06	2.63	.08	1.69	--	8.18	.0005**	2.08	--
Analogy x Ability	1.07	--	0.30	--	0.66	--	0.73	--	1.80	----	0.71	--
Relevance:												
Analogy	1.24	--	1.08	--	0.32	--	3.35	.04*	1.57	--	0.03	--
Analogy x Ability	0.94	--	1.28	--	1.25	--	0.21	--	0.31	--	0.68	--
Interest in learning more about topic:												
Analogy	3.65	.03*	1.62	--	0.75	--	0.28	--	3.10	.05*	1.08	--
Analogy x Ability	0.35	--	1.10	--	0.39	--	0.52	--	1.62	--	1.68	--
Interest level compared to other topics:												
Analogy	5.81	.004**	0.35	--	0.18	--	0.40	--	2.68	.07	1.77	--
Analogy x Ability	0.43	---	2.94	.02*	0.40	--	0.25	--	0.63	--	0.32	--
Total motivation:												
Analogy	3.35	.04*	2.57	.08	0.91	--	1.79	--	5.79	.004**	1.05	--
Analogy x Ability	0.42	--	0.70	--	0.14	--	0.41	--	1.32	---	0.17	--

df for all analogies (8, 122)

*$p \leq .05$
**$p \leq .01$

Table 2

Means, Standard Deviations and n's for Motivation Measures

		No Analogy Mean(SD)	n	Simple Analogy Mean(SD)	n	Enriched Analogy Mean (SD)	n
Interest in Topic:	Alloys **	2.34(0.79)	41	2.81(0.75)	41	2.44(0.63)	41
	Cryogenics+	2.70(0.69)	40	2.81(0.81)	41	3.05(0.62)	42
	Doppler	2.91(0.73)	42	2.68(0.66)	40	2.73(0.74)	41
	Ohm's	2.31(0.81)	42	2.02(0.72)	41	2.25(0.81)	40
	Half-life**	2.70(0.94)	40	2.56(0.78)	41	3.10(0.73)	42
	Isotopes	2.24(0.86)	41	2.45(0.74)	42	2.35(0.92)	40
Interest in format:	Alloys	2.54(0.64)	41	2.85(0.79)	41	2.66(0.69)	41
	Cryogenics+	2.48(0.72)	40	2.76(0.83)	41	2.86(0.65)	42
	Doppler +	2.95(0.70)	42	2.55(0.78)	40	2.73(0.87)	41
	Ohm's	2.17(0.73)	42	2.07(0.82)	41	2.38(0.71)	40
	Half-life**	2.68(0.86)	40	2.37(0.80)	41	3.07(0.75)	42
	Isotopes	2.15(0.88)	41	2.36(0.69)	42	2.53(0.92)	40
Relevance:	Alloys	2.37(0.89)	41	2.44(0.90)	41	2.66(0.83)	41
	Cryogenics	2.28(0.88)	40	2.34(0.83)	41	2.52(0.67)	42
	Doppler	2.36(0.91)	42	2.20(0.94)	40	2.32(1.01)	41
	Ohm's *	2.38(0.76)	42	2.22(0.91)	41	2.73(0.96)	40
	Half-life	2.25(0.93)	40	2.10(0.92)	41	2.45(0.86)	42
	Isotopes	2.20(0.95)	41	2.24(0.79)	42	2.25(0.81)	40
Interest in learning more about topic:	Alloys *	2.17(0.86)	41	2.66(0.91)	41	2.24(0.83)	41
	Cryogenics	2.40(0.93)	40	2.51(0.90)	41	2.74(0.77)	42
	Doppler	2.71(0.86)	42	2.48(0.88)	40	2.59(0.89)	41
	Ohm's	2.14(0.78)	42	2.00(0.87)	41	2.05(0.96)	40
	Half-life *	2.55(0.93)	40	2.39(0.97)	41	2.88(0.86)	42
	Isotopes	2.07(0.88)	41	2.33(0.82)	42	2.30(0.94)	40
Interest Level Compared to Other Topics:	Alloys **	2.49(0.81)	41	2.83(0.83)	41	2.22(0.79)	41
	Cryogenics	2.73(0.78)	40	2.85(0.88)	41	2.86(0.81)	42
	Doppler	2.64(1.01)	42	2.65(0.80)	40	2.76(0.99)	41
	Ohm's	2.14(0.93)	42	2.02(0.79)	41	2.20(0.97)	40
	Half-life +	2.75(0.93)	40	2.56(0.90)	41	3.00(0.73)	40
	Isotopes	2.05(0.92)	41	2.41(0.77)	42	2.33(0.97)	40
Total Motivation:	Alloys *	11.95(2.65)	41	13.44(3.27)	41	12.17(2.32)	41
	Cryogenics+	12.68(2.45)	40	13.27(3.07)	41	14.02(2.46)	42
	Doppler	13.55(3.05)	42	12.60(2.79)	40	13.15(3.57)	41
	Ohm's	11.14(2.83)	42	10.34(3.07)	41	11.63(3.26)	40
	Half-life**	12.93(3.68)	40	11.98(3.44)	41	14.50(3.09)	42
	Isotopes	10.85(3.48)	40	11.76(2.60)	42	11.83 (3.80)	40

Key: + $p < .10$ (approached significance)
* $p < .05$
** $p < .01$

Table 3

Duncan's Multiple Range Test Results For All Main Effects Reaching or Approaching Significance on Motivation Measures

Interest in Topic

Topic 1: Alloys

Simple Analogy	Enriched Analogy	No Analogy	F	p
2.80	2.44	2.34	4.50	.01

Topic 2: Cryogenics

Enriched Analogy	Simple Analogy	No Analogy	F	p
3.05	2.80	2.70	2.58	.08

Topic 5: Half-life

Enriched Analogy	No Analogy	Simple Analogy	F	p
3.10	2.70	2.56	4.88	.009

Interest in Format

Topic 2: Cryogenics

Enriched Analogy	Simple Analogy	No Analogy	F	p
2.86	2.76	2.48	2.85	.06

Topic 3: Doppler Effect

No Analogy	Enriched Analogy	Simple Analogy	F	p
2.95	2.73	2.55	2.63	.08

Topic 5: Half-life

Enriched Analogy	No Analogy	Simple Analogy	F	p
3.07	2.68	2.37	8.18	.0005

Relevance

Topic 4: Ohm's Law

Enriched Analogy	No analogy	Simple Analogy	F	p
2.73	2.38	2.12	3.35	.04

(Cont.)

Table 3 (Cont.)

Interest in Learning More About Topic

Topic 1: Alloys

Simple Analogy	Enriched Analogy	No Analogy	F	p
2.66	2.24	2.17	3.65	.03

Topic 5: Half-life

Enriched Analogy	No Analogy	Simple Analogy	F	p
2.88	2.55	2.39	3.10	.05

Interest Compared to Other Topics

Topic 1: Alloys

Simple Analogy	No Analogy	Enriched Analogy	F	p
2.83	2.49	2.22	5.81	.004

Topic 5: Half-life

Enriched Analogy	No Analogy	Simple Analogy	F	p
3.00	2.75	2.56	2.68	.07

Total Motivation

Topic 1: Alloys

Simple Analogy	Enriched Analogy	No Analogy	F	p
13.44	12.17	11.95	3.35	.04

Topic 2: Cryogenics

Enriched Analogy	Simple Analogy	No Analogy	F	p
14.02	13.27	12.68	2.57	.08

Topic 5: Half-life

Enriched Analogy	No Analogy	Simple Analogy	F	p
14.50	12.93	11.98	5.79	.00

Key: Means that are connected by a line are not significantly different from each other.

other two treatments. The only topic to reach significance on the subscale, Relevance, was topic 4, which again placed the enriched analogy treatment significantly higher than the simple analogy.

For Interest In Learning More About Topic, subjects rated the simple analogy treatment significantly higher than both other treatments for topic 1, while the enriched analogy was significantly higher than the simple analogy for topic 5. For Interest Compared To Other Topics, the simple analogy was significantly higher than the enriched analogy for topic 1; while the enriched analogy approached significance over the simple analogy treatment for topic 5.

Finally, for the Total Motivation measure for topic 1 the simple analogy was significantly higher than both other groups. For topic 2, the enriched analogy approached significance over the no analogy; and for topic 5, the enriched analogy was significantly higher than both other treatments.

Of the fourteen motivation measures that reached or approached significance, thirteen rated one of the analogy treatments significantly highest. In addition, for means for all measures (including those that did not reach significance), five of the six topics rated one of the analogy treatments highest for all five subscales and Total Motivation. Hence, hypotheses 1 and 2 were partially supported.

Achievement Measures

A total of 94 students completed the posttest. Thirty-one students were unable to complete the posttest, either due to lack of time or knowledge. Of those 31, three were high ability, fifteen were average ability and thirteen were low ability students. A total of 111 students completed the delayed test. Of the 31 who failed to complete the posttest, a total of 26 did complete the delayed test. Of the five who were unable to complete either test, three were of average ability and two were low ability students. In addition, three students who completed the delayed test but had not been present for the treatments were eliminated from the analysis.

Both the posttest and the delayed test were comprised of items on two different levels: recall and application. A separate 3 x 3 ANOVA was performed for each level of performance and the total posttest score. The F-ratios and significance levels are presented in Table 4 and the means are presented in Table 5. Wherever there was significance, a Duncan's Multiple Range Test was used to determine which of the three means differed significantly (see Table 6).

INSERT TABLES 4, 5 & 6 ABOUT HERE

Table 4

Significance Levels on All Achievement Measures for All Topics

	Topic 1 Alloys		Topic 2 Cryogenics		Topic 3 Doppler Effect		Topic 4 Ohm's Law		Topic 5 Half Life		Topic 6 Isotopes	
	F	p	F	p	F	p	F	p	F	p	F	p
Posttest Recall: Analogy	0.18	---	0.50	---	0.27	---	1.12	---	1.60	---	1.12	---
Analogy x Ability	0.78	---	1.39	---	0.48	---	1.16	---	0.43	---	0.67	---
Posttest Application: Analogy	2.58	.08	0.60	---	1.46	---	0.14	---	0.98	---	1.15	---
Analogy x Ability	0.40	---	0.27	---	0.87	---	0.22	---	0.22	---	0.75	---
Posttest Total: Analogy	0.37	---	0.46	---	0.18	---	0.56	---	0.98	---	1.46	---
Analogy x Ability	0.38	---	0.70	---	1.15	---	0.64	---	0.31	---	0.67	---
Delayed Test Recall: Analogy	3.83	.02*	0.04	---	1.77	---	1.51	---	2.46	.09	0.05	---
Analogy x Ability	1.10	---	0.60	---	1.52	---	0.85	---	2.21	.07	0.60	---
Delayed Test Application: Analogy	2.73	.07	0.32	---	0.95	---	3.49	.03*	0.89	---	2.22	---
Analogy x Ability	2.26	.06	0.94	---	0.86	---	2.41	.05*	3.93	.005**	2.31	06

df for all posttest achievement measures (9,95)
df for all delayed test achievement measures (9, 110)
*p ≤ .05
**p ≤ .01

Table 5
Means, Standard Deviations and n's for All Achievement Measures

		No Analogy		Simple Analogy		Enriched Analogy	
		Mean (SD)	n	Mean (SD)	n	Mean (SD)	n
Posttest Recall:	Alloys	4.12(0.91)	34	3.97(1.10)	31	4.07(1.31)	29
	Cryogenics	4.36(0.91)	28	4.18(0.94)	34	4.19(0.86)	32
	Doppler	3.59(1.21)	32	3.39(1.10)	28	3.53(0.96)	34
	Ohm's	3.94(1.29)	32	4.31(1.14)	29	3.91(1.26)	33
	Half-life	4.14(0.80)	28	3.74(1.21)	34	3.97(0.86)	32
	Isotopes	3.50(1.26)	34	3.09(1.55)	32	3.07(1.30)	28
Posttest Applic:	Alloys	4.47([illegible].71)	34	3.90(1.33)	31	4.03(1.27)	29
	Cryogenics	[illegible](1.65)	28	3.94(1.23)	34	3.63(1.52)	32
	Doppler	4.00(1.02)	32	4.36(0.73)	28	4.24(0.86)	34
	Ohm's	4.03(1.20)	32	4.17(1.07)	29	4.12(1.19)	33
	Half-life	3.96(1.35)	28	3.85(1.40)	34	3.53(1.39)	32
	Isotopes	3.97(1.31)	34	3.56(1.39)	32	3.57(1.45)	28
Posttest Total:	Alloys	8.59(1.26)	34	7.87(2.01)	31	8.10(2.24)	29
	Cryogenics	8.14(2.31)	28	8.15(1.86)	34	7.81(2.04)	32
	Doppler	7.59(1.74)	32	7.[illegible](1.51)	28	7.79(1.39)	34
	Ohm's	7.97(2.21)	32	8.48(2.12)	29	8.03(2.34)	33
	Half-life	8.12(1.81)	28	7.59(2.36)	34	7.50(1.85)	32
	Isotopes	7.47(2.30)	34	6.66(2.66)	32	6.68(2.41)	28
Delayed Test Recall:	Alloys*	2.59(0.60)	39	2.15(1.05)	34	2.50(0.73)	38
	Cryogenics	2.30(0.88)	37	2.33(0.90)	39	2.34(0.84)	35
	Doppler	2.86(0.36)	35	2.62(0.72)	37	2.77(0.49)	39
	Ohm's	2.40(0.78)	35	2.11(0.86)	38	2.18(0.80)	38
	Half-life	2.00(0.91)	37	2.39(0.67)	39	2.17(0.86)	35
	Isotopes	1.54(0.97)	39	1.54(0.95)	35	1.49(0.84)	37
Delayed Test Applic:	Alloys+	2.28(0.61)	39	1.91(0.93)	34	1.97(0.75)	38
	Cryogenics	2.49(0.80)	37	2.59(0.75)	39	2.60(0.78)	35
	Doppler	2.63(0.77)	35	2.73(0.65)	37	2.62(0.45)	39
	Ohm's*	2.54(0.78)	35	2.45(0.86)	38	2.79(0.53)	38
	Half-life	2.16(0.87)	37	2.23(0.90)	39	1.97(0.95)	35
	Isotopes	2.15(0.99)	39	1.83(1.22)	35	1.70(1.20)	37

+ $p \leq .10$ (approached significance)
* $p \leq .05$
** $p \leq .01$

Table 6

Duncan's Multiple Range Test Results For All Main Effects Reaching or Approaching Significance on Achievement Measures

Posttest Appication

Topic 1: Alloys

No analogy	Enriched analogy	Simple analogy	F	p
4.47	4.03	3.87	2.58	.08

Delayed Test Recall

Topic 1: Alloys

No analogy	Enriched analogy	Simple analogy	F	p
2.59	2.50	2.14	3.83	.02

Delayed Test Application

Topic 1: Alloys

No analogy	Enriched analogy	Simple analogy	F	p
2.28	1.97	191	2.73	.07

Topic 4: Ohm's Law

Enriched analogy	No analogy	Simple analogy	F	p
2.79	2.54	2.45	3.49	.03

Key: Means that are connected by a line are not significantly differer from each other.

There were no significant main effects reached on any of the immediate posttests (recall, application, or total). However, one of the six main effects approached significance for the application-level posttest for topic 1, and the no analogy mean was significantly higher than the simple analogy mean for the comparison. Similarly, for topic 1 on both the recall delayed test and the application delayed test, the no analogy treatment group scored significantly or near-significantly higher than the simple analogy group. However, on the recall delayed test for topic 1, the enriched analogy treatment also scored significantly higher than the simple analogy. Finally, on the delayed application test for topic 4, the enriched analogy treatment group scored significantly higher than the simple analogy group but not the no analogy group.

There were no significant interaction effects for analogy and ability for the three posttest measures. However, for the delayed test one of the six topics approached significance for the recall delayed test, while four of the six topics reached or approached a significant interaction for the application delayed test. The means of those interactions are reported in Table 7 and illustrated in Figure 5.

INSERT TABLE 7 AND FIGURE 5 ABOUT HERE

It was further hypothesized that higher ability students would achieve higher scores on the no analogy and simple analogy treatments, while average and lower ability students would achieve higher scores with the enriched analogy treatment. On all five interactions reported in Table 7, high ability students achieved highest on the no analogy or simple analogy treatments, as was hypothesized. However, the lower and average ability students scored significantly higher on the enriched analogy treatment for only one of the five tests that reached significance. Therefore Hypothesis 3 is only partially supported.

DISCUSSION

Since beginning our systematic research on the use of analogies in instruction, we have been impressed at the number of analogies used in textbooks, classroom lectures, and everyday conversation. It is obvious by the very commonness of their utilization that many teachers consider analogies to be important and effective contributors to learning and communication. Hence, we believe that the important question is not "are analogies useful instructional strategies?" Rather, it is "when are analogies useful?"

Based on personal experience and conversations with people who use analogies, we propose that analogies increase understand-

Table 7
Delayed Test Achievement Measure Significant Interaction Effects

Key:

mean (S.D.) n

1 = High ability
2 = Average ability
3 = Low ability

N = No analogy
S = Simple analogy
E = Enriched analogy

Analogy 3: Half-life Delayed Test Recall

	1	2	3
N	2.50 (0.67) 12	2.19 (0.66) 16	1.00 (0.87) 9
S	2.54 (0.52) 13	2.30 (0.77) 16	2.33 (0.58) 3
E	2.33 (0.65) 12	2.30 (0.89) 16	2.00 (1.16) 7

Analogy 1; Alloys Delayed Test Application

	1	2	3
N	2.31 (0.63) 13	2.17 (0.58) 23	3.00 (0.00) 3
S	2.27 (0.47) 11	1.94 (1.00) 16	1.27 (1.11) 7
E	2.23 (0.60) 13	2.00 (0.52) 16	1.27 (1.13) 9

Analogy 4; Ohm's Law Delayed Test Application

	1	2	3
N	3.00 (0.00) 11	2.75 (0.45) 16	1.50 (0.93) 8
S	3.00 (0.00) 14	2.44 (0.81) 16	1.50 (0.93) 8
E	3.00 (0.00) 12	2.70 (0.64) 23	2.67 (0.58) 3

Analogy 5; Half-life Delayed Test Application

	1	2	3
N	2.42 (0.90) 12	2.13 (0.72) 16	1.89 (1.05) 9
S	2.77 (0.44) 13	1.87 (0.97) 16	2.67 (0.58) 3
E	1.67 (0.89) 12	2.38 (0.72) 16	1.57 (1.27) 7

Analogy 6; Isotopes Delayed Test Application

	1	2	3
N	2.46 (0.88) 13	2.04 (1.02) 23	1.17 (1.16) 3
S	3.00 (0.00) 12	1.63 (1.03) 16	0.29 (0.49) 7
E	2.17 (1.19) 12	1.81 (1.11) 16	0.89 (1.05) 9

When metals are mixed together to create an alloy, they form (distinct layers, separate metals, a whole new substance).

An example of an alloy is (oxygen, hydrogen, bronze, sodium).

The Doppler Effect is a change in wave frequency caused by the (motion, stability, location) of the wave source or observer.

An example of the Doppler Effect is (shouting through a megaphone, the sound of a bullet whizzing past your ear, an echo, the sound of splashing waves).

Figure 5. Sample recall and application level questions for topics 1 and 3 from the immediate posttest.

ing by creating memory linkages and that they therefore promote a type of learning that may be qualitatively different than either recall or application. Hence, the type of measures used in this study were probably not very sensitive to that difference. But more importantly, the implication is that the decision as to whether or not to use an analogy should be based in part on the kind of learning desired. The results of this study indicate that analogies may not be very useful for either rote remember-level learning or application-level learning. However, they may often be very useful for creating linkages within memory that would have an important influence on meaningful understanding, long-term retention, far transfer, problem solving, and the skill of analogical reasoning.

Furthermore, analogies may not be useful for all kinds of topics. It seems likely that such factors as abstractness, unfamiliarity, and difficulty of the topic may influence whether or not an analogy would be useful in the instruction. It is not clear whether or not these three factors are parallel attributes, although they were equated in this study. Ways of better assessing them separately might contribute greatly to an understanding of the kinds of topics for which analogies are likely to be useful. Finally, we expect that not all analogies (vehicles) are equally useful for a topic that can benefit from an analogy. It seems likely that such factors as concreteness, familiarity, and degree of similarity with the topic may influence whether or not an analogy would be useful in the instruction. Hence, future research could also benefit from the development and use of better ways of measuring these characteristics of an analogy.

The ability of analogies to stimulate the creation of cognitive visual images and provide an important strategy for problem solving needs to be studied, and the development of more precise measurement instruments to determine the nature and scope of these qualitative differences should be carried out.

With these considerations in mind, let's proceed to a discussion of the results on each hypothesis.

<u>Hypothesis #1:</u> <u>The use of analogies will make difficult and abstract content more interesting and relevant to all students.</u>

This hypothesis was partially confirmed. The results of this study indicate that the inclusion of an analogy in difficult and abstract content will often increase interest in that content. For four of the six topics, the presence of an analogy improved motivation on at least one of the motivation measures. For one of the two remaining topics, there was no significance, while for the other remaining topic, the <u>no analogy</u> treatment approached significance over the simple analogy.

For three of the six topics, the Total Motivation score reached or approached significance in favor of one of the analogy treatments. Five of the six actual means for Total Motivation were highest for either the simple (1) or enriched (4) analogy groups.

Of the 30 motivation tests (six topics with five motivation subscales each), a total of 11 were significant or approached significance. Of those 11, six rated an analogy treatment more motivating than the no analogy treatment. In addition, for the 30 subscale means, 24 were highest for one of the analogy treatments.

For topic 3 (the Doppler Effect), students rated the no analogy treatment most motivating on four of the five subscales. However, the differences did not reach significance. They merely approached significance at the .08 level. If, in fact, real differences existed in this case, they might be attributable to either or both of the following reasons: either students found the passage already interesting and the analogy distracted from it, or the analogy itself may not have been understood, thereby making it uninteresting or the source of confusion.

Finally, it appears that analogies for topics 1 and 5 worked very well to increase motivation, while for topics 3 and 6 they had little or no effect. This may indicate that the interest in some topics may be greatly enhanced by the addition of an analogy, while others may not.

Hypothesis #2: Students will find an enriched analogy more motivating than a simple or no analogy.

It was found that for some motivation measures on some topics there were significant differences between the enriched analogy and the simple analogy but not the control group. The simple analogy group was significantly higher than the enriched analogy group on four motivation measures, while the enriched analogy group was significantly higher than the simple analogy group on six motivation measures. It was only for topic 5 (half-life) that the enriched analogy treatment approached or reached significance over both other treatments. Therefore, this study failed to confirm hypothesis #2.

However, on Total Motivation the actual mean scores for the enriched analogy treatment were highest for four of the six topics, which may indicate a preference (although only significant for topic 5) for the treatment containing the enriched analogy. Further research is needed to determine when information about the grounds and limitations of the analogous relationship is appropriate and motivational and when it is not.

Hypothesis #3: Average and lower ability students will achieve more when given instruction containing an enriched analogy, while higher ability students will achieve more with a simple or no analogy.

The prediction that no main effects would reach significance was supported by the results of this study because most of the significant main effects were coupled with significant interaction effects. However, the nature of the interaction effects was not consistent across analogies.

There were no significant interactions between analogy and ability on the immediate posttest (either the recall or application level). In contrast, significance was approached or reached on five of the 12 delayed achievement test measures---one on the recall level and four on the application level. Of those five, average and low ability students only achieved higher posttest scores with the enriched analogy treatment for one measure (one topic).

However, for high ability students, the no analogy and simple analogy treatment means were higher than the enriched analogy means for four of the five measures obtaining significance. These four measures were all delayed application-level tests. For the fifth measure, the high ability students' means were equal for all three treatments.

In this study, the presence of analogies did not seem to help any students learn the content. Therefore, hypothesis #3 failed to be supported in reference to average and low ability students and was partially supported for high ability students. It must again be emphasized that the lack of significant results may be due to the measures not being sensitive to the qualitatively different kind of learning that may result from analogies. We recommend that future research on analogies utilizes more appropriate measures to assess the contributions analogies make to learning (see earlier discussion).

In addition, a more normally distributed sample is desirable when studying the effect of analogies on all ability levels. In this study, a disproportionately smaller number of low ability students caused some cell sizes for the interaction effects to fall below 10.

One final comment is in order about the interactions which reached significance, especially considering the concern for equity in education. All three ability groups in the enriched analogy treatment appear to have achieved more nearly equal scores than with the simple or no analogy treatments. Proponents of equity in education may find analogies a useful tool toward achieving that equity among various ability groups.

In conclusion, the following recommendations are made for using analogies in instruction:

1. An analogy is generally useful for making instruction more interesting to the learner.
2. An analogy is more useful for application-level learning than recall-level learning, and its effects are more pronounced over time. However, testing the effectiveness of the analogy must be on a level other than strictly application or recall.
3. The analogy its lf must be within the knowledge of the learner before it can be used to learn new information. Otherwise it may cause confusion or misunderstanding. If the analogy is unknown to the learner, it should be taught before being used.

Reference Notes

Note 1. Curtis, R. V. The use of analogies in the instruction of concepts at the application level. Unpublished paper, Syracuse University, 1982.

References

Bell, M. S. and Gagne, E. D. Individual differences and the use of analogies in technical text. ERIC, 1979. (ED 183 617)

Bielinski, L. S. The effect of analogy-structured teaching on student achievement in ninth-grade physical science. Dissertation Abstracts International, 1973, 4855-6A.

Dick, W. and Carey, L. The systematic design of instruction. Glenview, IL: Scott, Foresman and Company, 1978.

Dodge, B. J. Learner interest and instructional design: A conceptual model. Paper presented at the annual convention of the Association for Educational Communications and Technology, Denver, April, 1980. (ERIC, ED 194 066)

Dreistadt, R. The use of analogies and incubation in obtaining insights in creative problem solving. The Journal of Psychology, 1969, 71 159-175.

Gabel, D. L. and Sherwood, R. D. Effect of using analogies on chemistry achievement according to Piagetian level. Science Education, 1980 64 (5), 709-716.

Gentner, D. The structure of analogical models in science. Washington, DC: Office of Naval Research, July, 1980. (ERIC, ED 193 011)

Hayes, D. A. and Tierney, R. J. Increasing background knowledge through analogy: Its effect upon comprehension and learning. Washington, DC: NIE, October, 1980. (ERIC, ED L95 953)

Jorgensen, S. Using analogies to develop conceptual abilities. Paper presented at the annual meeting of the Association for Educational Communications and Technology, Denver, April, 1980. (ERIC, ED 192 820)

Keller, J. M. Motivation and instructional design: A theoretical perspective. Journal of Instructional Development, 1979, 2 (4), 26-34.

Keller, J. M. Motivational design of instruction. In C. M. Reigeluth (Ed.) Instructional Design Theories and Models: An Overview of Their Current Status. Hillsdale, NJ: Lawrence Erlbaum, 1983.

McConnell, J. V. Confessions of a textbook writer. American Psychologist, February 1978, 159-169.

McCroskey, J. C. and Combs, W. H. The effects of the use of analogy on attitude change and source credibility. The Journal of Communication, 1969, 19, 333-339.

Merrill, M. D., Reigeluth, C. M., and Faust, G. W. The instructional quality profile: A curriculum evaluation and design tool. In H. F. O'Neil, Jr. (Ed.) Procedures for Instructional Systems Development. New York: Academic Press, 1979.

Nelson, R. F. Use of analogy as a learning-teaching tool. Journal of Geography, February, 1975, 83-86.
Ortony, A. Beyond literal similarity. Psychological Review, 1979 86 (3), 161-179.
Pylyshyn, Z. W. What the mind's eye tells the mind's brain: A critique of mental imagery. Psychological Bulletin, 1973, 80 (1), 1-22.
Reigeluth, C. M. Meaningfulness and instruction; Relating what is being learned to what a student knows. IDD&E Working Paper No. 1, Syracuse University, 1980.
Reigeluth, C. M. and Merrill, M. D. Classes of instructional variables. Educational Technology, March, 1979, 5-24.
Reigeluth, C. M. and Stein, F. The elaboration theory of instruction. In C. M. Reigeluth (Ed.) Instructional design theories and models: An overview of their current status. Hillsdale, NJ: Lawrence Erlbaum, 1983.
Rigney, J. W. Learning strategies: A theoretical perspective. In H. F. O'Neil, Jr. (Ed.) Learning Strategies. New York: Academic Press, 1978.
Rigney, J. W. and Lutz, K. A. Effect of graphic analogies of concepts in chemistry on learning and attitude. Journal of Educational Psychology, 1976, 68 (3), 306-311.
Royer, J. M. and Cable, G. W. Illustrations, analogies and facilitative transfer in prose learning. Journal of Educational Psychology, 1976, 68 (2), 205-209.
Rumelhart, D. E. and Norman, D. A. Analogical processes in learning. In J. R. Anderson (Ed.) Learning and Cognition, in press.
Sari, I. F. and Reigeluth, C. M. Writing and evaluating textbooks: Contributions from instructional theory. In D. Jonassen (Ed.) Technology of text: Principles for structuring, designing and displaying text. Englewood Cliffs, NJ: Educational Technology Publications, 1982.
Smith, D. A. et al. The effect of narrative analogies on the acquisition of passages describing scientific mechanisms. Paper presented at the annual meeting of the Western Psychological Association, Honolulu, May 5-9, 1980. (ERIC ED 189 605)
Smith, F. A. and Wilson, J. D. Electrical circuits and water analogies. The Physics Teacher, October, 1974, 396-399.
Souder, L. G. Analogies help! Industrial Education, May/June, 1981, 36.
Sternberg, R. J. Component processes in analogical reasoning. Psychological Review, 1977, 84 (4), 353-378.
Verbrugge, R. R. and McCarrell, N. S. Metaphoric comprehension: Studies in reminding and resembling. Cognitive Psychology, 1977, 9, 494-533.