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THE USE OF ANALOGIES IN WRITTEN TEXT

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ABSTRACT

Although analogies are commonly used in instruction, little is known for whom and under what conditions they are most beneficial. This descriptive study investigated the use of analogies in the design of instructional text. Twenty-six science textbooks, ranging from elementary to post-secondary level, were analyzed for the presence of analogies. A total of 216 analogies were identified and organized into several categories which were then synthesized into a classification system. Based on these results, a set of prescriptions regarding the nature and characteristics of the vehicle and topic and their relationship, the presence and amount of grounds and limitations and the appropriate format and position for an analogy in written instruction are proposed. Recommendations for additional research are suggested.

Introduction

Analogies have probably existed since the early development of language. Their use today is extraordinarily popular and frequent. Hardly a day elapses without encountering one – either in print (from Plato to Einstein to Agatha Christie) or in everyday spoken language. In fact, language and thinking themselves may be thought of as records of analogous experiences (Diack, 1966). Every new experience is related to a set of analogous experiences that help us understand it.

Analogical thinking occurs under either of two conditions: (1) when two or more things are similar in at least one way and the assumption is made that they probably have other commonalities; or (2) when a person draws a conclusion about an unknown factor on the basis of its resemblance to a factor that is familiar or known (Good, 1981). The importance of taking new information and relating it to a larger and more meaningful context of organized knowledge has been strongly advocated (Ausubel, 1969; Gagné and Briggs, 1974). This may be accomplished by providing cues to link new knowledge to that which was previously acquired, and analogies are one way of providing that link (Reigeluth, 1983a). This research focused on the ways in which analogies are used in the design of instructional text.

To increase the effectiveness of communication, words with meaningful referents are needed (Dale, 1969). In other words, good instruction must include appropriate amounts of concrete or direct experiences to prepare the learner for more abstract, complex experiences. Analogies are one way of providing a concrete experience.

In instructional settings, analogies help bridge the gap between an idea and direct, personal experience when that idea cannot be readily experienced (Carroll, 1974). Analogies evoke mental images within the learner's realm of personal knowledge.

Analogies may cause visual thinking to occur; i.e., mental images or models are formed when something more physically concrete is unavailable (McKim, 1980). They lead us to "see" a relationship in terms of "a picture" in order to compare and contrast various levels of abstraction and generality (Brown and Olmstead, 1962).

Analogies provide an explicit comparison between one area of knowledge and another area of knowledge that is completely outside the first (Ortony, 1979). It is critical that an instructionally useful analogy contain at least one element that is within the prior knowledge of the learner, while the other is distinctly unfamiliar (Reigeluth, 1983b). The familiar content is termed the *vehicle* and the new content is termed the *topic* (Ortony, 1979; Verbrugge and McCarrell, 1977).

The danger in using analogies occurs when either the analogy is carried too far or the vehicle is unknown to the learner. When the analogy is carried too far, that is, beyond the point of similarity, it becomes invalid and misleading for the learner (Brown and Olmstead, 1962; Diack, 1966). When the vehicle is unknown to the learner, the analogy will be meaningless or confusing.

Both of these points have special implications for the use of analogies in instruction. The careful construction of analogies and their inclusion in instruction must insure that the analogy is not carried too far and that the vehicle is within the knowledge of the learner. The former may be accomplished by providing the shared attributes, or the *grounds* of the topic and vehicle (Ortony, 1979; Verbrugge and McCarrell, 1977). It may also be important to include differences or *limitations* to the analogous relationship (Hayes and Tierney, 1980; Reigeluth and Stein, 1983). In addition, to insure that the vehicle is familiar to the learner, adequate information and explanation may be provided before proceeding to the topic (Curtis and Reigeluth [1]).

ANALOGIES IN TESTING

Many standardized tests use analogical reasoning as a testing device. The Miller Analogies Test, often used for admission to graduate schools, consists strictly of analogical problem solving. The common format or structure of analogies in a test situation is:

_____ : _____ : : _____ : _____

In such format, the first two terms have a relationship that must be discovered by the student; the third term is provided and the last term is left blank for the student to choose the correct term that completes a similar (analogical) relationship. An example of a *test analogy* is:

elephant : large : : ant : _____
(a) ground; (b) clean; (c) small; (d) loud; (e) happy

The first pair of words (elephant, large) are related as an animal to its size; therefore, the second pair must share a similar (analogous) relationship. Hence, the correct answer is (c) small.

ANALOGIES IN ORAL COMMUNICATION

A less formal context for analogies is oral communication, which may include oral instruction. Here, analogies are used to explain and clarify information that is given from one person to another. *Oral analogies* are often used to explain a concept to another person. This type of analogy may take on innumerable formats, depending on its ability to be understood. Oral analogies usually permit feedback from the receiver of the analogy so that the person using the analogy can clarify or explain it further.

ANALOGIES IN TEXT

The third context for analogies and the one that will be explored more fully here is written textbooks. A *text analogy* is quite different from a test analogy or an oral analogy. It differs from the test analogy because it is intended as a cognitive strategy to improve the learner's understanding of the more complex type of instructional content being presented, rather than as a means of determining the learner's general level of analogical reasoning ability. It differs from the oral analogy in that it has no mechanism for receiving feedback from the learner. It must anticipate any vagueness or incompatability that might confront the learner by providing as clear an explanation as possible at its initial presentation. With the continually increasing utilization of print and non-print mediated instruction in education, it is vital that these and other problems be addressed in order to design more effective and efficient instruction (Reigeluth, 1983b).

Although analogies are commonly used in instruction, there is much we do not know about them. Whereas they seem to be helpful for *explaining* complex content, it is not certain for whom and under what conditions analogies are beneficial for *learning* and *understanding*. In addition, it is important to determine what characteristics an analogy should have, such as the nature and characteristics of the vehicle and the topic and their relationship to each other, the presence and amount of grounds and limitations, their format, and their placement or position in the instruction, in order to develop valuable prescriptions for their use.

Theory is developed in order to supply answers to the "why" questions that we ask (O'Connor et al., 1968). Instructional scientists search for answers that offer more than simply appropriate methods of instruction. They seek to design and develop instructional principles that prescribe *when* those methods are optimal for achieving desired learning outcomes (Reigeluth, 1983b). The purpose of this study was to explore and inductively classify analogies in scientific text in order to provide a systematic description of the phenomenon and to generate prescriptive principles for their use in instruction (Reigeluth, 1983b; Snow, 1971).

Methods

DESCRIPTION OF TEXTBOOKS USED

Science textbooks were chosen for analysis, since they were thought to commonly contain a great number of complex concepts and principles. A total of 26 elementary, secondary and post-secondary science textbooks, published within the last twenty years, were surveyed for the presence of analogies. The breakdown of textbooks by science subject is biology (10), general science (6), chemistry (4), physics (3), earth science (2), and geology (1). The textbooks ranged from second-grade level to college level. Seventeen textbooks were published between 1963 and 1973; nine were published between 1974 and 1983. The textbooks are listed at the end of this article.

NUMBER OF ANALOGIES

A total of 216 analogies were identified within the 26 textbooks, averaging 8.3 analogies per text. The range of inclusion was wide, from one analogy present in five of the textbooks – one earth science text (Thurber et al., 1976), one physics text (Brown and Anderson, 1977) and three biology texts (Carter et al., 1971; Biological Sciences Curriculum Study, 1973; Weisz, 1963) – to highs of 22 in one chemistry text (Bolton et al., 1973) and 32 in the geology text (Flint and Skinner, 1974). Two possible explanations for such a disparity among texts are: (1) the preference of the authors and/or (2) the difficulty of the content to be taught (the more difficult content often requiring a greater use of analogies).

CATEGORIZATION OF ANALOGIES

The analogies were organized into categories as patterns emerged. Following the analysis of the 216 analogies, the categories were synthesized into a classification system for analogies. Once this classification system was developed, each analogy was again studied in order to confirm the categories in the classification system and to group the analogies according to those categories.

Results and Discussion

The classification system and the results of the categorization of the textbook analogies may be seen in Table I. In addition, an analysis by category and science subject and by category and individual textbook are reported in Tables II and III.

ANALOGICAL RELATIONSHIP

There are two major ways in which the vehicle and the topic can share an analogical relationship. First of all, they could have the same general physical appearance or be similarly constructed, which we call here a *structural relationship*. An example of an analogy with a structural relationship is "Each cell in the onionskin is something like a room. It has a 'floor' and a 'ceiling' as well as four 'walls'" (Smith and Lawrence, 1966, p. 23).

Another type of analogical relationship is one that compares what the topic *does*; i.e., they share similar functions. This relationship is called here a *functional relationship*. An example of a purely functional relationship is "Feedback works like a building thermostat. The thermostat is set at a certain temperature, a signal turns the heat on. When the temperature of the room reaches the set temperature, a signal turns the heat off. The signal to turn a gland on or off differs for different glands" (Ramsey et al., 1978, p. 291).

A third type of analogical relationship combines the structural and functional relationship. An example of a *structural-functional analogy* is the following:

> The structure and functions of our cells could be compared to a factory. The manufacturing processes may be compared to the life processes carried on in a cell. The finished products are the compounds that form the many parts of the cell . . . The main office and planning department of our factory cell is the *nucleus*. The nucleus is the control center of the cell. It controls everything that goes on inside the cell (Ramsey et al., 1978, p. 69).

In the textbooks surveyed, the vast majority of analogical relationships were functional (152, 70%), while far fewer shared a structural relationship (53, 25%) and only eleven (5%) shared both a structural and functional relationship. A combined structural-functional analogy may provide the most powerful relationship when there are extensive grounds and few limitations between the topic and vehicle. The purely structural relationship may be the weakest, since

TABLE I

Classification System and Number of Analogies in Each Category

Category	*n*	%
Analogical relationship		
Structural	53	25
Functional	152	70
Structural-functional	11	5
Presentation format		
Verbal	182	84
Pictorial-verbal	34	16
Condition		
Concrete/concrete	26	12
Abstract/abstract	12	6
Concrete/abstract	178	82
Position		
Advance organizer	50	23
Embedded activator	163	76
Post synthesizer	3	1
Level of enrichment		
Simple	14	6
Enriched	175	81
Extended	27	13
Pre-topic orientation		
Vehicle explanation	95	44
Strategy identification	32	15
Vehicle explanation & strategy identification	17	13
Absence of pre-topic orientation	106	49

Total of 216 analogies from 26 science textbooks.

the structural similarity often provides the only ground between the topic and vehicle, while the number of differences may be great.

It may be seen in Table II that the more difficult and/or abstract the content, the proportionately greater the use of functional analogies, while the easier and more concrete the content, the proportionately greater the use of structural analogies. Over 50% of the analogies used in the elementary level texts were structural, whereas 88% of the chemistry and 90% of the physics analogies were strictly functional.

PRESENTATIONAL FORMAT

There are two formats in which the analogies were presented in these textbooks. The first is the written or *verbal* format, where the analogy is

TABLE II

Number of Analogies by Category

	General science	Biology	Earth sci./ Geology	Chemistry	Physics
Total *n*	39	63	43	52	19
Texts	6	10	3	4	2
Mean	6.5	6.3	14.3	13	9.5
Structural	20 (51%)	17 (27%)	10 (23%)	5 (10%)	1 (5%)
Functional	16 (41%)	41 (65%)	32 (75%)	46 (88%)	17 (90%)
Struc./func.	3 (8%)	5 (8%)	1 (2%)	1 (2%)	1 (5%)
Verbal	32 (82%)	57 (90%)	39 (91%)	37 (71%)	17 (90%)
Pictorial-verbal	7 (18%)	6 (10%)	4 (9%)	15 (29%)	2 (10%)
Concrete/concrete	11 (28%)	9 (14%)	5 (12%)	0 (0%)	1 (5%)
Abstract/abstract	1 (3%)	2 (3%)	6 (14%)	1 (2%)	2 (10%)
Concrete/abstract	27 (69%)	52 (83%)	32 (74%)	51 (98%)	16 (85%)
Adv. org.	7 (18%)	13 (21%)	5 (12%)	23 (44%)	2 (10%)
Embedded activator	31 (79%)	49 (78%)	38 (88%)	28 (54%)	17 (90%)
Post synthesizer	1 (3%)	1 (1%)	0 (0%)	1 (2%)	0 (0%)
Simple	8 (21%)	2 (3%)	4 (9%)	0 (0%)	0 (0%)
Enriched	29 (74%)	53 (84%)	37 (86%)	42 (81%)	14 (74%)
Extended	2 (5%)	8 (13%)	2 (5%)	10 (19%)	5 (26%)
Veh. explanation	8 (21%)	31 (49%)	15 (35%)	36 (69%)	5 (26%)
Strat. ident.	0 (0%)	13 (21%)	7 (16%)	6 (12%)	6 (32%)
Veh. & strat.	0 (0%)	9 (14%)	0 (0%)	6 (12%)	2 (10%)
Absence	31 (79%)	28 (44%)	21 (49%)	16 (31%)	10 (53%)

TABLE III

Number of Analogies by Textbook

Textbook	n	Struc.	Func.	Struc.-func.	Verbal	Pict.-verbal	Conc./conc.	Abs./abs.
Elementary school science	2	1	1	0	1	1	0	0
Inquiring into science	15	9	6	0	14	1	4	0
Science for here and now	2	2	0	0	2	0	1	0
Science in your life	6	2	4	0	2	4	1	0
Science: understanding your environment (4)	9	5	3	1	8	1	5	1
Science: understanding your environment (5)	5	1	2	2	5	0	0	0
Biology	5	1	3	1	5	0	0	0
Biological science: an ecological approach	1	0	1	0	1	0	0	0
Biological science: an inquiry into life	5	2	2	1	5	0	1	0
Biological science: molecules to man (1963)	10	1	9	0	9	1	0	1
Biological science: molecules to man (1973)	8	1	7	0	6	2	0	1
Exploring biology	10	5	5	0	9	1	1	0
Life science	15	5	8	2	13	2	3	0
Life science: a problem-solving approach	1	0	0	1	1	0	0	0
Science horizons: the world of life	7	2	5	0	7	0	3	0
The science of biology	1	0	1	0	1	0	1	0
Earth science: a study of a changing planet	10	1	8	1	8	2	1	1
Exploring earth science	1	0	1	0	0	1	0	0
Physical geology	32	9	23	0	31	1	4	5
Action chemistry	22	1	21	0	14	8	0	0
Chemistry and you	11	0	10	1	11	0	0	0
Chemistry experiments and principles	9	0	9	0	2	7	0	0
Inquiries in chemistry	10	4	6	0	10	0	0	1
Physical sciences: a search for understanding (1972)	7	0	7	0	6	1	1	1
Physical sciences: a search for understanding (1977)	1	0	1	0	0	1	0	0
Physics	11	1	9	1	11	0	0	1
Total	216	53	152	11	182	34	26	12

Conc./ abs.	Adv. org.	Emb. act.	Post. syn.	Simple	Enr.	Ext.	Veh. expl.	Strat. ident.	Veh. & strat.	Absence
2	0	2	0	0	2	0	0	0	0	2
11	1	14	0	5	9	1	4	0	0	11
1	0	2	0	0	2	0	0	0	0	2
5	1	5	0	1	5	0	1	0	0	1
3	5	4	0	0	9	0	2	0	0	7
5	0	4	1	2	2	1	1	0	0	4
5	0	5	0	0	4	1	4	2	2	1
1	0	1	0	0	1	0	1	1	1	0
4	0	5	0	0	5	0	3	3	2	1
9	1	9	0	0	9	1	5	5	4	4
7	1	7	0	0	8	0	4	1	0	3
9	1	8	1	0	9	1	2	0	0	8
12	7	8	0	0	10	5	11	0	0	4
1	1	0	0	0	1	0	0	0	0	1
4	2	5	0	2	5	0	1	0	0	6
0	0	1	0	0	1	0	0	1	0	0
8	3	7	0	1	8	1	7	0	0	3
1	0	1	0	0	1	0	1	0	0	0
23	2	30	0	3	28	1	7	7	0	18
22	15	6	1	0	15	7	12	0	0	10
11	6	5	0	0	11	0	7	1	1	4
9	0	9	0	0	7	2	9	3	3	0
9	2	8	0	0	9	1	8	2	2	2
5	2	5	0	0	6	1	2	1	0	4
1	0	1	0	0	1	0	0	0	0	1
10	0	11	0	0	7	4	3	5	2	5
178	50	163	3	14	175	27	95	32	17	106

explained in words alone. The other presentation format is called here the *pictorial-verbal*, where the written analogy is reinforced by a picture or pictures of the vehicle. This picture may be a drawing or photograph. Pictorial-verbal analogies provide a visualization to the learner, while verbal analogies require the learner to provide his/her own visualization.

Of the 216 analogies found in this textbook survey, the overwhelming majority (182, 84%) was verbal. Only 34 (16%) combined both pictures and written text as pictorial-verbal analogies. This may be due to the already high visualization power of analogies themselves. However, three of the texts (Bolton et al., 1973; O'Connor et al., 1968; Schneider and Schneider, 1968) averaged 67% pictorial-verbal analogies (see Table III). It is possible that the first two, which are chemistry textbooks, may have been geared toward lower ability students and, due to the difficult nature of the subject matter, included more pictures in general. The third textbook is an elementary level science text in which at least one illustration appeared on every page, regardless of the presence of an analogy.

CONDITION

The subject matter or content of the vehicle and the topic may be categorized as either concrete or abstract. Conditions for analogies have been divided into three possible combinations – concrete/concrete (where both the vehicle and topic are of a concrete nature), abstract/abstract (where both the vehicle and topic are of an abstract nature), and concrete/abstract (where the vehicle is of a concrete nature and the topic is of an abstract nature). As expected, no abstract/concrete analogies were found in the surveyed textbooks since the purpose of analogies is to help explain abstract or difficult content.

Since analogies provide a bridge from the familiar to the unfamiliar and from simple to complex and difficult content, it was anticipated that the vast majority of analogies would be concrete/abstract and that there would be few, if any, concrete/concrete and abstract/abstract conditions found. This was, in fact, confirmed. Out of 216 analogies, 178 (82%) were of the concrete/abstract condition, 26 (12%) were concrete/concrete, and 12 (6%) were abstract/abstract.

POSITION

The placement of the vehicle in relationship to the topic may vary. The vehicle may be presented at the beginning of the instruction, as an analogical *advance organizer* (Ausubel, 1969). As such, it may provide background information necessary for learning the new, unfamiliar content (Hayes and Tierney, 1980). In addition, it allows the writer to refer back, and the learner to think back, to the analogy at various points in the instruction.

On the other hand, the vehicle may be presented somewhere during the instruction, at a point where the content is becoming most abstract and/or difficult for the learner. In this position, it acts as an *embedded activator* (Reigeluth, 1983a; Rigney, 1978), requiring the learner to use this cognitive strategy to facilitate learning. Embedding the analogy in the instruction not only allows the clarification of the information preceding it, but also can provide a lead-in to succeeding information on the topic.

Finally, the analogy may appear at the end of the instruction on a topic. As such, it acts as a *post synthesizer* for the information preceding it and concludes that topic, after which a new topic is immediately introduced.

Fifty (23%) of the textbook analogies were advance organizers. What is most interesting about this fact is that three of the textbooks accounted for over half (28) of those analogical advance organizers (Baker et al., 1966; Bolton et al., 1973; Ramsey et al., 1978 – see Table III). An example of one of those analogies is presented below.

> Two hundred years ago, our nation began to expand westward over the Appalachian Mountains and on to the Central Plains. Just staying alive was a full-time job. Each family unit that settled far from others had to do everything for itself. Raising food, finding water, building shelter, making tools and clothing were up to each family.
>
> As time went on, more and more families settled in the wilderness areas. Some of these people were better farmers than others. Some were skilled blacksmiths. Some could make and repair tools. Other had skills in carpentry.
>
> As these families settled closer together, a kind of exchange system developed. The skilled blacksmith would shoe the farmer's horse. The farmer would provide the blacksmith with food he didn't have time to raise. The carpenter would build an office for the doctor. The doctor would provide medical care for the carpenter's family.
>
> So as time went on, people tended to become specialists. They became more and more dependent on each other for survival...
>
> Single-celled organisms are similar to those early families of settlers. Each must perform all of the life functions by itself. The protoplasm in cells is organized into structures. Each structure has a special function. In the pioneer family everyone, even the children, had tasks to do. (Ramsey et al., 1978, pp. 81–2)

By far the greatest number of analogies in the surveyed textbooks (163, 76%) were positioned as *embedded activators*; that is they appeared during rather than before or after the instruction on the topic. An example is included below.

> Energy is needed to move objects through the air. In aircraft, that energy comes from gasoline or kerosene that is burned in the engines. In the early aircraft, the engines turned propellers. A propeller works something like a screw. When you turn a screw in a piece of wood, it moves into the wood. A fast-turning propeller "bites" into the air in much the same way a screw "bites" into wood. As the propeller turns, it pulls the aircraft forward. The increasing speed of the aircraft increases the push of air on the bottom of the wings. This push lifts the aircraft. (Mallinson et al., 1978, p. 62).

The final position in which an analogy may appear is at the end of the instruction as a *post synthesizer* for the information preceding it. As such, a new topic is introduced immediately following the post synthesizer. In this textbook survey, only three (1%) of the analogies found were post synthesizers. Here is one of them:

> "Why should I bother to learn to think? Why not let someone else do it, and I can just get the answers?" This is an understandable question.
>
> As long as you live, you will find yourself in situations that you have never learned about. Unless you know how to think your way out of them, you will be lost and bewildered. Throughout this course in chemistry you will be involved in "think training."
>
> An athlete trains to stay in shape for the game. Many of the skills the athlete acquires can be used in his daily life. Much the same is true of the study of chemistry. You will find many uses for your understandings and skills learned in chemistry. (Bolton et al., 1973, p. 11).

In this case, immediately following the analogy of athletic training to studying chemistry, the topic changed to the study of molecules.

LEVEL OF ENRICHMENT

The most basic level of an analogy is the *simple analogy*. A simple analogy is usually composed of three main parts – the topic, the vehicle, and a *connector* such as "is like" or "may be compared to." In written text, simple analogies are infrequently used because they require the learner to provide an explanation of the analogous relationship, including all of the pertinent similarities and differences between the topic and vehicle. This may be a difficult task for some learners, particularly when those similarities and differences are not readily apparent. Simple analogies tend to be used in cases where the relationship between topic and vehicle is highly obvious and needs little or no explanation. In the surveyed textbooks, only fourteen (6%) of the analogies could be classified as simple analogies. Of those fourteen simple analogies, over half (eight) were from the elementary level science texts. An example of a simple analogy is "The spinal cord is like a large cable which extends down through the hollow vertebrae." (Branley, Pelia and Urban, 1965, p. 69).

A simple analogy can be *enriched* for the learner by stating the grounds for the analogous relationship between the topic and vehicle. In addition, an enriched analogy may also contain the limitations to the analogous relationship. Most (175, 81%) of the analogies found in the surveyed textbooks were enriched analogies with varying degrees of grounds and limitations. The following example is an enriched analogy with grounds only:

> Winds carrying sand and soil act somewhat like sandblasting machines. Sandblasting machines clean the sides of buildings by blowing sand against the stone walls to wear away

dirt and stains. Similarly, winds that carry sand and soil wear away the sides of rocks. Because some parts of rocks often are softer than other parts, these rocks often have been worn to make strange shapes (Jackson, Lauby and Konicek, 1965, p. 19).

The most complex level of enrichment found is one in which the various grounds of a single vehicle are used to teach more than one topic or when various vehicles are used to explain a single topic. This is termed here an *extended analogy*. Models of each of the three levels of enrichment are presented in Fig. 1.

Extended analogies are more difficult to find and, therefore, are used much less frequently than enriched analogies. In the surveyed textbooks, only 27 (13%) of the analogies were extended analogies. One example was an extended analogy in which various grounds of a single vehicle were used to teach several topics. This extended analogy compared several concepts related to a bank account with various concepts related to a water budget (Daley, Higham and Matthias, 1976). Another example using two vehicles to teach one topic is presented below.

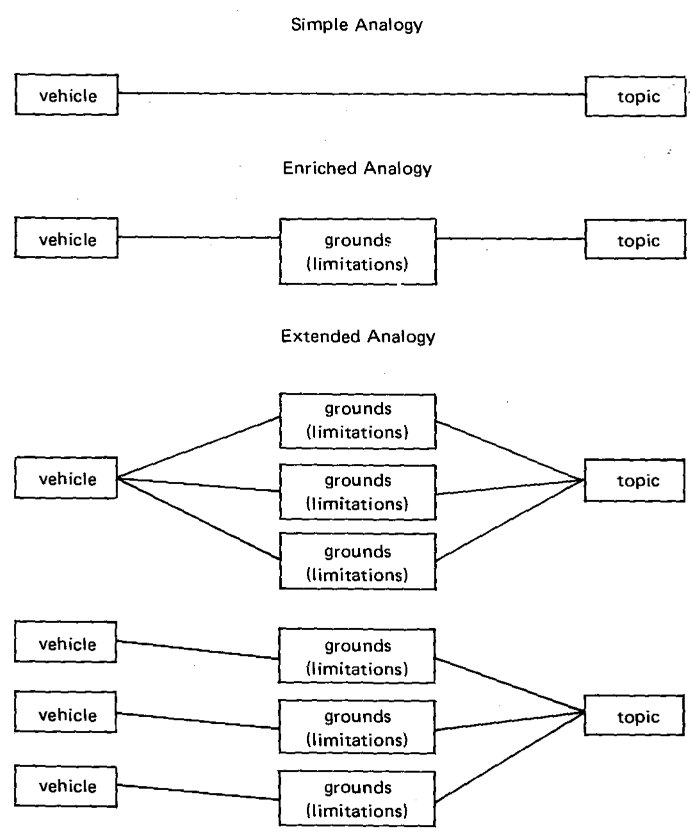

Fig. 1. Three levels of enrichment for analogies.

> Compare our body and the cells and organs that compose it to a flow tank . . . If the amount of water entering the tank is just equal to the amount of water leaving it, the water level will not change. Such a system is said to be actively balanced, or in *dynamic equilibrium.* The circus juggler who maintains an active balance as he juggles several objects keeps them in dynamic equilibrium. Our body processes are regulated so that many such dynamic equilibria are maintained. One of these is the balance of molecules of glucose entering and leaving the bloodstream (Biological Sciences Curriculum Study, 1963, p. 532).

PRE-TOPIC ORIENTATION

An analogy can be an important instructional strategy for helping the learner understand content that is unfamiliar or difficult. However, the vehicle must be highly familiar, simple and/or concrete for it to be useful for learning new information. Otherwise, it might cause confusion or misunderstanding (Curtis and Reigeluth [1]). It is often assumed, particularly by writers of textbooks, that the learner knows both the vehicle being used and the cognitive strategy of analogical thinking. This may explain why, of the 216 analogies, 106 (49%) made no attempt to describe the vehicle and/or cognitive strategy before presenting the topic. This assumption of prior student knowledge, however, may be incorrect.

In cases where the vehicle is unfamiliar to the learner, it may be worthwhile to explain or *describe the vehicle.* If the vehicle is familiar but complex, it may often be beneficial to review it before using it in an analogy (Curtis and Reigeluth [1]). In this textbook survey, there was a total of 95 (44%) examples in which the vehicle was explained before the topic was presented. Here is an example.

> A President's every action is thought about, talked about, debated, and analyzed. The result is a developing picture of the man, documented by a flood of evidence. But people also ask what he was like during his childhood and his formative years; do the experiences of those earlier days influence his actions? One way to seek answers is to talk to family members who shared in, and were influenced by, the same early experiences. In some respects Planet Earth is like a President . . . we know that little evidence of Earth's birth and childhood remains, because it has been destroyed by erosion. Nonetheless, we ask whether Earth's present activities reflect events that happened during those long-ago times, and as with a President, a way to answer the question is to examine Earth's neighbors in space. This way is promising, because all the planets were born together and have been neighbors a long time. It should be possible to glean from other planets clues to the childhood of Planet Earth (Flint and Skinner, 1974, p. 369).

Expressly *identifying analogy* as a cognitive strategy is another technique used by textbook writers. In this way, the learner is provided with a cue that a comparison between something unfamiliar and something familiar is about to occur in order to help the learner understand the unfamiliar term. Thirty-two (15%) of the analogies in the textbook survey included identification of the analogy. An example appears below.

The low-velocity zone, therefore, seems to be a key to the developing picture of Earth's internal processes. The picture has been clarified by measurements of Earth's free oscillations.

How this is done can be explained by analogy with bells. A bell made of rigid iron is very elastic and rings for many minutes. A bell made of lead or copper – metals that are softer and more plastic – will vibrate only for a few seconds. By analysis of the sound of a bell (which means analysis of the way it vibrates), it is possible to determine its elastic and plastic properties. The same can be done with Earth when an earthquake sets it vibrating (Flint and Skinner, 1974, p. 337).

Finally of those 127 analogies that either explained the vehicle or identified the strategy, only seventeen (8%) included both an *explanation of the vehicle and identification of the strategy*. This may be due to an assumption that explanation of the vehicle provides enough information for the learner to utilize the cognitive strategy, even if the learner is unaware of what the strategy is called.

As is shown in Table II, in this survey the chemistry textbooks explained the vehicle for 32 (69%) of the analogies used, an amount much higher than for any of the other subjects. Furthermore, the physics textbooks identified the cognitive strategy to a greater extent than any of the other subjects (7, 37%). It appears that chemistry and physics were the only subjects where the percentage of vehicle explanation surpassed the absence of pre-topic orientation. This, again, may be due to the difficult and abstract nature of the content.

The general science textbooks, however, were at the low end of the continuum for both explaining the vehicle and for identifying the cognitive strategy. The vehicle was explained eight (21%) times while the strategy was not identified even once. Because these books were written for elementary level students, it may be that the content was thought to be easier, simpler and/or more concrete.

Although this concludes the analysis of textbook analogies according to the classification system presented, two observations related to this analysis are worthy of mention. First of all, in a comparison of two different editions of two of the textbooks (Brown and Anderson, 1972; Brown and Anderson, 1977; Biological Sciences Curriculum Study, 1963; Welch et al., 1973), it was found that in both cases there were fewer analogies used in the later editions than in the earlier editions (see Table III). Furthermore, there were also fewer examples of pre-topic orientation included in the later editions. This may have been due to the difference in authors (in one case) or a need to condense some sections of text in order to expand others or add new text in the later editions. In the example below, the analogy from the earlier edition was duplicated verbatim in the later edition. However, the earlier edition chose to identify the strategy, while the later edition eliminated any reference to the strategy. The additional words from the earlier edition appear in parentheses:

A double helix is like a double coil. It can be understood by imagining a ladder . . . this

> impractical ladder has flexible uprights. The bottoms of the uprights of the ladder are held in place so that they cannot move. Twist the ladder from the top, and a double helix is formed.
> (To continue this analogy) [T]he uprights of this special ladder are made of the phosphate and deoxyribose portions of nucleotides. The rungs are made of nitrogen bases (Biological Sciences Curriculum Study, 1963, pp. 144–5; Welch et al., 1973, p. 208).

Secondly, throughout the 26 textbooks surveyed, certain analogies appeared repeatedly. Some of these analogies include the human skeleton compared to the framework of a building, the structure of DNA compared to a ladder, the replication of DNA compared to a zipper, electricity flow compared to water flow, the biological cell compared to a room, a scientist compared to a detective, and the human nervous system compared to a communication system. This repetition may be the result of convention and familiarity for the author, or it may offer a clue as to the necessary characteristics of a powerful analogy. It is possible that these analogies are thought to be particularly helpful for teaching those specific concepts.

Conclusions

Instructional designers attempt to improve methods of instruction by developing theories based on more precise and clearly defined strategy components such as analogies. By doing so, optimal models of instruction under given conditions may be determined to achieve desired goals (Reigeluth, 1983b).

This was an exploratory study designed to analyze and more clearly and precisely define the use of analogies in elementary through post-secondary level science textbooks. The results of this study allow the following general conclusions:

1. Analogies are used fairly often in a variety of ways in written text.
2. Analogies assume a variety of structures and positions in written text.
3. The type and amount of explanation included within the analogy varies and may depend upon the individual preference of the author, the level of the student and/or the nature of the analogy itself.

In addition, based on the classification system for analogies presented in this article, the following prescriptions for the inclusion of analogies in instruction are offered:

1. Analogies appear to be most useful for more complex and difficult content.
2. Analogies are most often constructed based on a structural relationship for easier, more concrete topics and a functional relationship for more difficult and abstract topics.
3. A strictly verbal presentation format may be sufficient for visualization of the

analogous relationship. However, pictorial-verbal analogies may be preferable for instruction intended for lower ability students.

4. In most cases, analogies should consist of a concrete vehicle and an abstract topic, in order to take the learner from simpler, more familiar content to more difficult, abstract content.
5. The most effective placement of analogies appears to be as either advance organizers or embedded activators. As an advance organizer, it may be used to provide information to which the learner may later refer. As an embedded activator, it may be used to explain preceding information and introduce subsequent information.
6. Analogies should include the pertinent grounds to the analogous relationship. Providing the limitations to that relationship may yield additional power for the analogy.
7. The vehicle should usually be explained or described before presenting the new content to help insure that the analogy is understood by the learner. If this explanation is provided, the learner is forced to use the cognitive strategy and, therefore, it may be unnecessary to identify or explain the strategy itself.

Classification schemes are arbitrary and phenomena may be categorized in various ways. Therefore, different classification schemes are not equally useful for prescribing instruction (Reigeluth, 1983b). Further research and analysis is recommended on the use of analogies in written text in order to continue to develop and test prescriptions such as the ones proposed here. Textbooks from a variety of content areas should be analyzed for possible additions and modifications in this classification scheme.

Also, experimental studies to determine appropriate characteristics and positions for analogies are recommended. Specifically, it may be important to define the nature and critical characteristics of the vehicle in order to help instructional designers select the most appropriate ones. Further classification of the grounds and limitations of enriched and extended analogies may provide important information for the successful use of analogies in instruction. The necessary attributes of the topic selected for an analogy, as well as possible links between structural, simple and concrete/concrete analogies, should be explored. Only through continuous interactions with ongoing observation and data analysis can there be the gradual emergence of useful models for the design of textual analogies (Snow, 1971).

Finally, although it seems evident, based on the frequency of inclusion in text, that analogies are thought to be useful for explanation and instruction, it is still unclear as to when they are most helpful to the learner for understanding and when they may become confusing and unclear. Furthermore, the relationship of learner characteristics to analogical learning needs to be explored.

Notes

1. Curtis, R. V. and Reigeluth, C. M. The effects of analogies on student motivation and performance in an eighth grade science context, submitted for publication.

References

Ausubel, D. P. (1969). "The use of advance organizers in the learning and retention of meaningful verbal material," *Journal of Education Psychology 51* (5): 267–272.
Brown, W. K. and Olmstead, S. P. (1962). *Language and Literature*. New York: Harcourt, Brace and World.
Carroll, J. S. (1974). "The potentials and limitations of print as a medium of instruction," in D. R. Olson (Ed.), *Media and Symbols: The Forms of Expression, Communication and Education*, 73rd Yearbook, Part 1. Chicago: National Society for the Study of Education.
Dale, E. (1969). *Audiovisual Methods in Teaching* (3rd ed.). New York: Dryden Press.
Diack, H. (1966). *Language for Teaching*. New York: Philosophical Library.
Gagné, R. M. and Briggs, L. J. (1974). *Principles of Instructional Design*. New York: Holt, Rinehart and Winston.
Good, C. V. (Ed.) (1981). *Dictionary of Education*. New York: Harper and Row.
Hayes, D. A. and Tierney, R. J. (1980). *Increasing Background Knowledge Through Analogy: Its Effects Upon Comprehension and Learning*. Washington, D.C.: NIE, October, 1980. (ERIC Document Reproduction Service No. ED 195 953)
McKim, R. H. (1980). *Experiences in Visual Thinking*. Monterey, CA: Brooks/Cole.
Ortony, A. (1979). "Beyond literal similarity," *Psychological Review 86* (3): 161–179.
Reigeluth, C. M. (1983a). "Meaningfulness and instruction: Relating what is being learned to what a student knows," *Instructional Science* 12 (3): 197–218.
Reigeluth, C. M. (1983b). "Instructional design: What is it and why is it?" in C. M. Reigeluth (Ed.), *Instructional Design Theories and Models: An Overview of Their Current Status*. Hillsdale, NJ: Lawrence Erlbaum.
Reigeluth, C. M. and Stein, F. (1983). "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.
Rigney, J. W. (1978). "Learning strategies: A theoretical perspective," in H. F. O'Neil, Jr. (Ed.), *Learning Strategies*. New York: Academic Press.
Snow, R. E. (1971). "Theory construction for research on teaching," in R. M. W. Travers (Ed.), *Second Handbook of Research on Teaching*. Chicago: Rand McNally.
Verbrugge, R. R. and McCarrell, N. S. (1977). "Metaphoric comprehension: Studies in reminding and resembling," *Cognitive Psychology* 9: 494–533.

Bibliography of Textbooks Studied

American Institute of Biological Sciences. *Biological Science: An Inquiry into Life*. New York: Harcourt, Brace and World, Inc., 1963.
Baker, P. S. et al. *Chemistry and You*. Chicago: Lyons and Carnahan, Inc., 1966.
Biological Sciences Curriculum Study. *Biological Science: Molecules to man*. Boston: Houghton Mifflin Company, 1963.

Biological Sciences Curriculum Study. *Biological Science: An Ecological Approach.* Chicago: Rand McNally and Company, 1973.

Bolton, R. P. et al. *Action Chemistry.* New York: Holt, Rinehart and Winston, Inc., 1973.

Branley, R. M., Pelia, M. O. and Urban, J. *Science Horizons: The World of Life.* Boston: Ginnand Company, 1965.

Brown, W. R. and Anderson, N. D. *Physical Science: A Searchfor Understanding.* Philadelphia: Lippincott, 1972.

Brown, W. R. and Anderson, N. D. *Physical Science: A Searchfor Understanding.* Philadelphia: Lippincott, 1977.

Carter, J. L. et al. *Life Science: A Problem-Solving Approach.* Boston: Ginn and Company, 1971.

Daley, R. B., Higham, W. J. and Matthias, G. F. *Earth Science: A Study of a Changing Planet.* Fairfield, NJ: Cebco Standard Publishing, 1976.

Flint, R. F. and Skinner, B. J. *Physical Geology.* New York: John Wiley and Sons, Inc., 1974.

Jackson, W. J., Lauby, C. J. and Konicek, R. D. *Inquiring into Science.* New York: American Book Company, 1965.

Mallinson, G. G. et al. *Science: Understanding Your Environment.* (4th grade ed.). Morristown, NJ: Silver Burdett Company, 1978.

Mallinson, G. G. et al. *Science: Understanding Your Environment.* (5th grade ed.). Morristown, NJ: Silver Burdett Company, 1978.

O'Connor, P. R. et al. *Chemistry Experiments and Principles.* Lexington, MA: D. C. Heath and Company, 1968.

Physical Science Study Committee. *Physics.* (2nd ed.). Boston: D. C. Heath and Company, 1965.

Ramsey, W. L. et al. *Life Science.* New York: Holt, Rinehart and Winston, 1978.

Rockcastle, V. N., Salamon, F. R. and Schmidt, V. E. *Elementary School Science.* Menlo Park, CA: Addison-Wesley Publishing Company, 1972.

Schneider, H. and Schneider, N. *Science for Here and Now.* Lexington, MA: D. C. Heath and Company, 1973.

Schneider, H. and Schneider, N. *Science in Your Life.* (3rd ed.). Boston: D. C. Heath and Company, 1968.

Smallwood, W. L. and Green, E. R. *Biology.* Morristown, NJ: Silver Burdett Company, 1977.

Smith, E. T. and Lawrence, T. G. *Exploring Biology.* (6th ed.). New York: Harcourt, Brace and World, 1966.

Thurber, W. A., Kilburn, R. E. and Howell, P. S. *Exploring Earth Science.* Boston: Allyn and Bacon, Inc., 1976.

Turner, A. M. and Sears, C. T., Jr. *Inquiries in Chemistry.* Boston: Allyn & Bacon, Inc., 1974.

Weisz, P. B. *The Science of Biology.* New York: McGraw-Hill Book Company, 1963.

Welch, C. A. et al. *Biological Science: Molecules to Man.* Boston: Houghton Mifflin Company, 1973.