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ABSTRACT

This study investigated the effects of analogy-based and conventional lecture-based instructional strategies on the achievement of four classes of high school biology students (N=123). Prior to treatment, students were assessed for cognitive ability and prior knowledge of the analogy vehicle. The analogy-based treatment consisted of teacher lecture and student examination of analogy text, diagrams, and charts comparing target information to an analogous domain. Conventional lecture-based strategies involved didactic teacher presentation of target concepts supplemented with reading assignments from the regular textbook. Findings indicate that: (1) analogy-based instructional methods appear to enhance student performance relative to conventional lecture-based instruction in achievement related to the digestive, nervous, and circulatory system; (2) both concrete and transitional/formal operational students benefited from analogy-based instruction; (3) with both treatments, transitional/formal operational students tended to show higher achievement than concrete operational students; (4) concrete operational students receiving analogy-based instruction scored higher than transitional/formal operational students receiving conventional lecture-based instruction; (5) students who comprehended analogies showed significantly higher achievement over those who did not comprehend them; and (6) the effects related to treatment tended to be more pronounced when comprehension of analogy was high. (Author/JN)

Effects of Teacher Use of Analogies on Achievement of High School Biology Students with Varying Levels of Cognitive Ability and Prior Knowledge

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INTRODUCTION AND PURPOSE

The use of analogies in the science classroom offers an intuitive appeal to many instructors, yet evidence supporting their effectiveness as an instructional method is mixed. Analogies seem especially appropriate for science instruction because of numerous theories and concepts that originated from analogical processes. For example, Kekule's benzene ring structure was first hypothesized via the image of a snake eating its own tail (Davidson, 1972) and Fermi analogized from radioactive decay theory to postulate his light emission theory (Oppenheimer, 1956). The planetary model of atomic structure and the hydraulic pump model for the circulatory system are other examples of analogy-based theories (Boden, 1977). Concepts such as these can be quite difficult to visualize or explain in literal terms. Analogies appear to be a viable means for facilitating comprehensior of abstract concepts.

In essence, analogies provide a window or vehicle for viewing target information in terms of previously know information. For instance, atomic structure (target information) is presented relative to the solar system (analogy vehicle). New ideas are expressed in terms of what one already knows. Analogies serve to highlight similarities or pattern repetitions between two different phenomena.

Numerous theoretical bases exist related to how analogies facilitate assimilation of new information. Some authors (Dreistadt, 1968; Khatena, 1973; Templeton, 1973) state that analogies make target information more manipulable or imageable. Other (Goodstein & Howe, 1978; Dreistadt, 1969; Royer & Cable, 1976) claim that analogies help to "concretize the abstract." The commonly used dancing partners/chemical reaction analogy (Last, 1983) is an illustration. It is easy to visualize or even demonstrate the switch of dancing partners. As for the chemical reaction, students cannot see the breakage of molecular bonds and recombination of atoms to form new molecules. In some cases, a change of color or heat may be detectable but rearrangement or reactants is not visible.

Other theories emphasize the organizational and prior experience aspects of analogies. Hayes and Tierney (1982) state that analogies provide a structure or schema for new information. Mayer (1983) suggests that analogies aid assimilation and interpretation of new informatin by providing an analogous system familiar to the learner. The organizational nature is further described using mapping or attribute matching (Anderson & Bower, 1973). Mapping is a process which ascertains the degree of similarity between two analogous domains. In mapping the attributes found in the planetary model/atomic structure analogy, one finds that both have a large central mass (sun and nucleus) and orbiting bodies (planets and electrons). Additionally, planets revolve around the sun at varying distances while electrons may be located in different orbitals.

The term analogy can invoke multiple meanings. Formal analogies in the form A:B::C:D (for instance, hand:finger::foot:toe) are frequently used on general intelligence tests. Analogy is sometimes used as an all-encompassing term for simile, metaphor and figures of speech that compare similarities between two seemingly unrelated phenomena. Three dimensional models, maps and diagrams may also be classified as a form of analogy. In this study, an analogy is viewed as a comparison of two distinct domains of knowledge. These domains are called the vehicle and target. In the example of the planetary model of atomic structure, the solar system serves as the vehicle and atomic structure is the target information.

Given this definition of analogy, what student characterisitcs influence comprehension of an analogy? Prior knowledge of the analogy vehicle (solar system) appears crucial to understanding target information (atomic structure). Otherwise, students are confronted with assimilating two sets of information instead of one set. Additionally, certain cognitive skills are required. With the given definition, the capacity to deal with similarities appears vital. Formal operational skills such as correlational and proportional reasoning abilities may also be necessary for analogy comprehension.

The purpose of this study was to investigate the effects of analogy-based instruction on student achievement in biology. In addition, the students' cognitive ability level and prior knowledge of the analogy vehicle were used as variables in the study. The specific research questions addressed were:

1. Do differences in biology achievement exist between high school students receiving analogy-based instruction and conventional lecture-based instruction?
2. Do differences in biology achievement exist between high school students at concrete and transitional/formal cognitive ability levels?
3. Do differences in biology achievement exist among high school students with varying amounts of prior knowledge of the analogy vehicles?
4. Are the effects of analogy-based and conventional lecture-based instruction consistent across levels of:
   a. cognitive ability
   b. prior knowledge
   c. cognitive ability and prior knowledge

Review of the Research

Some empirical studies exist to support the contention that analogies facilitate learning among high school students. In interpreting the research, it becomes difficult to make any generalizations concerning the effects of analogies in instruction because of the variety of analogy forms, experimental methods and assessed outcomes used in the studies (Polland, 1982).

One problem encountered when using analogies is that students frequently do not understand them. In a study that used analogies to teach chemistry concepts, Gabel and Sherwood (1980) reported that nearly half of the subjects did not understand the analogies. In a review related to metaphor comprehension (The fog was pea soup.), Reynolds and Schwartz (1983) stated that subjects frequently lack the necessary knowledge of the domain to which the metaphor relates (vehicle).

With respect to cognitive development and the use of analogies, the evidence is mixed. One study (Sheehan, 1970) suggests that both concrete the formal operational students benefit from instructional analogies. Other studies tend to indicate that formal operational students are more apt to benefit then concrete operators. Goodstein and Howe (1978) found that physical models aided formal operational students in the achievement of stoichiometry concepts but did not help concrete operators. Gabel and Sherwood (1980) used analogies to teach concepts on kinetics, stoichimetry, entropy and atomic theory and found that early formal operational students seemed to benefit more than students at other stages of cognitive development.

General research related to cognitive development and instructional strategies indicates that formal operators will show higher achievement than pre-formal students regardless of the teaching methods employed (Cantu & Herron, 1978; Sayre & Ball, 1975). Based on a study involving high school and college science students, Kolodiy (1975) suggests that traditional lecture is an ineffective method for all students except those at the highest level of formal operations.

Prior knowledge of the analogy vehicle appears to have an effect on whether or not an analogy facilitates learning. Hayes and Tierney (1982) found prior knowledge of baseball to be a key factor as to whether or not subjects understood analogical text passages comparing baseball to cricket. In a study using formal analogy items, Gentile (1968) found that supplying subjects with definitions of the terms in the analogy (in essence, supplying prior knowledge) improved their performance. While prior knowledge may aid analogy comprehension, the knowledge may also lead to incorrect inferences about target concepts (Rumelhart & Norman, 1981; Schustack & Anderson, 1979) and give false impressions of causality (Eckstein, 1983). Using the planetary model/atomic structure analogy, a false inference would be that some electrons (Jupiter, Saturn) are many times larger then other electrons (Mercury, Pluto). To remedy this, Polland (1982) suggests that instructors give explicit directions as to how the analogy is to be applied.

Another factor contributing to the effectiveness of analogies is the degree of attribute match between the vehicle and target. Polland (1982) states that analogies possessing a large number of matching attributes (more complex) will be more effective then analogies with fewer corresponding attributes (less complex). Gick and Holyoak (1980) found that complex analogies facilitated problem solving tasks better than less complex analogies.

Although accurate generalizations from the literature are difficult to substantiate, theory and certain evidence can be combined to provide clues to using analogies effectively. In order to increase the probability of a high level of prior knowledge, analogies should be derived from a domain that is familiar to students. The number of corresponding attributes between the vehicle and target should be large. Additionally, teachers should give explicit directions concerning how the analogy is to be applied. Attention to these factors may enhance the effectiveness of instructional analogies.

Development of Analogies

Analogy materials consisting of texts and diagrams were composed for each of three science topics. These were the human digestive, nervous and circulatory systems. The digestive system was paralleled to a garbage disposal system of the future. Figure 1 shows a portion of this text. The nervous system analogy was dual in nature. Nervous system structure was analogous to a mainframe computer network. Nerve impulse transmission was approached via comparison to passing a note in a classroom. The final analogy compared the circulatory system to a typical school day. In addition, other concepts that were not included in one of the major analogies were addressed through analogical statements. For instance, the increase in absorption surface area created by microvilli was addressed by describing a shoreline with many peninsulas and inlets.

Two primary considerations in the compositions of the analogies were that they be derived from a familiar domain and have a high degree of attribute match to the target information. Each of the analogy domains (in particular, note-passing and typical school day) should have been familiar to the students. Thus, a reasonably adequate level of prior knowledge was expected. In addition, attributes or concepts related to the target information were matched to attributes of the analogy. Two science educators evaluated each analogy by indicating whether or not the analogy could account for each target concept. This information was used to compute the percent of target concepts accounted for by the analogy (Table 1).

Each analogy text was six to eight pages in length. Additionally, the analogies were supplemented with diagrams of the analogy vehicles (e.g., a garbage disposal system) and a summary chart which matched vehicle and target concepts.

Description of Instruments

Prior knowledge was assessed one week prior to the treatment period. A 30-item, four alternative multiple choice test was used to assess prior knowledge of the analogy vehicles. The test was divided into 10 item subtests related to the analogies for each of the three instructional units. Content validity was assessed by having a teacher and two colleagues review the items by selecting answers, keying items to objectives and suggesting revisions. Rater agreement was unanimous for over 85% of the items.

Students were assigned a prior knowledge score for each unit based on the number of correct answers on the corresponding subtest. These data were used to block students into low, middle and high prior knowledge categories. The distributions of prior knowledge subtest scores clustered near the top of the scale because of student familiarity with the analogy vehicles. On two of the subtests, over 80% of the students scores above 80%. The clustering of scores and shortness of the subtests contributed to the low Cronback's alpha reliability coefficients (Nie & Hull, 1981). They were .49 for the garbage disposal, .44 for the computer network/note-passing, and .20 for the school day analogies (Table 2).

Cognitive ability was also assessed prior to treatment by a 12-item version of the group Assessment of Logical Thinking (Roadrangka, Yeany & Padilla, 1983). GALT is a four-alternative, double multiple choice exam in which students must select both an answer and a justifiction from two sets of alternatives. In this study, GALT had a coefficient alpha of .68 (Table 2). Reports of the test suggest that it adequately measures conservational, proportional, correlational, probabilistic, combinatorial and controlling variables reasoning modes. Its author reported an overall validity coefficient of .71 (Roadrangka, et al., 1983).

Students with a raw scores below five on the GALT test were categorized as concrete operational while those scoring five or more were classified as transitional/formal operational. These two groups of students were identified because of the conflicting nature of previous research as to whether or not concrete operational students could benefit from the use of instructional analogies.

An achievement test consisting of multiple choice, identification and matching items was constructed for each of the three units. Test items were keyed to instructional objectives. The researcher and two colleagues assessed content validity by selecting correct answers and matching items to objectives. Rater agreement was over 90% for each test. With regard to the cognitive domain of Bloom's taxonomy, knowledge, comprehension and application level items were included on each test (Gronlund, 1971). Cronbach's alpha reliability coefficients were .66 for the digestive test, .74 for the nervous system test, and .85 for the circulatory system test. Table 2 shows the achievement test characteristics.

Students in the analogy-based instruction group were given an additional item on each test which entailed matching the corresponding attributes between the analogy vehicle and the target information. These items were used in an effort to ascertain the level of understanding of the analogies. Matching item data were correlated with achievement test scores.

Procedures

The study was conducted with 132 biology students (grades 9-11) in a suburban upper-middle class school. Four intact classes and two instructors were used. One instructor taught analogy-based lessons in the morning and conventional lecture-based lessons in the afternoon. The other teacher used the treatments in reverse order.

A 2x2x3 (treatment x cognitive ability level x prior knowledge level) fixed factor design was used in the study. The numeric grade from the previous quarter of biology served as the covariate. In order to be included in the data analysis of a given unit, students had to be in class during all instructional periods related to that unit.

Each of the three instructional periods was two days followed by an achievement test on the third day. During the first day of instruction in the analogy-based treatment, students were allotted 30 minutes to read the analogy and approximately 15 minutes of questions and discussion. The second day involved matching attributes of the analogy vehicle to the target information. Students were instructed to use the analogy as a means for organizing target information. This procedure was followed on all units.

Students in the conventional lecture-based treatment read appropriate passages in their text (Haynes, 1978) followed by a question/discussion period. In addition, they received a list of unit objectives since the text passages did not correspond exactly to the analogy-based passages. This was done to help students focus on pertinent information. During the second day of instruction the teachers lectured on the appropriate biological system. Lecture was supplemented with overhead transparencies depicting the structure of the system.

Results

Students in the analogy-based instructional group showed higher achievement than those receiving conventional lecture-based instruction on all outcome measures (Table 3). For each test, the difference between treatment group was approximately one standard deviation. The treatment effect sizes related to digestive, nervous and circulatory achievement were .91, .81. and .95, respectively. Analysis of covariance data for each test indicates significant effects ($p=.001$) due to treatment (Table 4). This table shows only treatment and cognitive ability level information. Prior knowledge and all interactions were not significant on any measures.

Transitional/formal operators outscored concrete operators on each outcome measure (Table 5). Analysis of covariance data, reveals significant differences related to cognitive ability for circulatory achievement (p=.001) and nervous achievement (p=.055). No differences were found for digestive achievement (Table 4).

Further examination of these data provides surprising findings. All achievement means of concrete operational students receiving analogy-based instruction were higher than the means of transitional/formal students in the lecture-based treatment. Pair wise t-tests showed significant differences between the group means for the digestive and circulatory system units (Table 6.)

Following each test, subjects in the analogy-based treatment group were administered an additional item which involved matching attributes of a human system to their corresponding analogy attribute. Scores from these items were used to group students into levels of analogy comprehension. Students were classified as low comprehenders if they had incorrect responses on at least one third of the matches (below 67%). High comprehenders were those students who answered the entire item correctly or transposed no more then two responses.

Table 7 displays the mean achievement scores of the low and high comprehenders. Students with high levels of analogy comprehension had higher achievement than those with low comprehension levels. Pair-wise t-test indicate significant differences on all three measures (Table 7).

Discussion of Results

Significant differences favoring analogy-based treatment were found on all achievement measures. One possible explanation is that the analogy provided a schema or organization for target information. This contention is supported by the research of Hayes and Tierney (1982) that used a baseball/ cricket /. In particular, the analogy relating the circulatory system to a school day exemplifies provision of a schema. Subjects in the study possessed knowledge of the usual sequence of events during a school day. The analogy helped to match these known sequential events to a series of corresponding circulatory occurrences.

Another possible explanation for the achievement edge maintained by the analogy-based group involves the visual nature of the analogies. The classroom note-passing analogy used to explain nerve impulse transmission is a case in point. It is difficult to visualize a nerve impulse. While a note certainly doesn't bear a physical resemblance to an impulse, they are similar in function in that each transmits information. More importantly, most students have experienced the note-passing phenomenon as either a participant or spectator. This concurs with the ideas of Khatena (1973) and Templeton (1973) which state that analogies can make new information more visual.

A third possible explanation is that the analogies acted as advance organizers by providing a coherent set of connecting links for subsequent target concepts. In essence, the analogy may have functioned like an outline of the lesson. Studies by Mayer (1980) and Mayer and Bromage (1980) that used analogies as advance organizers yielded similar favorable results.

The degree of attribute match between analogy vehicles and target information was also strong. Therefore, nearly all target concepts could be linked to a corresponding component of the analogy vehicle. Students in the lecture-based treatment were presented target information in the same sequence as those in the analogy-based group but did not receive a structured set of connecting links prior to presentation of target information. Subsequently, organization of target material probably varied according to individual skills in this area. While organizational skills were not considered in this study, it may be that students are generally weak in the ability to arrange information in some sort of hierarchical fashion.

A final contributing factor to the differences between treatment groups may have been the texts. One weakness in the study is that the reading assignments of the two treatment groups did not cover exactly identical information. While students in the lecture-based groups received a list of objectives to help focus them on relevant information, there was no guarantee that these students used the objectives as a study guide.

Transitional/formal operational students showed significantly higher achievement on two of the measures but no significant differences were found for digestive system achievment. To some extent, these findings are in agreement with Cantu and Herron's (1978) assertion that formal operational students will show higher achievement then preformal students regardless of the teaching method.

When analogy-based concrete operators are compared with lecture-based transitional/formal operators, the results demonstrate the power of the analogy treatment in this study. The analogy-based concrete operators had significantly higher achievement on two of the measures. Kolodiy's (1975) assertion that traditional lecture is effective only for those at the highest level of formal operations may provide partial explanation for the achievement differences. Only 17 of 68 subjects in the lecture based treatment were formal operational, thus conventional lecture may have been an ineffective teaching method for the majority of students. The analogy-based instruction, however, was also dominated by teacher lecture. In this treatment, only 14 of 65 formal operational. Therefore, other factors also contributed to the achievement differences.

One explanation is that comprehension and use of analogies of this type involves only the ability to deal with similarities or match attributes.

Correlational reasoning skills may not be a prerequisite for analogy comprehension. Additionally, students typically possessed high levels of prior knowledge of the analogy vehicles. Thus, connecting links for the target information were probably pre-existant. Since the degree of attribute match between vehicle and target domains was high (from 76% to 90%), students could have connected most target information to its corresponding attribute. This, in turn, would also provide organization and structure to the target concepts.

Another contributing factor is that the analogy may have provided an alternate retrieval route at the time for testing. For example, students may have been able to recall the note-passing analogy and subsequently arrive at concepts related to transmission of nerve impulses.

It should be noted that the above discussion does not say that analogy-based concrete operators outperformed lecture-based formal operators. Further data analysis using three levels of cognitive ability (instead of two) needs to be conducted in order to compare concrete and formal operators.

Analyses of covariance suggest that levels of prior knowledge had virtually no effect on achievement differences. Certain problems arose with the prior knowledge variable as it was used in this study. First, student scores on prior knowledge subtests were clustered in the 80 to 100 percent range. Since the researcher desired analogy vehicles that would be common to student experience, it was difficult to construct test items that would discriminate among students. Because the scores were not evenly distributed, students classified as having low levels of prior knowledge were not markedly different from those in the high prior knowledge group.

Additionally, each subtest was only 10 items in length. A longer test may have helped to better discriminate among students. Prior knowledge subtest reliabilities were also relatively low due to their brevity and lack of distribution of scores. Any differences among subjects with varying levels of prior knowledge may have been masked because of low subtest reliabilities.

As stated previously, students generally possessed high levels of prior knowledge. Students in the analogy-based group were afforded the opportunity to use their knoweldge of the analogy vehicle in order to organize and assimilate target information. Lecture-based students possessed similar levels of prior knowledge but it was of little value to them because it wasn't linked to target information in any manner.

Implications

The results of this study suggest that high school biology students can benefit from analogy-based instruction, regardless of their cognitive developmental level. Prior knowledge of the analogy vehicles and the degree of attribute match between vehicles and target information were generally high. Therefore, students wer more apt to comprehend the analogies. In several previous studies which used instructional analogies, a lack of comprehension of the analogies was cited as a possible cause for the inability to increase student performance. If analogies are to be used effectively in instruction, it is important for the analogy vehicle to be common to student experience and/or visual in nature. The corresponding attributes between the analogy vehicle and target information should be highly matched. Teachers should then systematically explain the similarities between corresponding attributes.

The idea that analogies provide structure or organzation to target information cropped up frequently throughout the discussion of the results. If an analogy vehicle is common to student experience and prior knoweldge is high, then the structure for linking or anchoring target information probably already exists in students' minds. Matching target attributes to analogy vehicle attributes would then facilitate organized encoding of the new information. Subsequent retrieval may be enhanced because target information is encoded with an already entrenched knowledge network.

Certainly, analogies are not the sole method for organizing information. Supplying students with a lesson outline prior to instruction may yield similar results with respect to subsequent student achievement. Imposition of some type of coherent organization or target information would appear to be an important consideration prior to employing an instructional strategy.

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Table 1

Summary of Prepared Analogy Materials

Topic	Analogy Vehicle	Number of Target Attributes	Average Percent of Attributes Matched by Analogy	Materials Prepared
Human digestive System	Garbage disposal system of the future	34	85	Seven page text, 2 diagrams, 1 chart
Human nervous system	Computer network	37	76	Four page text, 1 diagram, 1 chart
Nerve impulse transmission	Passing a note	10	90	Two page text, 2 diagrams, 1 chart
Human circulatory system	Typical school day	34	79	Five page text, 2 diagrams, 2 charts

Table 2

Summary of Test Characteristics

Name	Number of Items	$\bar{X}$	s	Mean Item Difficulty	Reliab. (Cronbach's α)
Garbage Disposal Prior Knowledge	10	7.34	1.58	.73	.49
Computer Network/ Note-Passing Prior Knowledge	10	8.43	1.30	.84	.44
School Day Prior Knowledge	10	8.82	1.04	.88	.20
Group Assessment of Logical Thinking	12	6.52	2.50	.65	.68
Digestive System Achievement	28	21.71	3.12	.78	.66
Nervous System Achievement	22	13.62	3.76	.62	.74
Circulatory System Achievement	28	19.76	5.42	.70	.85

Table 3

Unadjusted and Adjusted Means, Standard Deviations and Frequencies for the Digestive, Nervous and Circulatory System Achievement Tests

	Test								
	Digestive System (max = 28)			Nervous System (max = 22)			Circulatory System (max = 28)		
Treatment	n	$\bar{X}$	s	n	$\bar{X}$	s	n	$\bar{X}$	s
Analogy-Based Instruction	58	23.21 (23.03)*	2.81	56	15.11 (14.90)*	4.03	58	22.38 (22.20)*	4.31
Lecture-Based Instruction	64	20.86 (20.52)*	2.76	64	12.31 (12.50)*	2.97	57	17.10 (17.30)*	5.15

*Means adjusted for winter quarter grade.

Table 4

Analysis of Covariance Summary Table
for
Digestive, Nervous and Circulatory Achievement*

Test	Source of Variation	df	SS	MS	F	p
Digestive System Achievement Test	Treatment	1	192.44	192.44	28.97	.001
	Cognitive Level	1	.09	.09	.01	.910
	Residual	105	697.58	6.64		
Nervous System Achievement Test	Treatment	1	118.79	118.79	11.49	.001
	Cognitive Level	1	39.11	39.11	3.78	.055
	Residual	100	1033.66	10.34		
Circulatory System Achievement Test	Treatment	1	654.47	654.47	33.33	.001
	Cognitive Level	1	78.32	78.32	3.99	.001
	Residual	97	1904.56	19.63		

*Prior knowledge and all interactions were not significant for any measures.

Table 5

Observed Means, Standard Deviations and Frequencies of Concrete and Transitional/Formal Students for the Biology Achievement Tests

Measure	Cognitive Level	n	$\bar{X}$	s
Digestive System Achievement Test (max score=28)	Concrete	28	21.21	3.49
	Trans/Formal	93	21.90	3.00
	Combined Group	121	21.74	3.12
Nervous System Achievement Test (max score=22)	Concrete	30	12.20	3.54
	Trans/Formal	89	14.16	3.70
	Combined Group	119	13.66	3.74
Circulatory System Achievement Test (max score=28)	Concrete	27	17.67	5.92
	Trans/Formal	87	20.56	4.94
	Combined Group	114	19.88	5.31

Table 6

Comparisons of Unit Test
Means of Concrete Operational Students Receiving
Analogy-Based Instruction and Transitional/Formal
Students Receiving Conventional Lecture-Based Instruction

Measure	Means	Frequencies	*t*-value	*p*
Digestive System Achievement Test	$\bar{X}_1 = 22.83$ $\bar{X}_2 = 20.53$	$n_1 = 12$ $n_2 = 47$	2.28	.025
Nervous System Achievement Test	$\bar{X}_1 = 13.17$ $\bar{X}_2 = 12.71$	$n_1 = 12$ $n_2 = 45$	*	*
Circulatory System Achievement Test	$\bar{X}_1 = 20.08$ $\bar{X}_2 = 17.90$	$n_1 = 13$ $n_2 = 42$	1.30	.10

Note: 1 = concrete operational students receiving analogy-based instruction

2 = transitional/formal operational students receiving conventional lecture-based instruction

*No significant difference found

Table 7

Comparison of Achievement Test Means for Students with Low and High Analogy Comprehension Levels

	Test								
	Digestive System (max=28)			Nervous System (max=22)			Circulatory System (max=28)		
	n	$\bar{X}$	s	n	$\bar{X}$	s	n	$\bar{X}$	s
Low Comprehension of Analogy	7	20.71	1.89	23	12.96	4.38	9	17.78	3.63
High Comprehension of Analogy	43	23.84	2.40	25	16.76	3.15	37	24.30	2.97
t		3.28			3.47			5.60	
p		<.005			<.005			<.005	

Figure 1. Sample Analogy Text

Many of us have probably heard someone describe their eating habits in terms of a human garbage disposal. There are, in fact, certain parallels between a human digestive system and a garbage disposal. I want you to imagine the efficient home of the future where garbage is broken down and used to supply the energy needs of that home. Let's take a little tour.

Typically, a disposal unit is located below the sink. The drain will have rubber flaps to funnel the garbage down toward the grinding unit. When garbage is pushed past the rubber flaps into the grinding area it is wise to turn on the faucet to let some water flow into the grinding area also. A switch is turned on and the garbage is broken down into smaller pieces by the teeth of the grinding unit.

Let's compare this much with our own digestive system. We put food into our mouths just like we put garbage into the disposal. This process is called ingestion. We use our tongue and cheeks to help manipulate or move the food around so that we can chew it much like th rubber flaps help to guide the garbage toward the grinding unit. As we chew our food, the teeth break the food down into smaller pieces as does the grinding unit of our disposal. By breaking the food down into smaller pieces, we increase the amount of surface area. For example, think of an apple. If you swallowed it whole, the only surface area would be its bright red skin. But suppose you cut it into 12 wedges. Not only would all of the skin be exposed, but the sides of the wedges would be exposed, as well. If each wedge was sliced a few more times, then even more surface area would exist. So as you can see, if something is physically broken down into smaller and smaller pieces, then more surface area is exposed. This physical digestion is important for the chemical digestion that occurs later.