DOCUMENT RESUME

ED 396 259 CS 012 500

AUTHOR	Glynn, Shawn M.
TITLE	Effects of Instruction To Generate Analogies on Students' Recall of Science Text. Reading Research Report No. 60.
INSTITUTION	National Reading Research Center, Athens, GA.; National Reading Research Center, College Park, MD.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE	96
CONTRACT	117A20007
NOTE	20p.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Instructional Effectiveness; Junior High Schools; Middle Schools; Reading Research; *Recall (Psychology); *Science Instruction; *Scientific Concepts; Study Skills
IDENTIFIERS	*Analogies; Text Factors

ABSTRACT

A study examined the role that instructions to generate analogies can play when 56 middle-school eighth-grade and seventh-grade students learn a science textbook unit. The target concept on the unit was the cell and the key features of the concept were the cell parts and their functions. Prior to studying the unit on the cell, the students received a study guide, encouraging them to read carefully in preparation for a test on the unit. The study guide explained that the test would require the students to explain, in writing, the cell to another (hypothetical) student who was unfamiliar with the cell. The students in the experimental group were additionally instructed to generate analogies when they studied and to include these analogies in their explanations; these students were also given an example analogy in their study guide. Results indicated that the students in the experimental group included more analogies in their explanations than the students in the control group. In addition, the students in the experimental groups tended to recall more cell parts and functions than the students in the control group, but these differences were not statistically significant. Findings suggest that analogy instructions have the potential to increase text recall, but instructions in future studies should be more extensive and incorporate multiple examples of analogies. (Contains 20 references and 4 tables of data.) (Author/RS)

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The work reported herein is a National Reading Research Project of the University of Georgia and University of Maryland. It was supported under the Educational Research and Development Centers Program (PR/AWARD NO. 117A20007) as administered by the Office of Educational Research and Improvement, U.S. Department of Education. The findings and opinions expressed here do not necessarily reflect the position or policies of the National Reading Research Center, the Office of Educational Research and Improvement, or the U.S. Department of Education.

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National Reading Research Center
Universities of Georgia and Maryland
Reading Research Report No. 60
Summer 1996

Effects of Instructions to Generate Analogies on Students' Recall of Science Text

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Abstract. *The present study examined the role that instructions to generate analogies can play when eighth-grade and seventh-grade students learn a science textbook unit. The target concept in the unit was the* cell *and the key features of the concept were the cell* parts *and their* functions. *Prior to studying the unit on the* cell, *the students received a study guide, encouraging them to read carefully in preparation for a test on the unit. The study guide explained that the test would require the students to explain, in writing, the* cell *to another (hypothetical) student who was unfamiliar with the* cell. *The students in the experimental group were additionally instructed to generate analogies when they studied and to include these analogies in their explanations; these students also were given an example analogy in their study guide. The results indicated that the students in the experimental group included more analogies in their explanations than students in the control group. In addition, the students in the experimental group tended to recall more cell parts and functions than the students in the control group, but these differences were not statistically significant. These findings were interpreted to suggest that analogy instructions have the potential to increase text recall, but instructions in future studies should be more extensive and incorporate multiple examples of analogies.*

Meaningful learning from text involves a process of integrating new knowledge with existing knowledge. Students should learn concepts as organized networks of related information, not as lists of facts (Anderson, 1990, 1993), because rote learning results in knowledge that is easily forgotten and not readily transferable to new situations that the student may encounter. Teachers and textbook authors realize this but are not sure how to facilitate meaningful learning in students, particularly when concepts are complex.

Complex concepts are the rule rather than the exception in biology (e.g., the *cell*), chemistry (e.g., the *atom*), physics, (e.g., *gravity*), earth science (e.g., *precipitation*), and astronomy (e.g., the *sun*). Concepts such as these are introduced to students in textbooks during the middle school years. Learning these concepts from textbooks can be difficult for students. To facilitate students' meaningful comprehension of science text, teachers and text authors should help students relate new concepts to concepts with which they are already familiar (Glynn & Muth, 1994; Holliday, Yore, Alvermann, 1994; Roth, 1991). How can teachers and authors do this? One strategy that shows promise is to help students reason analogically about concepts.

The role of analogical thinking in teaching and learning science has received increasing attention in recent years (e.g., Lawson, 1993; Thagard, 1992). Analogies constructed by teachers or textbook authors were found to enhance students' recall of science text when certain operations were carried out (Glynn, Duit, & Thiele, 1995; Thiele & Treagust, 1995; Glynn, 1991, 1994; Harrison & Treagust, 1993; Treagust, Duit, Joslin, & Lindauer, 1992). These operations included: introducing the target concept to students, reminding students of the analog concept, identifying relevant features of the target and analog, mapping similarities, indicating where the analogy breaks down, and drawing conclusions. Some textbook authors routinely use analogies when introducing a new concept. For example, in a unit on the *cell*, DiSpezio, Linner-Luebe, Lisowski, Skoog, and Sparks (1994) compared the cell to a town:

> Imagine a small town or city. What are some of its parts? There are roads, factories, schools, and houses. There are power lines and telephone lines. Each person has a special job to do. Each building has a special use. All the people, services, buildings, and other structures work together to make the town function properly.
>
> A cell is like a small town or city. The different parts of a cell have special jobs. Each part helps the cell carry out its life processes. Each part helps to keep the cell working properly. Like the parts of a town must work together, the parts of a cell also must work together to live. . . . In a town, the mayor and city council make important decisions about the workings of the town. They govern the town. In a cell, the nucleus governs the cell. The *nucleus* is the control center for most of the cell's activities. (pp. 78, 80)

Other authors use analogies rarely, if at all. In such instances, it would be advantageous to students if they could strategically generate their own analogies to enhance their text learning.

The purpose of the present study was to determine if instructions to generate analogies could enhance middle-school students' recall of a science textbook unit. The unit was about the *cell*, including the cell parts and the functions of those parts. The *cell* was selected as the target concept because it has been identified by teachers as one of the most important biology concepts (Finley, Stewart, & Yarroch, 1982). Cells are the basic structural and functional units of living things and, therefore, are fundamental to an understanding of life processes.

Method

Participants

The participants were 56 (27 males and 29 females) seventh- and eighth-grade students from the science classes of a rural, public middle school. All students were between 11 and 13 years old (M = 12.18, SD = 0.62) and came from lower to middle socioeconomic homes; 11 of the students were African Americans, with no other minorities among the students.

Materials and Design

The students had not yet been taught a lesson on the cell this school year, nor had they read about it in their textbooks, but the concept had been covered at a more basic level in previous school years.

The materials included a study guide and a text. In the *control condition*, the study guide encouraged the students to study the text carefully and prepared the students for the test they would take after text study. In the *experimental condition*, the study guide additionally instructed the students to generate analogies when studying the text and to use these analogies in the test. The instructions to generate analogies were modeled from instructions to generate imagery, a strategy of interest in many text-learning studies (e.g., Gambrell & Jawitz, 1993; Gibson, Glynn, Takahashi, & Britton, 1995; Levin & Pressley, 1978). The analogy-generation instructions illustrated the operations that lead to an effective analogy.

The students read a 1,038-word text about *animal cells* that was adapted from a unit on *cells* in a leading middle school textbook, *General Science* (Alexander et al., 1989). This textbook was selected because its section on animal cells included only one short analogy, comparing *mitochondria* to "powerhouses." This analogy was deleted, so as not to confound the experimental manipulation. The text and an accompanying diagram of an animal cell focused on seven of the major cell parts and their functions. These parts were the *cell membrane*, the *nucleus*, the *cytoplasm*, the *ribosomes*, the *endoplasmic reticulum*, the *Golgi bodies*, and the *mitochondria*. The following excerpt about the cell membrane is representative of the text:

> Although cells have a wide variety of shapes, sizes, and colors, every cell has an outer covering. The covering that surrounds the cell is called the *cell membrane*. The structure of the cell membrane allows certain materials to pass through it and keep other materials out. The cell membrane has tiny openings that let water, food, and oxygen enter the cell. Waste products exit through the cell membrane. The cell membrane prevents harmful substances from entering and keeps useful substances inside.

Procedure

Within each class, the students were randomly assigned to the experimental and control conditions. Prior to text study, all students read a *study guide* that instructed them on how to study the text and how to prepare for the subsequent text. Students in the *control condition* received the following instructions in their study guide:

> The text you will read in this booklet is about *animal cells*. This important topic will be covered in class in a future lesson. In the next 30 minutes, please study this text carefully and learn the *parts of the animal cell* and the *functions* of these parts (that is, what the parts do). When you finish reading the booklet one time, please continue to review it and study it until the time is up. After 30 minutes, your booklet will be collected and you'll be asked to write an essay explaining animal cells to another student (a "pretend" student) who does not know anything about animal cells, their parts, and the functions of those parts. In your essay, you should include as much information as you can recall from the text you read. It's OK to guess.

Students in the *experimental condition* received the preceding instructions in their study guide, plus instructions to generate analogies. These instructions were:

> While you are studying, please try to think of analogies for the cell, its parts, and their functions. Compare things you know to the cell. For example, if you were studying about how the human eye works, you might compare it to a camera. To do this, you would do the following: (1) Think about the eye, (2) Remember what you know about a camera, (3) Think about the features of the eye and a camera, (4) Compare similar features (e.g., both have a lens, and the lens cap is like an eyelid), (5) Think about where the analogy breaks down (e.g., the camera lens is made of glass, but the eye's lens is made of cells), and (6) Draw conclusions (e.g., about causes of vision problems). Just as this analogy compared the camera to the eye, you should compare things you're familiar with to the cell, its parts, and their functions.

All students then read the same text on the animal cell. When 30 min had elapsed, the students were asked if they had sufficient time to study the text. All indicated "yes" and the booklets were collected.

After the text was collected, the students were tested by asking them to write an essay explaining the text. They received the following written instructions:

> Now, in the next 20 minutes, please write an essay to a "pretend" or "make-believe" student. Pretend that this student does not know anything about the cell, its parts, and their functions. Your task is to explain the cell to the student. Think about the text you read when you do this and try to recall as much information as you can. It's OK to guess.

In addition to the preceding instructions, the students in the experimental condition were also instructed to "remember the analogies you thought of when studying the text and use these analogies in your essay to explain the cell, its parts, and their functions."

All students completed their essays within 20 min, with no need for additional time. The students were then debriefed and thanked for their participation.

Performance Measures

All measures were scored by two independent raters, with interrater reliabilities of $r = .94$ or better on each measure. Disagreements between raters on items were then resolved by discussion. When scoring the essays, tallies were made of (a) the number of analogies used, (b) the number of correct animal cell-part names, (c) the number of incorrect animal cell-part names, (d) the number of correct animal cell-part functions, and (e) the number of incorrect animal cell-part functions. When scoring the cell parts and their functions, the raters compared them to a list of parts and functions compiled from the unit on cells and the glossary in the textbook, *General Science* (Alexander et al., 1989).

Table 1. Mean Numbers of Analogies Generated by Middle-School Students

	Grade	
Instructions	Seventh	Eighth
Analogy-generation		
M	3.36	4.29
SD	2.21	2.40
Control		
M	1.36	2.14
SD	1.15	2.03

Note. $N = 56$, with equal groups.

Results

Analyses of variance were used to assess the effects of the two between-subjects variables, Experimental Treatment and Grade Level, on the five performance measures: analogies generated, cell parts correctly recalled, cell parts incorrectly recalled, cell-part functions correctly recalled, and cell-part functions incorrectly recalled. In addition, Pearson product-moment correlations among the performance measures were computed. For all analyses, an alpha < .05 was the Type 1 error probability selected for all hypotheses.

Analogies Generated

The students who received analogy-generation instructions included significantly more analogies in their essays ($M = 3.83$) than students who received control instructions ($M = 1.75$), and this difference was statistically significant, $F(1, 52) = 14.95, p < .001$, $MSE = 4.02$. There was no statistically significant difference between eighth-grade students ($M = 3.22$) and seventh-grade students ($M = 2.36$) in the number of analogies generated. The interaction between the experimental treatment and the grade level of the students was not statistically significant. All means and standard deviations are reported in Table 1.

For students who received analogy-generation instructions, the analogies recalled and the rounded percentages of students recalling them were: the cytoplasm is like jelly/jello/gel (61%), the nucleus is like the brain of the cell (54%); the membrane is like a door/gate/entrance/exit (50%), the mitochondria are the powerhouses/engines/motors of the cell (46%), the cell is like an atom (43%), the cell is like a factory (39%), the nucleus is the control center of the cell (21%), the nucleus is like a computer in the cell (14%), and the endoplasmic reticulum is like a street/road (11%). Each of the remaining analogies (e.g., the cell is like an egg, the cell

Table 2. Mean Numbers of Cell Parts Correctly Recalled by Middle-School Students

	Grade	
Instructions	Seventh	Eighth
Analogy-generation		
M	4.14	4.21
SD	1.61	1.67
Control		
M	3.07	3.64
SD	1.54	1.69

Note. $N = 56$, with equal groups.

is like a jellyfish, and the cell is like a pond) was generated by less than 10% of the students. A sample excerpt from a student's essay that included an analogy is:

> An animal cell is the basic unit of life . . . the building block of tissues, like an atom in science. It carries out jobs like respiration, carrying messages, getting food, making the body go.

For students who received control instructions, the analogies recalled and the percentage of students recalling them were: the nucleus is like the brain of the cell (46%), cytoplasm is like jelly/jello (29%), the nucleus is like the control center of the cell (27%), and mitochondria are the powerhouses of the cell (14%). Each of the remaining analogies (e.g., the membrane is like a wall, a cell is like an animal, and cytoplasm is like air) was generated by less than 10% of the of the students.

Correct Cell Parts

The students who received analogy-generation instructions tended to recall more correct cell parts ($M = 4.18$) than students who received control instructions ($M = 3.36$), $F(1, 52) = 4.01$, $p < .07$, $MSE = 2.66$. There was no statistically significant difference between eighth-grade students ($M = 3.93$) and seventh-grade students ($M = 3.61$), and the interaction between Experimental Treatment and Grade Level was not statistically significant. All group means and standard deviations are reported in Table 2.

Since the experimental and control groups did not differ in recall of correct cell parts, and since the groups recalled cell parts in similar rank orders, the groups were combined to index the frequency of the parts recalled. The animal cell parts correctly recalled and the percentages of all students recalling them were: nucleus (77%), cell membrane (71%), cytoplasm (63%), mitochondria (48%), ribosomes

Table 3. Mean Numbers of Cell-part Functions Correctly Recalled by Middle-School Students

	Grade	
Instructions	Seventh	Eighth
Analogy-generation		
M	3.29	3.79
SD	2.02	1.89
Control		
M	2.29	2.93
SD	1.27	1.54

Note. $N = 56$, with equal groups.

(43%), and endoplasmic reticulum (38%). Each of the other cell parts (e.g., Golgi apparatus) was recalled by fewer than 10% of the students.

Incorrect Cell Parts

With respect to incorrect cell parts recalled, the numbers were small and there was no statistically significant difference between students who received analogy-generation instructions ($M = 0.65$) and students who received control instructions ($M = 0.68$). There was no statistically significant difference between eighth graders ($M = 0.54$) and seventh graders ($M = 0.79$), nor was the interaction of Experimental Treatment and Grade Level statistically significant.

For the experimental and control groups combined, the errors and the percentage of students making them were: cell wall (23%), chloroplasts (13%), and blood cells (11%). Cell walls and chloroplasts were errors because these are plant cell parts, not animal cell parts. Each of the other errors (e.g., plasma and paramecium) were made by fewer than 10% of the students.

Correct Cell-part Functions

The students who received analogy-generation instructions tended to recall more correct cell-part functions ($M = 3.54$) than students who received control instructions ($M = 2.61$), $F(1, 52) = 4.16$, $p < .06$, $MSE = 2.9$. There was no statistically significant difference between the recall of eighth-graders ($M = 3.36$) and seventh graders ($M = 2.79$). The interaction between Experimental Treatment and Grade Level was not statistically significant. All group means and standard deviations are reported in Table 3.

Incorrect Cell-part Functions

With respect to incorrect cell-part functions (paired with correct cell parts), the numbers were small and there was no statistically

Table 4. Correlations Among Performance Measures for Each Condition

	Performance Measures		
Instructions	1	2	3
Analogy-generation			
1. Analogies generated		.73*	.74*
2. Cell parts recalled			.93*
3. Cell-part functions recalled			
Control			
1. Analogies generated		.86*	.78*
2. Call parts recalled			.97*
3. Cell-part functions recalled			

Note. $N = 28$, for each correlation.
$*p < .001$.

significant difference between students who received analogy-generation instructions ($M = 0.50$) and students who received control instructions ($M = 0.68$). There was no statistically significant difference between eighth graders ($M = 0.54$) and seventh graders ($M = 0.64$). The interaction of Experimental Treatment and Grade Level was not statistically significant.

Correlations Among Performance Measures

The preceding analyses indicated that students with analogy-generation instructions tended to recall more cell information than students without these instructions. If analogy generation facilitates text learning, then it is reasonable to expect that the number of analogies generated would be positively correlated with the recall of cell information. This was found to be the case, as can be seen in the Pearson product-moment correlations reported in Table 4. The number of analogies generated were correlated (all p's $< .001$) with the recall of cell parts and cell-part functions. This was true not only in the experimental group where students were instructed to generate analogies, but also in the control group where some students spontaneously generated analogies without being instructed to do so.

Discussion

The present study examined the effects of analogy-generation instructions on middle-school students' recall of a science textbook unit. The target concept in the unit was the *cell*, and the key features of the concept were the cell parts and their functions. The analogy-generation instructions did induce students to include analogies in their recall. These analogies, in turn, were expected to help students map familiar schemas onto new schemas, thereby making the new schemas more meaningful and memorable. The analogy-generation instructions did tend to improve students' recall of cell parts and functions, but this difference was not statistically significant. And, analogy generation by students was related to recall, but this finding was correlational, not causal. Thus, the present findings provided only limited support for the hypothesis that analogy-generation instructions can enhance students' text learning. This was unexpected because analogies provided by teachers and textbook authors have been found in other studies to improve students' text learning.

It is possible that the instructions in the present study were relatively ineffective because they were not sufficiently detailed. The instructions provided students with only one example of an analogy—a comparison of a camera to the human eye. It may be that multiple analogies on several topics are needed for students to comprehend, generalize, and apply the operations that lead to effective analogies. It also may be that middle-school students require more than just instructions; the students may need explicit training and practice in generating analogies in order for them to benefit from this strategy. Middle-school students can apply this strategy spontaneously to some degree, as demonstrated by the presence of analogies in the recall of some students who received control instructions, but the application was very limited. On a more positive note, the students who did use analogies did not make any obvious errors associated with the analogies, such as recalling that the nucleus is an actual brain in the cell.

The rank order of cell parts correctly recalled by these middle-school students parallels the importance accorded these features in textbooks. In general, the nucleus, the membrane, and the cytoplasm are introduced first in textbooks (e.g., DiSpezio et al., 1994) and given more coverage than features such as the mitochondria, the ribosomes, the endoplasmic reticulum, and the Golgi bodies.

The students' recall revealed several misconceptions (alternative frameworks) about the cell. Some students thought that an animal cell has a cell wall (when, in fact, only plant cells have walls). This misconception seems to be based on students' belief that the animal-cell membrane alone is not up to the task of keeping the cell intact. The emphasis placed in textbooks on the membrane being *semipermeable* may unintentionally reinforce this misconception. Another misconception was that animal cells are built of blood cells and plasma. Students with this misconception seemed to equate blood plasma with cytoplasm. This too is understandable given the similarity of the names and the extensive coverage given to blood cells and plasma in most textbooks. Misconceptions such as these are probably not a cause for alarm because they are "normal" consequences of meaningful text learning that arise when students integrate their knowledge (Glynn & Duit, 1995). Teachers can warn students about such misconceptions when assigning textbook reading and, thereby, help students to avoid them.

In conclusion, this study has shown that analogy-generation instructions can increase students' generation of analogies when learning science text. The students' analogies, however, were only marginally effective in enhancing text recall. In future studies, multiple analogies will be included in the instructions in order to help students activate, generalize, and apply the operations that lead to effective analogies. In addition, it also may be necessary to train the students in analogy generation and give them practice with sample texts. Given the demonstrated effectiveness of teachers' analogies and textbook authors' analogies in increasing students' text learning, it is well worth the effort to develop strategies by which students can generate their own analogies and become more autonomous in their text learning.

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