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ABSTRACT

A study examined the role that an elaborate analogy can play when high school students learn a concept from a leading science textbook. The elaborate analogy had graphic and text components that integrated and mapped key features from the analogy (a factory) to the target concept (an animal cell). The target features were parts of the cell and, by association, their functions. Subjects were 72 ninth-grade students in 3 standard biology classes of an urban, public high school. The analogy increased the students' recall of the target features in the analogy, but not the other features. By mapping the features of the familiar factory schema onto those of the animal cell, the analogy presumably acted as a mediator and made the corresponding features of the animal cell more meaningful and memorable. The students did not make any errors associated with the analogy during recall; however, the students did make other errors that revealed basic misunderstandings about cells. (Contains 34 references, and 2 tables and 3 figures of data.) (Author/RS)

# Learning from Science Text: Role of an Elaborate Analogy

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READING RESEARCH REPORT NO. 71
*Winter 1997*

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The work reported herein is a National Reading Research Center 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
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# Learning from Science Text: Role of an Elaborate Analogy

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**Abstract.** *The present study examined the role that an elaborate analogy can play when high school students learn a concept from a leading science textbook. The elaborate analogy had graphic and text components that integrated and mapped key features from an analog (a factory) to the target concept (an animal cell). The target features were the parts of the cell and, by association, their functions. The analogy increased the students' recall of the target features in the analogy, but not the other features. By mapping the features of the familiar factory schema onto those of the animal cell, the analogy presumably acted as a mediator and made the corresponding features of the animal cell more meaningful and memorable. The students did not make any errors associated with the analogy during recall; however, the students did make other errors that revealed basic misunderstandings about cells.*

In 1665, Robert Hooke examined thin slices of cork through a light microscope. Hooke noted that the cork seemed to consist of tiny cavities surrounded by thin walls. Hooke called the cavities *cells* because they reminded him of the small rooms that monks lived in. More than 300 years later, Lewis Thomas (1974) wrote:

> I have been trying to think of the earth as a kind of organism, but it is no go. I cannot think of it this way. It is too big, too complex, with too many working parts lacking visible connections. The other night, driving through a hilly, wooded part of southern New England, I wondered about this. If not like an organism, what is it like, what is it *most* like? Then, satisfactorily for that moment, it came to me: it is *most* like a single cell. (p. 10)

Throughout the history of science, scientists and scientist educators have used analogies to explain their observations (Hesse, 1966; Hoffman, 1980; Lawson, 1993; Thagard, 1992). Analogies have been particularly useful when a new perspective must be adopted to understand observations (Brown, 1993; Clement, 1989, 1993). It is not surprising, therefore, that textbook authors routinely use analogies to explain science concepts to students. Authors frequently preface their explanations with expressions, such as "Similarly," "Likewise," "Just as," and "That is comparable to." These expressions are all ways of saying, "Let me give you an analogy." Authors are becoming increasingly aware that students have trouble learning from science texts (Finley, 1991;

**ANALOGY**

| | | | | | | |
|---|---|---|---|---|---|---|
| ANALOG | .... | compared with | | .... | TARGET |
| Feature | .... | " | " | .... | Feature |
| 1 | .... | " | " | .... | 1 |
| 2 | .... | " | " | .... | 2 |
| 3 | .... | " | " | .... | 3 |
| n | .... | " | " | .... | n |

*Figure 1.* An abstract representation of an analogy, with its constituent parts.

Holliday, 1991). By drawing analogies for students, authors are attempting to make science texts more learnable.

Unfortunately, authors' analogies are often ineffective, failing to increase students' recall of text information (Gilbert, 1989). That is because authors, lacking guidelines for using analogies, sometimes use them unsystematically, often causing confusion and misconceptions in their students (Thiele & Treagust, 1994). The distinctions among a target concept, features of the concept, examples of the concept, and an analogy become blurred in students' minds. One solution, of course, would be to advise authors not to use analogies in textbooks. That would be unrealistic because authors, like all human beings, are predisposed to think analogically, and they will use analogies, consciously or unconsciously, during explanation (Lakoff & Johnson, 1980; Piaget, 1962). The better solution is to adopt guidelines for constructing and using analogies in science text. One source of guidelines is the Teaching-with-Analogies Model (Glynn, 1991, Glynn, Duit, & Thiele, 1995; Harrison & Treagust, 1993; Thiele & Treagust, 1995).

In the Teaching-with-Analogies Model, an analogy is drawn by identifying similarities between two concepts. In this way, ideas can be transferred from a familiar concept to an unfamiliar one. The familiar concept is called the *analog* and the unfamiliar one the *target*. Both the analog and the target have *features* (or subconcepts). If the analog and the target share similar features, an analogy can be drawn between them. A systematic comparison, verbally or visually, between the features of the analog and target is called a *mapping*. An abstract representation of an analogy, with its constituent parts, appears in Figure 1.

The guidelines in the Teaching-with-Analogies Model were developed from *task analyses* of the analogies used in science textbooks by exemplary authors, such as Paul Hewitt (1993). A task analysis is "the process of breaking down an instructional task to determine its essential components and the relationship of those components" (Goetz, Alexander, & Ash, 1992, p. 337; see also Ryder & Redding, 1993; Wiggs & Perez, 1988). The task analyses identified six guidelines for drawing analogies in science text:

1. Introduce the target concept;
2. Cue readers' recall of the analog concept;
3. Identify relevant features of the target and analog;
4. Map similarities;
5. Indicate where the analogy breaks down;
6. Draw conclusions.

The purpose of the present study was to determine if the addition of an *elaborate analogy* to a unit in a leading science textbook could enhance high-school students' learning of a major concept. Learning was assessed by measuring the students' recall of the concept's features. The elaborate analogy integrated graphic and text components that mapped key features of the target concept. In the past, the analogies manipulated in text-learning studies did not do this. The elaborate analogy also was constructed following the guidelines in the Teaching-with-Analogies Model. The role of the analogy was to map features of a familiar schema (conceptual structure) onto a new, but in some ways similar, schema; thereby making features of the new schema more meaningful and memorable to the students. It was hypothesized, therefore, that the elaborate analogy would increase the students' learning of the target concept's features.

## Method

### *Participants*

The participants were 72 (38 males and 34 females) ninth-grade students in three standard biology classes of an urban, public high school. In the three classes, there were 28, 22, and 22 students, respectively. All students were between 13 and 15 years old ($M$ = 14.10, $SD$ = 0.53) and came from lower to middle socioeconomic homes; 23 of the students were African Americans, with no other minorities among the students.

### *Materials and Design*

The *animal cell* was selected as the target concept to be learned by the students. The features of the concept to be learned included the names of major cell parts and the functions of those parts. The *cell*, in general, has been identified by high school teachers as one of the most important biology concepts (Finley, Stewart, & Yarroch, 1982) because it is fundamental to an understanding of biological processes. Recalling the major cell parts and their functions represents a very basic level of understanding, but it is a necessary one if students are to progress in their understanding of the cell.

In the *comparison (control) condition*, students read a standard text (in booklet form) on the structure and function of the animal cell. The students were asked to study the text as they normally would in preparation for a standard classroom test. This text was a 1,657-word

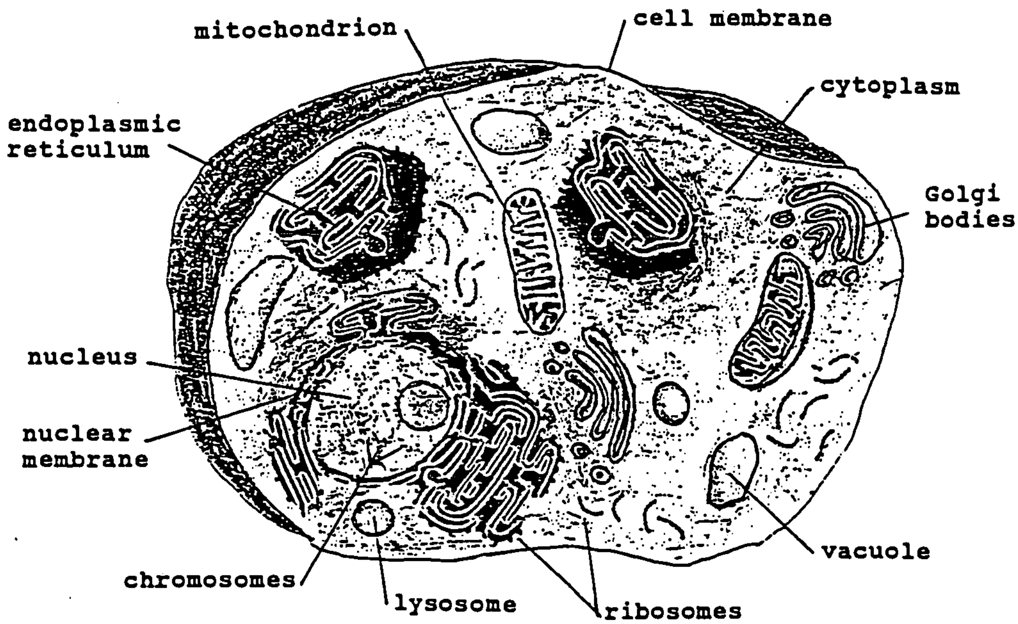


*Figure 2.* An illustration of an animal cell.

section from the unit *Cells* in the students' textbook, *Modern Biology* (Towle, 1989, pp. 66–72), a leading high school textbook. The following excerpt is representative of the section:

> The nucleus is the site where nucleic acids are synthesized and it therefore directs the activities of the cell. It is surrounded by a double membrane called the **nuclear envelope**. Substances enter and leave the nucleus through holes in this envelope called nuclear pores. The pores form channels that allow large molecules, such as nucleic acids, to pass back and forth from the interior of the nucleus to the cytoplasm.
>
> Inside the nuclear envelope is a dense, protein-rich substance called nucleoplasm. The nucleoplasm contains fine strands of **chromatin**, a combination of DNA and proteins. When a cell is dividing, a strand of chromatin coils up and condenses and can be seen under a microscope as a **chromosome**.

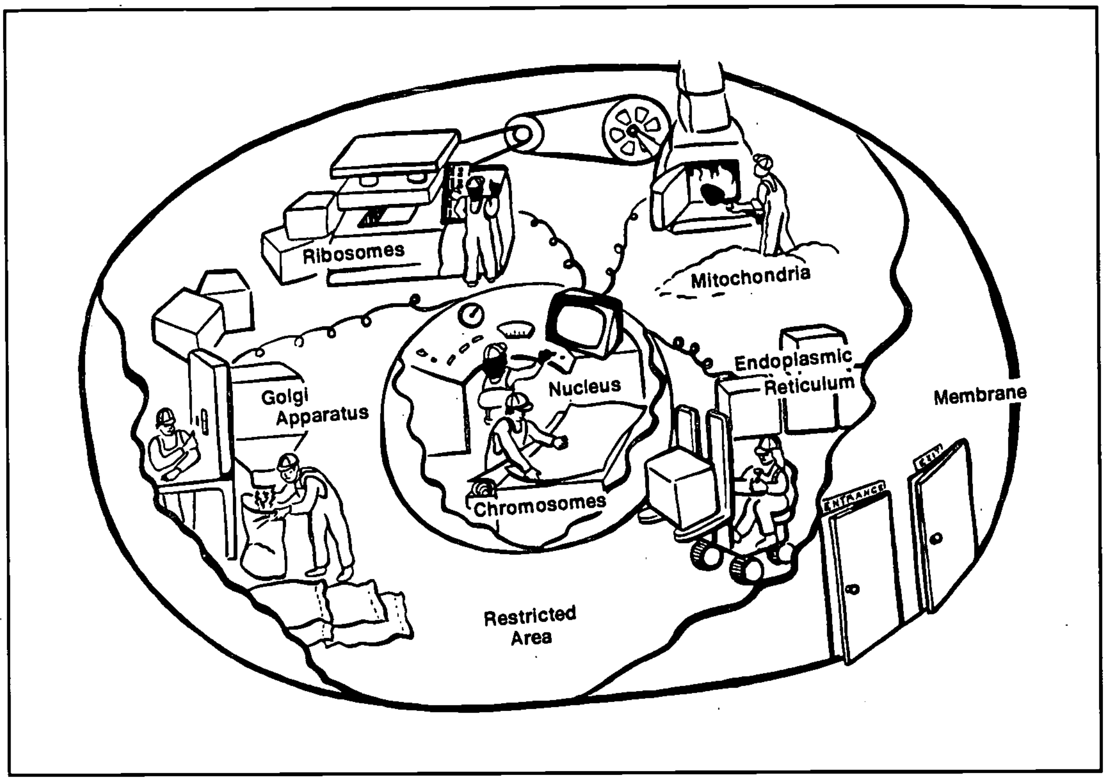


*Figure 3.* An analogy drawn between a factory and an animal cell.

> Chromosomes thus are mostly DNA, the genetic information of the cell.
>
> Most nuclei also contain at least one special body called the **nucleolus**. Ribosomes are synthesized and partially assembled in the nucleolus. After assembly they migrate to the cytoplasm. (p. 72)

In the *experimental condition*, students read an analogy-enhanced text that was created by adding an elaborate analogy to the standard text. The elaborate analogy was inserted in the beginning of the standard text, just after the introduction and an illustration of an animal cell (see Figure 2). The analogy compared a factory (analog) to an animal cell (target concept)—this is a popular analogy, often recommended in journals for teachers (e.g., Cavese, 1976). The analogy used illustration (see Figure 3) and text to identify seven corresponding features (subconcepts) of the factory and cell, map the features, point out where the analogy breaks down, and draw conclusions. The text component (shown in Box 1) explained the analogy to students.

### *Measures*

*Prior achievement.* The students' achievement test scores were available for *Biological*

An animal cell is like a miniature factory that carries out activities important for life. In this analogy, there are the following similar features:

| FACTORY | ANIMAL CELL |
|---|---|
| 1. restricted entrance/exit | selectively permeable membrane |
| 2. production machines | protein-producing ribosomes |
| 3. internal transport and warehouse system | endoplasmic reticulum |
| 4. assembly and external distribution system | Golgi apparatus |
| 5. power generators | mitochondria |
| 6. control center | nucleus |
| 7. design blueprints | chromosomes |

Think carefully about each of the preceding similarities and study the illustration. But remember that this analogy, like all analogies, breaks down in places. For example, the selectively permeable membrane envelops the entire cell and has many tiny openings, whereas the entrances to the factory are in specific locations and are few in number. In general, however, if you remember how an animal cell is like a factory, it will be easier for you to remember the cell parts and their functions. It also will help you to remember that a cell is a collection of smaller, essential structures that interact and perform important functions that support life.

**Box 1.** Analogy text used to identify corresponding features (subconcepts).

*Principles*, the first unit in *Modern Biology* (Towle, 1989) and the one that prepared students for the following unit on cells. The achievement test consisted of 120 standard multiple-choice and completion items from the teacher's item bank that accompanies *Modern Biology*. The students' scores ($M$ = 86.99, $SD$ = 17.39) were used as a covariate to control for students' prior knowledge and to increase the power of the statistical tests.

*Cell parts*. As a *pretest* prior to text study, and again as a *posttest* after text study, students drew an animal cell and labeled its parts. The cell parts pretest, like the achievement measure, was used as a covariate to control for prior knowledge differences and to increase statistical power.

The pretest results provided an index of the animal cell parts correctly remembered from a lesson taught the previous school year. The cell parts correctly recalled ($M$ = 1.31; $SD$ = 1.19) and the rounded percentages of students recalling those parts were: cell membrane (53%), nucleus (49%), cytoplasm (14%), chromosomes (8%), and DNA (4%). Other cell parts (e.g., mitochondria) were recalled by less than 2% of the students. The errors were: cell wall (a plant cell part, 32%), electrons (10%), proton (8%), plasma (8%), white/red blood cell (7%), neutron (6%), bacteria (3%), and atom (3%). Other errors (e.g., platelets) were made by less than 2% of the students.

*Cell-part functions*. After text study, the students also recalled the functions of cell parts. The cell part functions were precisely defined in the text versions read by students. For example, the functions of the cell membrane and nucleus were, respectively:

> The cell membrane . . . separates the cell from its external environment. It gives shape and flexibility to the cell. [It] is a complex barrier that keeps out some molecules but allows others to permeate, or pass, into the inside of the cell. (Towle, 1989, p. 66)

> The nucleus is the site where nucleic acids are synthesized and it therefore directs the activities off the cell. (Towle, 1989, p. 72)

*Perceived analogy value*. After text study, the students responded to a short questionnaire. The students in the experimental condition were asked: Did the factory analogy in the beginning of the text help you to think about cell parts and their functions? The students responded on a Likert-type, 5-point scale, with the following range: 1 = no, 3 = somewhat, and 5 = yes. The students then explained, in writing, their answers to this question.

### *Procedure*

In each of the three classes, the students were randomly assigned to the experimental and control conditions, with the restriction that there be an equal number of students in each condition in each class. All students were read the following instructions for the cell-part pretest:

> The first thing we're going to do today is draw an animal cell based on what you can recall from lessons in previous school years. In the next 10 minutes, on the sheet in front of you, please draw a typical cell from an animal (e.g., a bear or fox) and all the things inside the cell. Write the names of those things, using arrows to point to the things. It's ok to guess. You may remember a lot or only a little—that's fine. Just do the best you can.

After the students completed the cell-part pretest, they were given their texts with the following instructions:

> This booklet is based on a section of your textbook about *animal cells*. This important topic will be covered in class in a future lesson. In the next 30 minutes, please study this booklet carefully and learn the *parts of the animal cell* and the *functions* of these parts. After 30 minutes, the booklets will be collected and you'll be asked to recall, as best you can, this information. Please study quietly.

When 30 min had elapsed, the booklets were collected and the students completed a short written questionnaire that asked: Did you have enough time to study the booklet? The students responded on 5-point scale, with a range of 1 = no, 3 = somewhat, and 5 = yes. All students marked "5" (yes). The version of the questionnaire given to the students in the experimental condition also included the analogy-value question described previously.

After the questionnaire was completed, the cell-part posttest was administered to the students, with these instructions:

> Now, once again, in the next 10 minutes, please draw a typical animal cell and all the things inside the cell. As before, write the

**Table 1**
*Correlations between Covariates and Performance Measures* (N = 72)

| | Covariates | | |
|---|---|---|---|
| Performance Measures | Achievement | Pretest Component A | Pretest Component B |
| Cell parts in analogy | .37** | .53*** | — |
| Cell parts not in analogy | .32** | — | .30* |
| Definitions of cell parts in analogy | .56*** | .32** | — |
| Definitions of cell parts not in analogy | .51** | — | .53*** |

**Note**. Pretest components A and B refer to those cell parts in the analogy, and not in the analogy, respectively.
*$p < .05$. **$p < .01$. ***$p < .001$.

> names of those things, using arrows to point to the things. It's ok to guess. Think about the information in your booklet when you do this please.

All the students completed the cell-part posttest in 10 min, and all stated they had no need for additional time at the end of 10 min. The students were then asked to provide cell-part functions:

> Please make a list of all the animal cell's parts. Next to each part, please write what that part does—that is, what is the function of that part. It's ok to guess. Think about the information in your booklet when you do this please.

All students completed the cell-part definitions within 15 min, with no need for additional time. The students were then debriefed and thanked for their participation.

### *Scoring*

All measures were scored by two independent raters, with interrater reliabilities of $r$ = .98 or better on each measure. Disagreements between raters on items were then resolved by discussion. When scoring the cell part pretests and posttests, tallies were made of (a) correct animal cell-part names (requiring only approximate structural appearance and location) and (b) erroneous animal cell-part names. When scoring the cell-part functions, the raters compared them to a list of functions compiled from the unit on cells and the glossary in *Modern*

*Biology* (Towle, 1989) and gave full credit for student responses that were synonomous.

## Results

Analyses of covariance were used to test predicted differences between the experimental and control groups on the measures of performance. The two covariates in each analysis were the students' prior achievement and the relevant component of their cell-part pretest scores. The relationships between the performance measures and the covariates were linear, and the regression slopes were equal, thus satisfying these assumptions of analysis of covariance (Stevens, 1992). As can be seen in Table 1, the covariates were significantly correlated with all performance measures, $ps < .05$. The means reported in the following sections are adjusted ones, unless otherwise specified.

### *Cell Parts*

The elaborate analogy enhanced students' recall of the seven cell parts that were in the analogy. For these cell parts, the posttest recall of students in the experimental group ($M = 4.37$) was significantly higher than that of students in the control group ($M = 2.91$), $F(1, 68) = 4.56, p < .05, MSe = 1.40$.

Did the elaborate analogy enhance students' recall of cell parts that were not in the analogy? This question was answered by analyzing students' recall of the 11 other animal-cell parts in the text, plus parts that were not in the text, but were nevertheless correct. The posttest recall of non-analogy cell parts was not found to be significantly different in the experimental ($M = 2.33$) and control groups ($M = 2.11$), $F < 1$. Thus, the elaborate analogy only affected cell parts that were in the analogy.

### *Index of Cell Parts*

Although the recall of cell parts in the analogy was higher in the experimental group than in the control, the two groups recalled cell parts in similar rank orders of frequencies, Spearman's rho = .96, $p < .01$. Therefore, the groups were combined to index the cell parts recalled. The animal cell parts correctly recalled and the rounded percentages of all students recalling them were: nucleus (96%), cell membrane (92%), cytoplasm (61%), ribosomes (47%), mitochondria (32%), nucleolus (31%), DNA (28%), endoplasmic reticulum (24%), chromosomes (18%), Golgi apparatus (18%), lysosomes (17%), nuclear envelope (17%), protein (11%), vesicle (7%), and lipid (6%). Other cell parts (e.g., RNA and centriole) were recalled by fewer than 2% of the students. The errors were: cell wall (18%), plasma (6%), and white/red blood cells (4%). Other errors (e.g., protozoa) were made by fewer than 2% of the students.

### *Functions of Cell Parts*

The elaborate analogy enhanced students' recall of the functions associated with the seven cell parts in the analogy. For these parts, the function recall of students in the experimental group was low ($M = 3.18$), probably due to the complexity of the material, but still significantly higher than that of students in the control group ($M = 2.04$), $F(1, 68) = 9.79, p < .01, MSe = 1.20$.

The function recall of cell parts not in the analogy was equivalent in the experimental ($M = 1.08$) and control groups ($M = 1.30$), $F < 1$.

*Perceived Value of the Analogy*

Did the analogy help students to think about cell parts and their functions? The average (unadjusted) response in the experimental group was "somewhat" ($M = 3.67$; $SD = 1.31$). A sample of students' explanations for their responses is presented in Table 2. Although the analogy increased students' recall of cell parts in the analogy, and the functions of these parts, the correlations between these measures and students' perceived value of the analogy were not significant, both $ps > .05$.

## Discussion

The present study examined the role that an elaborate analogy can play when high school students learn a concept from a leading science textbook. The analog was a factory and the target concept was an animal cell. The target features were seven parts of the cell and, by association, the functions of those parts. By mapping the features of the familiar factory schema onto those of the animal cell, the analogy presumably acted as a mediator and made the corresponding features of the animal cell more comprehensible and memorable. Only the corresponding features were made more memorable, however. The analogy had no effect on the recall of cell features not in the analogy.

Although the elaborate analogy enhanced students' recall of cell features, the students tended to perceive the analogy as only "somewhat" helpful in thinking about the cell. This perception may be due more to the difficulty of the task, than to the limitations of the analogy. There were only seven cell features in the analogy, but students were asked to learn many more than that from the text. Because the analogy pertained to only some of the text features, the students may have judged it to be only "somewhat" helpful. Also, the students' judgments were found to be unrelated to their recall of the cell features in the analogy. In other words, the students' were not good judges of whether the analogy really helped them or not. This finding is consistent with the findings of other studies (e.g., Hunter-Blanks, Ghatala, Pressley, & Levin, 1988; Pressley & Ghatala, 1990) that have shown that "learners often fail to monitor how a strategy is affecting them as they use it" (Pressley & McCormick, 1995).

Before text study, the students were able to remember only one or two cell parts from lessons taught in previous school years. Typically, these parts were the nucleus and the cell membrane. This finding is disappointing because a basic understanding of cell structure is an important component of scientific literacy (American Association for the Advancement of Science, 1989, 1993). This finding underscores the importance of reviewing previously taught lessons on the cell before teaching a new lesson, and making these lessons as meaningful as possible by relating them to familiar schemas.

After text study, students again tended to recall the nucleus and cell membrane most

**Table 2**
*A Representative Sample of Students' Responses to the Question: Did the Factory Analogy Help You to Think About Cell Parts and their Functions?*

| | |
|---|---|
| **Four Students Who Responded "Yes"** | |
| *David*: | It was much more "eye catching" than a microscope picture. I could also remember by relating the factory to a cell. |
| *Ria*: | If you see a "restricted sign" in an area, most likely only certain people are allowed there. That's how it is with the membrance; certain things can enter and others can't. Most interesting to me was the chromosone/blueprint example. Chromosomes are what the object is going to look like, and the same for the blueprint of a building. |
| *Susan*: | It did because it helped me get a better image in my mind because I understand how factories work better than how a cell works. |
| *Ben*: | The diagram helped by turning biological gibberish (at least to me) into something I could understand. |
| **Four Students Who Responded "Somewhat"** | |
| *Kimberly*: | It doesn't help a great deal to me, but it does help some. It helped to put something we don't know a lot about with something we did. |
| *Robyn*: | It helped me to think about how the cell functions. Because they made it similar to something I could relate to. |
| *Clark*: | I really didn't know much about factory parts and functions anyway, so it didn't really relate to me that well. |
| *Ashley*: | Instead of a bunch of words it gave me a funny picture that was kind of interesting. Because if it would have been a regular picture of a cell, I wouldn't have ever looked at it. |
| **Four Students Who Responded "No"** | |
| *Teresa*: | It confused me because I don't know what those people are doing and I don't know the different jobs in a factory. It made the cell parts harder to understand. I'd rather figure it out and remember my own way. |
| *Alexis*: | No, it was not clear. They need to go about how they explain things differently; however, the diagram of the cell is very helpful. |
| *William*: | It made me think a little bit about how things work and wonder about the cell. It made me wonder also about the main parts of the cell and what makes them work. |
| *Anthony*: | I do not particularly like Science, but I like it more than Health. I would rather study about animals. |

**Note**. The students responded on a Likert-type 5-point scale, with the following range: 1 = no, 3 = somewhat, and 5 = yes. They then explained, in writing, their responses. For readability, students' spelling errors have been corrected.

frequently, followed by cytoplasm, ribosomes, mitochondria, nucleolus, endoplasmic reticulum, DNA, chromosomes, and Golgi apparatus. This rank order was similar for students reading the analogy-enhanced text and the standard text because both texts emphasized the cell parts in the analogy. Those parts were included among the parts most frequently recalled by the students, attesting to their importance, both in the texts and in the students' minds.

The students did not make errors associated with the analogy, such as including factory components in their cells. The students did make other errors, however, that revealed a number of "alternative frameworks" (misunderstandings). The most frequent one was that an animal cell has a cell wall. This was the most frequent error on both the pretest and posttest, underscoring the persistence of this misunderstanding. Some students had both a wall and a membrane in their animal cells, while other students simply substituted the wall for the membrane. The misunderstanding that an animal cell must have a wall seems to be based on the belief that the membrane alone is not up to the task of keeping the outside "out" and the inside "in." The emphasis placed in textbooks on the membrane being *semipermeable* may unintentionally reinforce this misunderstanding: "The cell membrane is a complex barrier that keeps out some molecules but allows others to permeate, or pass, into the inside of the cell" (Towle, 1989, p. 66).

Other common errors, but only on the pretest, were to include electrons and protons in the animal cell. These errors are understandable if one considers how often textbook authors draw an analogy between the atom and a cell, when introducing a unit on cells:

> Just as atoms are the basic structural and functional units of all matter, cells are the basic structural and functional units of living things. In Unit 1 you learned how a knowledge of atoms helps scientists understand and predict the behavior of chemical substances. In this unit you will gain a knowledge of cell structure and function that will help you to better understand the processes that take place within living things. (Towle, 1989, p. 60)

A comparison such as this, in conjunction with the presence of a "nucleus" in both the cell and atom, prompts students to connect atoms with cells. Over a long period of time, features of the two schemas become mixed in some students' minds, causing the students to recall cells with features of atoms. The period of time in this case was about 1 year, when a lesson on the cell was last taught to the students. The misunderstanding was apparently cleared up, however, when the students read their texts, as none of the students recalled atom parts on the posttest.

Still another group of errors seemed to be based on a misunderstanding that animal cells are built of blood cells and plasma. These students equated blood plasma with cytoplasm (and were unaware of the definition of plasma as *protoplasm*, and thus it could be argued, cytoplasm).

Science teachers might view these misunderstandings as causes for concern, particularly from the standpoint of scientific literacy. But, from the standpoint of meaningful learning, perhaps there is no real cause for concern, unless particular misunderstandings are recurrent and resistant to instruction (e.g., an "animal cell wall"). These misunderstandings were meaningful ones, in the sense that they represented efforts by students to connect schemas. Meaningful learning is, after all, *relational* in nature. Students should learn textbook concepts as organized networks of related knowledge, not as lists of unrelated facts (Glynn & Muth, 1994; Holliday, Yore, & Alvermann, 1994; Roth, 1991). When learning meaningfully, students will construct relations, some of which may be incorrect. This is a normal consequence of meaningful learning and one that teachers can prepare for when assigning textbook reading.

In conclusion, this study has shown that an elaborate analogy can be a useful tool for supporting students' learning of concepts from science text. Learning becomes relational rather than rote, and thus more meaningful. This is the bright side of learning with analogies. There is a dark side as well. When students overgeneralize and map noncorresponding features of concepts (e.g., atoms and cells), misunderstandings can result. Therefore, analogies are best thought of as double-edged swords. An analogy can be used to explain some aspects of a target concept, but at some point every analogy breaks down. If the analogy is carried beyond that point, misunderstandings may begin to form.

## References

American Association for the Advancement of Science. (1989). *Project 2061: Science for all Americans*. Washington, DC: Author.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. Washington, DC: Author.

Brown, D. E. (1993). Refocusing core intuitions: A concretizing role for analogy in conceptual change. *Journal of Research in Science Teaching, 30*, 1273–1290.

Cavese, J. A. (1976). An analogue for the cell. *The American Biology Teacher, 38*, 108–109.

Clement, J. (1989). Learning via model construction and criticism. In J. A. Glover, R. R. Ronning, & C. R. Reynolds (Eds.), *A handbook of creativity: Assessment, theory, and research* (pp. 341–381). New York: Plenum.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching, 30*, 1241–1257.

Finley, F. N. (1991). Why students have trouble learning from science texts. In C. M. Santa & D. E. Alvermann (Eds.), *Science learning* (pp. 22–27). Newark, DE: International Reading Association.

Finley, F. N., Stewart, J., & Yarroch, W. L. (1982). Teachers' perceptions of important and difficult science content. *Science Education, 66*, 531–538.

Gilbert, S. W. (1989). An evaluation of the use of analogy, simile, and metaphor in science texts. *Journal of Research in Science Teaching, 26*, 315–327.

Glynn, S. M. (1991). Explaining science concepts: A Teaching-with-Analogies Model. In S. M. Glynn, R. H. Yeany, & B. K. Britton (Eds.), *The psychology of learning science* (pp. 219–240). Hillsdale, NJ: Erlbaum.

Glynn, S., Duit, R., & Thiele, R. (1995). Teaching with analogies: A strategy for constructing knowledge. In S. M. Glynn & R. Duit (Eds.), *Learning science in the schools: Research re-*

*forming practice* (pp. 247–273). Mahwah, NJ: Erlbaum.

Glynn, S. M., & Muth, K. D. (1994). Reading and writing to learn science: Achieving scientific literacy. *Journal of Research in Science Teaching, 31*, 1057–1073.

Goetz, E. T., Alexander, P. A., & Ash, M. J. (1992). *Educational psychology*. New York: Merrill.

Harrison, A. G. & Treagust, D. F. (1993). Teaching with analogies: A case study in grade-10 optics. *Journal of Research in Science Teaching, 30*, 1291–1307.

Hesse, M. B. (1966). *Models and analogies in science*. Notre Dame, IN: University of Notre Dame Press.

Hewitt, P. G. (1993). *Conceptual physics* (3rd ed.). Menlo Park, CA: Addison-Wesley.

Hoffman, R. R. (1980). Metaphor in science. In R. P. Honeck & R. R. Hoffman (Eds.), *Cognition and figurative language* (pp. 393–423). Hillsdale, NJ: Erlbaum.

Holliday, W. G. (1991). Helping students learn effectively from science text. In C. M. Santa & D. E. Alvermann (Eds.), *Science learning* (pp. 38–47). Newark, DE: International Reading Association.

Holliday, W. G., Yore, L. D., & Alvermann, D. E. (1994). The reading—science learning—writing connection: Breakthroughs, barriers, and promises. *Journal of Research in Science Teaching, 31*, 877–893.

Hunter-Blanks, P. Ghatala, E. S., Pressley, M., & Levin, J. R. (1988). Comparison of monitoring during study and during testing on a sentence-learning task. *Journal of Educational Psychology, 80*, 279–283.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: University of Chicago Press.

Lawson, A. E. (1993). The importance of analogy: A prelude to the special issue. *Journal of Research in Science Teaching, 30*, 1213–1214.

Piaget, J. (1962). *Play, dreams, and imitation in childhood*. New York: Norton.

Pressley, M., & Ghatala, E. S. (1990). Self-regulated learning: Monitoring learning from text. *Educational psychologist, 25*, 19–34.

Pressley, M., & McCormick, C. (1995). *Cognition, teaching, and assessment*. New York: HarperCollins.

Roth, K. J. (1991). Reading science texts for conceptual change. In C. M. Santa & D. E. Alvermann (Eds.), *Science learning* (pp. 48–63). Newark, DE: International Reading Association.

Ryder, J. M., & Redding, R. E. (1993). Integrating cognitive task analysis into instructional systems development. *Educational Technology Research and Development, 41*, 75–96.

Stevens, J. P. (1992). *Applied multivariate statistics for the social sciences*. (2nd. ed.). Hillsdale, NJ: Erlbaum.

Thagard, P. (1992). Analogy, explanation, and education. *Journal of Research in Science Teaching, 29*, 537–544.

Thiele, R. B., & Treagust, D. F. (1994). The nature and extent of analogies in secondary chemistry textbooks. *Instructional Science, 22*, 61–74.

Thiele, R. B., & Treagust, D. F. (1995). Analogies in chemistry textbooks. *International Journal of Science Education, 17*, 783–795.

Thomas, L. (1974). *The lives of a cell*. New York: Bantam.

Towle, A. (1989). *Modern biology*. Austin, TX: Holt, Rinehart and Winston.

Wiggs, C. L., & Perez, R. S. (1988). The use of knowledge acquisition in instructional design. *Computers in Human Behavior, 4*, 257–274.

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