MARY CATHERINE H. MAY
Elaborate Analogies in Science Text: A Strategy to Enhance Middle School Students' Conceptual Knowledge, Interest, and Self-Efficacy
(Under the direction of SHAWN GLYNN)

The present study was designed to examine the role of elaborate analogies in enhancing middle school students' understanding of science text and their attitudes toward learning science concepts. In this study, eighth grade students were given a text with an elaborate analogy, a text with a simple analogy, and a control text with no analogy. An elaborate analogy consisted of pictorial components and text information in which similarities between the target concept and analog were made explicit. In addition, the students were given analogy activation instructions, to think of something the cell is analogous to or were simply told that they would be asked to recall information about a cell. Text learning was measured by conceptual drawings and explanations, students' perceptions of interest, understanding, strategy, and self-efficacy. Analyses of variance were conducted. Qualitative responses from the students supplemented the quantitative data. The results indicated that elaborate analogies in text increased students' conceptual understanding of science concepts, as reflected in their explanations and drawings. Students indicated that they were more interested in these concepts immediately after the treatment than three weeks later. Their understanding and self efficacy were also higher immediately after reading the text. The present findings suggest that elaborate analogies can be effectively used to enhance middle school students' learning of concepts in science text. Future research should examine middle school students younger than eighth grade because this study showed that many eighth grade students already had developed their own cognitive strategies for remembering information, thus rendering the elaborate analogy redundant for these students. Future research should investigate the role of analogies created by students themselves on the understanding and retention of science concepts.

INDEX WORDS: Analogical thinking, Analogies, Constructivism, Interest, Middle school, Motivation, Science concepts, Science knowledge, Science text, Self-efficacy

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A STRATEGY TO ENHANCE MIDDLE SCHOOL STUDENTS'

CONCEPTUAL KNOWLEDGE, INTEREST, AND SELF-EFFICACY

by

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CHAPTER I

INTRODUCTION AND RATIONALE

Middle school students often have difficulty understanding new concepts in science because they find the concepts complex and unfamiliar. Limited classroom experiences combined with inadequate textbook instruction have left them with a small base of information on which to build scientific knowledge (Finley, 1991; National Research Council, 1996). Research has shown that these students learn through connecting new information to prior knowledge (Anderson, 1993; Piaget, 1962). Many of these students have difficulty understanding key concepts because they have no concrete experiences with which to construct knowledge (Gilbert, 1989; Hand & Keys, 1999).

Students should be able to connect new concepts to ideas with which they are familiar rather than learning unrelated facts that will be forgotten when the unit is over. Learning will be meaningful only if new knowledge is integrated with existing knowledge (Glynn & Muth, 1994). Students must organize data in a way that is meaningful so that new ideas relate to their knowledge base in an organized network of information rather than processed as unrelated facts.

Textbooks often do not explain new concepts in a systematic manner that builds upon students' existing knowledge. Complex concepts are introduced to students during the middle school years. Learning these concepts from textbooks can be difficult; however, text authors and teachers could help students understand new concepts through relating this new knowledge to ideas that are familiar to students (Glynn & Muth, 1994; Holliday, Yore, Alvermann, 1994; Roth, 1991).

Historically, scientists have often used analogies to explain new discoveries and concepts to colleagues and nonscientists (Brown, 1992; Clement, 1993; Gentner, 1989; Lawson, 1993; Thagard, 1992; Venville & Treagust, 1997). Likewise, teachers and textbook authors use analogies to explain science phenomena, but there is a need for guidance on how and when to effectively use analogies. Analogies connect new knowledge to prior experiences so that understanding of new concepts can take place. During the process of learning, students assimilate information into existing schema of knowledge, or reconstruct knowledge so that they are able to accommodate new information (Piaget, 1962).

Textbook authors find analogies to be a convenient tool for enhancing students' understanding of new science concepts. Studies have documented that analogies often facilitate students' recall of concepts, as well as helping them identify specific features by drawing conclusions based on prior knowledge (Glynn, Duit, & Thiele, 1995; Glynn, 1994; Harrison & Treagust, 1993). Sometimes, however, analogies in text are ineffective and confuse students because the analogies have no systematic form and students are unable to understand the related concepts (Gilbert, 1989; Thiele & Treagust, 1994).

This present study will investigate the use of the Teaching With Analogies (TWA) model in constructing effective analogies (Glynn, 1994, 1996; Glynn & Law, 1993; Glynn & Takahashi, 1998). The Teaching With Analogies model was developed through the observation of exemplary teachers and textbook authors who used analogies in systematic ways to help students understand key science concepts. When analogies are provided in textbooks, teachers can use the Teaching With Analogies model to improve understanding of concepts in science. In particular, this study will examine the role that an elaborate analogy can play when middle school students learn key science concepts in text.

This study also will explore the relationship between analogies and intrinsic motivation (Deci, Vallerand, Pelletier, & Ryan, 1991; Lepper & Hodell, 1989). Specifically, it is important to understand how analogies can be used to enhance middle school students' interest in key concepts in science textbooks. Interest may engage a wider network of personal experience through which students identify a desire to build new knowledge. This study will examine students' interest in particular science concepts and whether analogies in text have an effect on that interest.

Another purpose of this study is to investigate self-efficacy and its relationship to learning from science text with analogies. Self-efficacy refers to the feeling of confidence in one's ability to understand a concept or to perform a task within a specific domain (Bandura, 1986). It may be that increased self-efficacy is one of the benefits of increased analogy-enhanced learning because analogy increases familiarity and, therefore, confidence.

This study will extend prior research on the Teaching with Analogies model by examining the different ways that analogies can be used to help middle school students learn specific science concepts by relating new information to prior information. When the concept becomes familiar, it may become easier to learn.

In conclusion, this study has potential theoretical significance because it examines the role of analogies in text as they relate to learning knowledge in a meaningful fashion. Although analogical reasoning has been addressed theoretically in the psychological literature, researchers have focused primarily on problem solving of a rather abstract nature. In this study, the focus is on using analogy as a conceptual tool to explain and learn concepts in middle school science text. The development of knowledge by middle school students is complex in that the students' prior experience in science is often limited or misconceived. Analogies can be used to help students clarify and extend prior knowledge. Elaborate analogies, in particular, may be used to map a familiar, concrete schema onto a new schema so that students can better learn new concepts.

CHAPTER II

REVIEW OF RELATED LITERATURE

Classroom instruction prior to the 1970's consisted primarily of lessons designed to meet specific behavioral objectives. Teachers established the objectives and often taught students without reference to strategic ways in which students could learn and remember information or concepts. Beginning in the late 1970's educators began to realize the importance of involving students in their own learning process. Educators discovered that learning became meaningful when students were able to establish a relationship between concepts and prior knowledge. This also increased self-efficacy as students took responsibility for learning and became confident in their ability to understand new concepts and information.

The review that follows presents an overview of the theoretical concepts that provide a foundation for this study. These include analogy, science learning, motivation, and self-efficacy.

Analogy

Analogy is a general learning strategy that is used to understand new concepts. When one experience or problem parallels another we can use this strategy for understanding and remembering the unfamiliar concept: it is the process of comparing two similar ideas that share common traits (Glynn, 1991; Pate, Alexander, & Kulikowich, 1989). Analogical reasoning is powerful because through it students construct a complete set of associations between features of specific concepts (Castillo, 1998; Tice, 1997). The power of an analogy to explain a concept depends on the number of features that can be compared, the similarity of the features, and their conceptual significance (Fast, 1999; Glynn, 1991).

Piaget (1962) viewed analogical thinking as a fundamental cognitive process. In his view, cognitive development depends on four factors: experience with the physical environment, experience with the social environment, physical maturation, and equilibration. Equilibration in learning is based on analogical experience. Equilibration, or adaptation, of cognitive structures and the environment takes place through the processes of assimilation and accommodation. We interpret our experiences and alter the nature of reality to make it fit our own cognitive structure. Through assimilation we build on what we already know by comparing it to similar experiences. Through accommodation we reconstruct the schema of knowledge to understand concepts in a new way.

As adolescents in middle school move from concrete operational thought to formal operations, they must begin with knowledge of that which is concrete or real to them. They can reason only with ideas and concepts that are personal experiences. As they acquire new information they adapt it to their own personal knowledge of a concept. Through formal operations these adolescents are no longer bound by concrete ideas, but have moved into a more flexible way of acquiring knowledge:

> In other words, formal operations adolescents are able through inductive reasoning to systematize their ideas and deal critically with their own thinking to be able to construct theories about it. Furthermore, they can test these theories logically and scientifically, considering several variables, and are able to discover truth, scientifically, through deductive reasoning. . . . they have the capacity to construct and test theories. (Rice, 1999, p. 136)

These adolescents are not stuck with preconceptions of an idea. They can think about abstract ideas. Sometimes these students may generate new and inventive ideas based on original thinking and may elaborate on these ideas. Through developing their abstract reasoning, adolescents can expand the possibilities rather than become limited by what they already know to be true. Formal operational thought allows adolescents to process and remember more information, consider logical relationships, and generate various solutions to a problem before deciding on an accurate answer or the best course of action.

Analogies play an important role in problem solving and explanation of scientific concepts (Glynn, Duit, & Thiele, 1995; Inglis, 1996, Sternberg, 1982). Making analogies sets the stage for devising new thought patterns. Mapping a new academic concept onto a familiar example often helps understanding and facilitates cognitive development (Glynn, 1996; Holyoak, 1984). Learning takes place when students analyze and construct similarities between what they know and the new knowledge they are setting out to learn.

Many research studies have shown that analogical reasoning can play an important role in teaching and learning science (Britton & Glynn, 1987; Glynn, 1991, Glynn, Law, Gibson, & Hawkins, 1994; Glynn & Takahashi, 1998; Halpern, 1987; Lawson, 1993; Thagard, 1992). Analogy is thought to be a major factor in the flexibility of the human mind to solve problems (Holyoak, 1984). It is a way of analyzing unfamiliar situations to develop a deeper understanding of new concepts.

Finally, analogies in text may increase students’ ability to understand and remember key science concepts by relating new knowledge to existing schema of information. By connecting abstract concepts to visual models, students may be able to understand complex ideas and activate knowledge schema more effectively.

The Teaching-With-Analogies (TWA) model (Glynn, 1995), based on studies of exemplary classroom science teachers, shows how teachers employ strategies of analogical reasoning to help students understand concepts of science. The TWA model consists of six operations:

1) Introduce the target concept: What is the basic idea that students need to understand?
2) Cue retrieval of analog: What related concept is familiar to students?
3) Identify relevant features of target and analog: How are the concepts similar?
4) Map similarities: Compare the concepts to see how they are the same through diagrams, experiments, or ideas.
5) Indicate where the analogy breaks down: What are the differences in the concepts? Where are they not alike?
6) Draw conclusions: What "general statements can we make about the two ideas? Will this include any other cases?"

Teachers may also use the Teaching With Analogies model with analogies from science textbooks. For example, the science textbook may compare the heart to a pressure pump. Teachers may bring to class a pressure pump to show students how it works and compare it to the parts and functions of the heart.

Teachers should encourage students to use analogies as a learning strategy. Analogies could also be used in study guides, as test questions, and in class discussions. Students have internalized the strategy when they begin using it across domains for constructing their own knowledge.

Though many teachers believe that students are constructive learners who actively determine what they learn, they often fail to give students the tools to become autonomous in their learning (Meichenbaum & Biemiller, 1998). Over time, the goal of education should be to see that students apply previously acquired knowledge and skills to new and more complex tasks. In various new situations, students become self directed experts who share what they learn. As students become aware of the ways in which they learn, their goals in learning may specifically dictate the strategies that they use to acquire knowledge.

Individual students' learning from text may be affected by metacognition, inference-making ability, working memory, and domain knowledge (Britton, Stimson, Stennett, & Gulgoz, 1998). Students may effectively use analogies to influence and improve all these variables. Though good strategy use is complex, teachers can encourage students to develop various strategies through scaffolding (Gaskins & Elliot, 1991, Meichenbaum & Biemiller, 1998). When students are capable of developing strategies for themselves they need less direct assistance and the teacher may direct them through prompts to generate their own task directions. This direction is known as *scaffolding* (Meichenbaum & Biemiller, 1998).

If analogy is used consistently in the classroom students will improve their ability to learn. In their study of sixth grade students taught through analogies, Pate, Alexander, and Kulikowich (1989, p. 27) found that, "It is often difficult to deliver effective, detailed (analogy) training in the actual classroom setting, and yet, our research not only found significant results (in domain knowledge and strategic knowledge), but also seemed to be motivating to the students."

Science Learning

Science is a discipline that has evolved over thousands of years. It is broad based with many faces and many diverse ideas (Chiappetta, Koballa, & Collette, 1998; Martin, Kass, & Brower, 1990). Recently, the National Research Council (1996) developed content standards based on a broad consensus about what students need to know and what they should be able to do to be literate in science.

Originally, the focus of science educators was on the products of science: the body of knowledge formed by facts, concepts, principles, laws, hypotheses, theories, and models. More recently, science educators have focused on processes as well as products. Scientists are, after all, naturally curious and imaginative. They apply reason in their quest for understanding natural phenomena. Clues are discovered through experimentation and observation and reasoned out through human thought. Science educators have come to realize that learning science is an active process of building and organizing knowledge into various schema of information to understand ourselves and our natural environment (Cobern, Gibson, & Underwood, 1995; National Research Council, 1996).

Middle school children are also curious in their quest to understand natural phenomena. When students engage in activities that encourage them to construct a meaningful understanding of science, these activities also engage students' intrinsic motivation (Deci, Vallerand, Pelletier, & Ryan, 1991; Lepper & Hodell, 1989). Intrinsic motivation can lead to more positive attitudes about learning science (Koballa, 1995; Koballa & Crawley, 1985). These attitudes affect learning goals in a positive way and encourage the development of meaningful scientific knowledge.

Wittrock (1985) defines meaningful learning as a "student generative process that entails construction of relations, either assimilative or accommodative, among experience, concepts, and higher order principles and frameworks. It is the construction of these relations between and within concepts that produces meaningful learning." (pp. 261-262). Along similar lines, Glynn and Duit (1995) have summarized the learning of science in this way:

> In our view, students learn science meaningfully when they activate their existing knowledge, relate it to instructional experiences, and construct new knowledge in the form of conceptual models. We believe that the process of relating existing knowledge to new experiences can be intrinsically motivating and that students should be encouraged to continually apply, evaluate, and revise the conceptual models they have constructed. (p. 23)

Studies of experts and novices in the field of science have shown that experts have developed knowledge in the form of interrelated networks of conceptual models (Chi, Glaser, & Farr, 1988; Ericsson & Charness, 1994; Schneider, 1993). Since this knowledge is relational, it is stored easily, retrieved quickly, and applied successfully (Glynn, Duit, & Thiele, 1995). Conversely, much of what students learn is by rote and is easily forgotten. They cannot transfer the knowledge to similar situations and the experience is lost rather than applied to existing schema. Research has shown that students need more meaningful experiences with science concepts so that they may construct conceptual knowledge (Blunck & Yager, 1990; Glynn, 1997; Yager, 1995).

Traditionally, analogies have played an important role in meaningful scientific explanation. Galileo in his explanation of the rotation of the earth, Joseph Priestly in explaining the law of electrical force, and Robert Hooke in the explanation of the cell all used analogies to explain their theories (Glynn, 1994, 1995, 1997). It is natural, therefore, that teachers and textbook authors have used analogy to explain other concepts in science. In the quest to understand the natural world, it is common for students to compare new concepts to familiar knowledge (Glynn & Duit, 1995).

Learning science from text involves various individual differences for each student. Britton, Stimson, Stennett, and Gulgoz (1998) discovered that learning from text involves making connections with prior knowledge and experience. Analogies are a practical and interesting way to access prior knowledge and make connections to new information. Individual students also call upon processes such as metacognition and domain knowledge when they learn from text. Students can effectively use cognitive strategies to influence and improve all these processes.

Textbook authors often use analogies to explain a concept and increase students' interest in it. Often, however, these analogies do more harm than good (Duit, 1991; Gilbert, 1989; Thagard, 1992; Treagust, Duit, Joslin, & Lindauer, 1992). Students may be confused and form misconceptions if analogies lack guidelines and are used unsystematically. The Teaching With Analogies model is a strategy for teaching students fundamental concepts in a meaningful way (Glynn & Takahashi, 1998). Unfortunately, there has been relatively little research on the use of textbooks in teaching science concepts, in a way that promotes meaningful, constructivistic learning. The National Research Council (1996) has encouraged the teaching of science through inquiry and active investigation. The Teaching With Analogies model could contribute significantly to the development of better methods of explaining science concepts in text.

Motivation

Teachers and educators have recently expressed concern over a lack of desire on the part of students to learn. Research has documented the decline of motivation over the life of a child, especially as students enter the middle school years (Eccles, Flanagan, Lord, Midgely, Roeser, & Yee, 1996; Eccles, Lord, & Buchanan, 1996). The problem has become even more serious in subjects related to math and science (Anderman & Young, 1994; Nolen & Haladyna, 1990).

There are many theories of motivation that give us an understanding of the ways in which children approach a learning task. Current theory describes motivation as having three psychological functions: energizing or activating behavior, directing behavior, and regulating the persistence of behavior. The unifying of these functions, however, is a focus on cognitive and emotional variables that influence achievement (Bandura, 1997; Graham & Weiner, 1996; Stipek, 1996; Weiner, 1990). These variables are composed of beliefs about oneself; for example, self-efficacy, causal attributions, and self-worth.

Developmental theorists have proposed that children's motivation to explore and understand their world is the foundation on which learning is based (Bjorkland, 1995; Erikson, 1963; Flavell, 1992; Piaget, 1962). The acquisition of knowledge involves the activation of several efficient learning systems that are unique to each individual. Learning in the classroom requires a combination of skills including knowledge, metacognitive strategies, learning skills, and critical thinking processes, with motivation driving the elements (Sternberg, 1999). Motivation is at the base of the school learning experience. Without motivation, some children will not even try to learn. Stipek (1988) contends that theories of motivation should help us understand and predict behavior of children and students in the classroom.

Motivation to learn and make sense of the environment begins from almost the first moment of life. Natural curiosity and the desire to learn stimulate the process. Young children rarely think about the possibility of failure, however, as children mature they begin to compare themselves to others in their social environment. Theorists have added goals and perceptions of ability as well as other cognitive variables to their theories of motivation (Bandura, 1986; Eccles, 1983; Wigfield, 1994).

The initial cognitive processes in an achievement-oriented environment not only involve the evaluation of the task, but also the potential for success or failure based on past experiences. Motivation depends on personal goals, self-concept, and task difficulty. Further, self-concept is related to the belief of students in their ability to succeed within specific domains. It is interesting to note that the *perception* of task difficulty is more important than the *actual* difficulty level of the task. If one *believes* one can accomplish the task, one has a high level of motivation. When students succeed in a task, this raises their level of expectation for future success (Bandura, 1986).

Working on a task because you have an internal, or intrinsic, interest in it is believed to be more enjoyable than working on a task for external, or extrinsic, rewards, such as a grade (Deci, 1975; 1992). With the proper environment and subjects of interest students may become intrinsically motivated. There is evidence to suggest that students who are intrinsically motivated to complete a task develop a better conceptional understanding of the subject than students who are working for extrinsic rewards (Grolnick & Ryan, 1984). Nicholls (1983) and Maehr (1983) found that students with intrinsic motivation most often have a mastery goal orientation and value the learning process more than students who are extrinsically motivated.

Many teachers would argue that the world of education is controlled by extrinsic rewards, particularly grades, and that students cannot develop intrinsic motivation when their interest is focused on grades. However, when students are given the opportunity to develop their own cognitive learning strategies, self-determination and self-efficacy will thrive (Pressley & Woloshyn, 1995).

While it is true that much of the subject matter and learning tasks in school are not intrinsically motivating to students, there are ways to ensure student participation and help students become aware of their own abilities to activate a desire to learn. Student engagement in the learning process is critical to success in school. The nature of the learning tasks and the context for learning affects the degree to which students invest in the process.

Self-efficacy

Self-efficacy refers to a personal judgment one makes about his or her capability to learn a concept or perform a task within a specific domain (Bandura, 1986; Bandura & Schunk, 1981). Self-efficacy is the central theme of Bandura's social cognitive theory. Self-efficacy is not the same as knowing what to do, but refers to the feeling of confidence one has that he or she will be able to do the job. It is the connection between knowledge and action. In his studies of self-efficacy, Bandura found that when students succeed in learning a concept, their level of expectation for future success is increased. He labeled this "outcome expectation", the perception of doing well on similar learning tasks in the future. A general finding of Bandura's studies (1986, 1997) was that expectancies and task-specific self-concepts are mediators between environmental contexts and achievement.

Research has shown that effort and persistence are greater when students possess a sense of efficacy or confidence in their own ability to succeed on a task (Carr & Jessup, 1995; Collins, 1982; Schunk, 1991). In contrast, students who doubt their abilities and fail to acquire the needed skills will lose confidence in their ability to achieve and will, ultimately, avoid the challenge. They give up easily when they become frustrated or face failure. In many ways this perception leads to low self-efficacy and a helpless orientation to achieving learning goals (Bandura, 1997; Carr, Borkowski, & Maxwell, 1991; Schunk, 1991).

Self-efficacy develops through successful experiences. Children evaluate the effectiveness of their own actions, compare it to the actions of others, and are told by others how their behavior meets certain standards. Children who believe they are competent develop feelings of positive self-efficacy. This feeling of positive self-efficacy not only impacts intellectual development, but emotional and social development as well.

The self-efficacy of middle school students learning science has been linked to attitudes and previous experiences in science (Cannon & Simpson, 1985; Ebenezer & Zoller, 1993; Misiti, Shrigley, & Hanson, 1991). For example, at least in the past, girls have not been encouraged to study science and, as a result, have felt less able to learn scientific concepts.

The science attitudes of middle school students have been evaluated by a number of researchers using a range of assessment techniques. For example, Bohardt (1975) examined changes in science attitudes of children in grades 4-8. In his study, positive attitudes toward science decreased as students advanced in school. In a study of seventh grade students, Cannon and Simpson (1985) found that science attitudes were higher at the beginning of the year indicating that new concepts were found to be interesting topics. In a study of gender differences, Simpson and Oliver (1985) concluded that males had more positive attitudes toward science, but that females were more highly motivated to achieve in science than males. In a study of seventh to ninth grade students, Shemesh (1990) found that when formal learning skills and learning interests were considered there were no significant differences in overall relations between interest and cognitive development for males and females. Moreover, the boys' interests were observed not to change with grade level, but the girls became more interested in humanities, social sciences and the arts. In addition, Mason and Kahle (1989) found that students who had positive experiences in science classes indicated a higher self-efficacy to learn science. They developed positive attitudes toward science and were motivated to pursue other science courses. The use of elaborate analogies in text may improve students' science attitudes in general and their self-efficacy in particular because linking familiar knowledge with new concepts may build students' confidence.

The Present Study

In general, the present study will examine the role that elaborate analogies can play in enhancing middle school students' learning of concepts in science text. In addition, the study will look at ways to enhance middle school students' interest and self-efficacy with respect to learning these concepts.

It is hypothesized that students' retention of text information about the concept of a human cell will be highest for those students who study a text with an elaborate analogy. It will be lower for students who study a text with a simple standard analogy, and lowest for those who study a control text with no analogy. Furthermore, it is hypothesized that students who receive instructions that activate the analogy will score higher on the topic measures than those who receive no activation instructions. As students' prior knowledge is activated by the elaborate analogy and they encode the new information better, learning should be enhanced. As a result, students' retention will be better with analogy-enhanced text, both immediately after text study and over a longer interval of three weeks. The statistical null hypotheses are included in Table 1. It is also hypothesized that the elaborate analogy text will be rated most interesting, most understandable, and most conducive to self-efficacy.

Table 1

Statistical Null Hypotheses for Text Treatment and Text Instructions Effects

Text Treatment	
H_0: $\mu_1 = \mu_2 = \mu_3$	There will be no statistically significant differences between mean scores in the three text treatment conditions on any of the dependent measures.
Text Instructions	
H_0: $\mu_1 = \mu_2$	There will be no statistically significant differences between mean scores in the two text instruction conditions on any of the dependent measures.

CHAPTER III

METHODS

Participants

Participants for the study were eighth-grade students from a suburban public school district near Birmingham, Alabama. Parents are typically college-educated middle-class professionals. The sample consisted of 198 students and was drawn from a school population of 90% Caucasian-American students, .3% Hispanic students, 5.3% African-American students, .2% Native American students, and 4.3% Asian students. From the population, approximately 3% of the students were in a free lunch or reduced cost lunch program. Participation was by random assignment based on current enrollment in the eighth grade science classes.

Design and Materials

The materials in this present study were compiled partly from those in Glynn and Takahashi's study (1998) in which sixth and eighth grade students used analogies to learn concepts in science. The control standard text reading used for Glynn and Takahashi's study and for the present study consisted of a 1,014 word text concerning the animal cell from the textbook General Science (Alexander, Fiegel, Foehr, Harris, Krajkovich, May, Tzimopoulos, & Voltmer, 1989) written for sixth-grade students. The text was rated on the eighth grade level (8.0) using the Flesch-Kincaid readability index.

The study of the cell is basic to the study of life structures. Knowledge of the cell is necessary for middle school students to pursue more advanced studies in life science as they strive to understand the function of living organisms. Many middle school students have difficulty understanding the cell because it is an abstract topic (Cavese, 1976).

Initially, all participants were given a pretest the day before treatment to determine prior knowledge on cell function. Immediately before the treatment, participants were asked to draw a picture of a typical animal cell and label the parts. Then participants were randomly assigned to six groups, formed by the factorial combination of two instructional conditions (control and analogy activation) and three text conditions (control, simple analogy, and elaborate analogy). The design is presented in Table 2.

In the control instructional condition, students were simply told that they would be asked to study and recall a text about animal cells. In the analogy activation condition, students were additionally told that it would be helpful for them to think about what animal cells might be analogous to.

In the control text condition, students read a text that described the animal cell and its parts (see appendix A). The text also included the function of each part and its contribution to the operation of the cell in the human body. In addition, there was a drawing of a typical animal cell with all the parts labeled. The simple analogy text contained the control text, plus an introductory sentence that compared the animal cell to a factory (see appendix B). The elaborate analogy text contained the control text, plus an elaborate analogy that, verbally and visually, systematically compared the parts

Table 2

Design of the Study

	MEASURES			
	Cell Function	Cell Structure	Interest	Understanding
Conditions	Pre/Post/Delay	Pre/Post/Delay	Post/Delay	Post/Delay
Analogy Activation Instructions				
Elaborate Analogy Text				
Participants	1 : 33			
Simple Analogy Text				
Participants	34 : 66			
Control Text				
Participants	67 : 99			
Control Instructions				
Elaborate Analogy Text				
Participants	100 : 132			
Simple Analogy Text				
Participants	133 : 165			
Control Text				
Participants	166 : 198			

Note. There are 198 participants, 66 in each of three text treatment groups and 99 in each of two text instruction groups.

and functions of an animal cell to those of a factory (see appendix C). The "cell-factory" analogy is a popular one that is often recommended for use with middle school and high school students (e.g. Cavese, 1976; Glynn, 1995). Following the Teaching With Analogies model (Glynn & Duit, 1995), the elaborate analogy performed the following six operations:

1. Introduced the target concept, the cell, to students.
2. Reminded students of what they know of the analog concept, a factory.
3. Identified relevant features of the cell and a factory.
4. Mapped similarities between the cell and a factory.
5. Indicated where the analogy between the cell and a factory breaks down.
6. Drew conclusions about the functions of cell structures.

The text identified seven corresponding features of the cell and the factory and pointed out where the analogy breaks down. There was a drawing of a cell-like factory as well as the drawing of the human cell that was present in the other two conditions. A total of 198 students completed all required pretests, posttests, and delayed posttests. The factorial combination of two instructional conditions and three text conditions produced six groups, each with 33 students.

Performance Measures

After text study, all students were administered a cell knowledge measure: this asked them to draw a cell and label its parts, then respond to a written completion test on cell parts and their functions. In addition, after text study, all students were administered a text attitude measure: this assessed on Likert-type scales students' perceptions of text interest and understandability (see Appendix B). Without informing the participants in advance, the knowledge measure and the text attitude measure were administered again three weeks later to assess retention and long-term effects of the treatment. Finally, immediately after text study and again three weeks later, all students were asked to rate text interest and understandability. Following the posttest and delayed posttest, students were also asked to reflect on the strategies they used. After the delayed posttest, students reflected on their self-efficacy. These reflections were used as supplementary information in interpreting the data gathered from the knowledge measures. A representative sample of the students (15%) was also interviewed orally in an open-ended fashion in much greater detail.

Following the treatments and performance measures, two independent raters scored a random sample of student drawings and written completion responses. Interrater reliabilities of $r = .95$ and $r = .98$, respectively, were established. The few responses that were not scored identically by the two raters were discussed and agreement reached.

Procedures

A consent form was sent to participating teachers for their students' parents or guardians to complete (see Appendix G). The consent form was delivered with accompanying instructions one month prior to the study. All data from the study were collected during normal class periods three times during a four-week period in late February and March.

The researcher, with the assistance of the classroom teachers, carried out the procedures. Students were administered a pretest the day before treatment to determine their prior knowledge. On the day of the first treatment, participants were asked to draw a diagram of a typical animal cell and label the parts. They were given five minutes to complete the drawing. Then they were randomly assigned to the conditions within each class. In the control instructional condition, students were simply told that they would be asked to study and recall a text about animal cells. In the activation condition, students were additionally told that it would be helpful for them to think about what animal cells might be analogous to. The word “analogous” was explained to the students and they were given examples of familiar analogies (e.g., “a heart is like a pump” and “a brain is like a computer”) of which they were all aware. The participants were each given a text booklet that contained either a control text, a simple analogy text, or an elaborate analogy text. Then the participants were given 20 minutes to read and study the booklet. At the end of 20 minutes, the participants stopped reading and returned their booklets. All participants had finished reading and no one needed more time to read or study.

Immediately following the collection of the text booklets, students were given drawing paper and asked to draw a diagram of a typical animal cell. They were given 10 minutes to complete the drawings. After these papers were collected, students were given the written completion test and instructed to complete it. Students were instructed to turn their papers face down when finished. After 20 minutes students were instructed to stop. No one needed more time to complete the test. Three weeks later the students were again asked to draw and complete the written test under similar conditions. In addition, students responded to the questions about interest, understandability, strategy, and self-efficacy.

During the week following the final performance measure, in-depth open-ended interviews were conducted with 30 of the participants who represented a typical sample of the group. The interviews were designed to assess their perspectives regarding the use of analogies as a learning strategy and the use of learning strategies in general. This information was helpful to the researcher in analyzing results on the performance measures and interpreting free response questions about the use of analogies as a learning strategy.

CHAPTER IV

RESULTS

The effects of the independent variables on each of the performance measures were examined by means of analyses of variance. In all data analyses, a Type 1 error probability of $\alpha < .05$ was used to test hypothesized effects.

Knowledge Measure for Cell Functions

Participants' knowledge was assessed before text study, immediately after text study, and three weeks following text study. Students were asked to explain in writing the functions of seven major parts of the cell. The group means and standard deviations are recorded in Table 3. A three-way mixed analysis of variance was performed in which there were two between-subjects factors, text instructions (analogy activation and control) and text treatment (elaborate analogy, simple analogy, and control), and one within-subjects factor, retention of text information over time.

There was a statistically significant main effect for the text treatment, $F\ (2, 192) = 3.16$, $p < .05$, and for the effect of time, $F\ (1.93, 369.52) = 412.61$, $p < .001$. The interaction of text treatment, text instructions, and time was also significant, $F\ (3.85, 369.52) = 2.74$, $p < .05$. As can be seen in Table 4, the other main effect and the interactions were not significant. The degrees of freedom were adjusted using the Hundt-Feldt method because the sphericity assumption was violated, Mauchly's $W = .92$, approximate $\chi2 = 15.15$, $df = 2$, $p < .001$, and $\varepsilon = .96$. The complete results of the analyses are recorded in Table 4. The raw quantitative data used in the analyses are included in Appendix (H).

Table 3

Mean Scores of Knowledge of Cell Functions

Performance Measure:	Pretest M	Pretest SD	Posttest M	Posttest SD	Delayed test M	Delayed test SD
Analogy Activated Instructions:						
Elaborate Analogy Treatment	1.42	1.30	5.27	1.46	3.45	1.97
Simple Analogy Treatment	1.73	1.64	4.27	2.35	3.24	2.28
Control Treatment	1.15	1.25	4.21	2.10	2.70	1.96
Control Instructions:						
Elaborate Analogy Treatment	1.61	1.32	4.67	2.22	3.73	2.35
Simple Analogy Treatment	1.39	1.37	4.45	2.35	2.67	1.98
Control Treatment	0.91	1.04	4.12	2.30	2.67	1.96

Note. Possible range of scores was 1-7. In all six groups N = 33. ($p < .05$)

Table 4

Analysis of Variance for Cell Function

Source	Sum of Squares	df	Mean Square	F
Between Ss		197		
Text Instruction (A)	2.83	1	2.83	0.34
Text Treatment (B)	53.24	2	26.62	3.16*
Instruction X Treatment	0.93	2	0.47	0.06
Error between	1616.47	192	8.42	
Within Ss	381.08			
Tests over time (C)	973.35	1.93	505.74	412.61**
A X C	9.43	1.93	4.90	.04
B X C	10.02	3.85	2.60	2.12
A X B X C	12.95	3.85	3.36	2.74*
Error within	452.93	369.52	1.23	

*$p < .05$.
**$p < .001$.

The three-way interaction implied that students receiving analogy instructions and the elaborate analogy text treatment performed better than students in any other condition on the posttest. This was confirmed by paired-samples t tests that were conducted to follow up the significant interaction. Familywise error rate across these tests was controlled using the Bonferroni adjustment. This measure adjusts the alpha level based on the number of comparisons conducted to reduce the Type I error rate (Keppel, 1991). Type 1 error probability was adjusted ($p < .017$) to allow for the number of treatment groups involved.

These findings indicate that there was a significant difference in students' learning of new concepts. It was expected that students exposed to the elaborate analogy condition would remember more information and retain it for a longer period of time than students in the other groups. The analyses indicated that students in the analogy activated elaborate analogy group scored higher on the posttest than the other groups. This advantage, however, did not carry over to the delayed test.

Knowledge Measure for Cell Structures

The effects of text instructions and text treatments on participants' ability to remember and accurately construct a diagram of an animal cell were also tested using a three-way mixed analysis of variance. Students were asked to draw and label a typical animal cell. The group means and standard deviations are reported in Table 5.

The analysis of the knowledge measure of cell structures indicated significant main effects for the text treatment, $F(2, 192) = 4.32$, $p < .05$, for text instructions, $F(1, 192) = 4.04$, $p < .05$, and for testing over time, $F(2, 384) = 309.85$, $p < .001$.

Table 5

Mean Scores of Knowledge of Cell Structure

Performance Measure:	Pretest		Posttest		Delayed test	
	M	SD	M	SD	M	SD
Analogy Activated Instructions:						
Elaborate Analogy Treatment	3.06	1.64	5.91	1.23	4.42	1.32
Simple Analogy Treatment	3.27	1.63	5.67	1.38	4.21	1.82
Control Treatment	2.58	1.50	5.45	1.48	3.76	1.68
Control Instructions:						
Elaborate Analogy Treatment	3.06	1.77	5.42	1.30	4.36	1.64
Simple Analogy Treatment	2.76	1.71	5.27	1.48	3.61	1.92
Control Treatment	2.27	1.26	5.09	1.70	3.09	1.72

Note. Possible range of scores was 1-7. In all groups N = 33 ($p < .05$)

None of the interaction effects were significant. The results of these analyses are recorded in Table 6. The raw quantitative data used in the analysis are included in Appendix (H).

The analysis implied that students in the elaborate analogy treatment performed better than students in the control text treatment. Furthermore, students who received analogy activated instructions performed better than students who received control instructions. Finally, scores were higher on the posttest than on the delayed test; scores were lowest on the pretest as would be expected. These outcomes were confirmed by paired-samples t-tests that were conducted to follow up the significant main effects. Familywise error rate was controlled across these tests using the Bonferroni adjustment ($p < .017$).

In summary, these results show significant differences in the text treatment groups. Participants in each treatment group were able to use diagrams and text information to remember the structures of the cell.

It was expected that the participants who received activation instructions and studied the elaborate analogy text would learn more and be able to construct more accurate drawings than students in control. This was found to be the case. The simple analogy text treatment fell between the elaborate analogy and the control in its effectiveness, not significantly different from either. Finally, participants were able to remember more information immediately following the text treatment than after the three-week period, as expected.

Table 6

Analysis of Variance for Cell Structure

Source	Sum of Squares	df	Mean Square	F
Between Ss		197		
Text Instruction (A)	21.12	1	21.12	4.04*
Text Treatment (B)	45.09	2	22.55	4.32*
Instruction X Treatment	2.92	2	1.46	0.28 Error
between	1003.23	192	5.23	
Within Ss		396		
Tests over time (C)	695.85	2	347.92	309.85**
A X C	0.83	2	0.42	.37
B X C	7.70	4	1.92	1.71
A X B X C	3.10	4	0.77	0.69
Error within	431.14	384	1.12	

**$p < .001$. *$p < .05$.

Text interest

The participants' interest in the text was assessed after text study and three weeks later. The participants completed a Likert-type question on which they rated their interest in the cell compared to other topics in life science. The rating alternatives were: 1 (not interesting), 2 (a little interesting), 3 (somewhat interesting), 4 (interesting), and 5 (very interesting). The group means and standard deviations for interest are reported in Table 7. An analysis of variance indicated that there were no statistically significant differences in interest among participants due to the three text treatment conditions, the text instruction conditions, or the time periods involved. None of the interaction effects were significant.

Text Understandability

Students were also asked to complete a Likert-type question on their understanding of the text presented. The rating alternatives for understanding were: 1 (not well), 2 (a little bit), 3 (somewhat), 4 (well), and 5 (very well). The group means and standard deviations for understanding are reported in Table 8. There were no statistically significant differences in understanding among participants due to the three text treatment conditions, the instruction condition, or the time periods involved. None of the interaction effects were significant.

Strategies

The effects of the text treatments on the responses to two questions were examined by means of content analysis. The first question was, "Does the way a cell works remind you of anything similar? In a few sentences, please explain what it is that a cell reminds you of." Responses from this question indicated that a large

Table 7

Mean Scores of Interest in Cell Structure and Function

Interest Performance Measure:	Posttest		Delayed test	
	M	SD	M	SD
Analogy Activated Instructions:				
Elaborate Analogy Treatment	2.91	1.01	2.24	0.94
Simple Analogy Treatment	2.39	1.06	2.36	0.96
Control Treatment	2.39	1.00	2.48	0.83
Control Instructions				
Elaborate Analogy Treatment	2.91	1.07	2.64	0.96
Simple Analogy Treatment	2.61	0.93	2.42	1.12
Control Treatment	2.48	0.76	2.52	0.80

Note: Possible range of scores was 1-5. In all groups N = 33.

Table 8

Mean Scores of Understanding of Science Text

Interest Performance Measure:	Posttest		Delayed test	
	M	SD	M	SD
Analogy Activated Instructions:				
Elaborate Analogy Treatment	3.12	1.02	2.55	0.90
Simple Analogy Treatment	3.36	1.11	2.88	1.05
Control Treatment	3.21	0.78	2.94	0.86
Control Instructions				
Elaborate Analogy Treatment	3.24	0.83	2.55	0.90
Simple Analogy Treatment	3.33	0.99	3.21	1.05
Control Treatment	3.21	0.78	3.63	0.74

Note: Possible range of scores was 1-5. In all groups N = 33.

percentage of the students used analogies based on working systems as something the cell reminded them of. On the posttest, many students used the analogy to a factory (53% of the students in the analogy activation instruction group and 40% of the students in the control instruction group.) Students used analogies to other systems as well (26% of the students in the analogy activation group and 42% of the students in the control group.). This effect appeared to be long lasting as shown by the number of students who used analogies on the delayed test. A total of 82 (83%) students in the analogy activation group and 81 students (82%) in the control group mentioned some type of working system analogy on the delayed posttest (see Table 9).

The second question was, “Explain in a few sentences how you remembered what the parts of the cell do. Was there anything in the text that helped you to remember the functions of cell parts? Explain what it was.” On the posttest, responses to this question indicated that a large percentage of the students used analogies in helping them remember key concepts (17% in the analogy activated instruction group and 18% in the control group used analogies.)This effect appeared to be long lasting in that 18% of the students in the analogy activated group and 16% of the students in the control group used the analogy again on the delayed posttest (see Table 10). These were primarily students who read and studied the elaborate analogy text. Students mentioned other learning strategies for remembering the information such as key words, word association games, mnemonics, and diagrams. A large percentage of participants mentioned the way information was represented in the text (23%) as helpful in activating prior knowledge and remembering the information.

Table 9

Posttest Responses of Students to the Question:

"Does the way a cell works remind you of anything similar?"

Conditions:	Factory analogy		Other systems analogy	
	Posttest	Delay	Posttest	Delay
Analogy Activated Instructions:				
Elaborate Analogy Text	27	27	5	5
Simple Analogy Text	15	12	9	13
Control Text	11	13	12	12
% Total Group	53	52	26	30
Control Instructions				
Elaborate Analogy	29	24	2	6
Simple Analogy	7	6	18	21
Control	4	4	22	20
% Total Group	40	34	42	47

Note. Responses considered for the analogy response category were based on the ability of students to map the function to the target, similar to the factory.
There are 198 participants, 66 in each of three text treatment groups and 99 in each of two text instruction groups.

Table 10

Posttest Responses of Students to the Question:

"Explain in a Few Sentences How You Remember What the Parts of a Cell Do."

	Thought about Factory Pre/Post		Studied Booklet Pre/Post		Used other Strategy Pre/Post	
Analogy Activated Instructions						
Elaborate Analogy Text	14	13	3	3	8	5
Simple Analogy Text	1	1	10	8	8	6
Control Text	2	4	3	6	14	8
% Total Group	17%	18%	16%	17%	30%	19%
Control Instructions						
Elaborate Analogy	16	12	7	5	4	6
Simple Analogy	1	---	16	7	8	4
Control	1	4	7	5	9	8
% Total Group	18%	16%	30%	19%	21%	18%

Note. Categories were based on participants' free response answers. There are 198 participants, 66 in each of three text treatment groups and 99 in each of two text instruction groups.

Self-efficacy

Following the delayed posttest participants were asked, “Do you feel confident that you will be able to remember the information about the cell because of what you read and studied in the booklet? Why?” About a third of the students in both text instruction groups felt that they would remember the information (see Table 11). There were no significant differences in self-efficacy among the groups.

These findings indicate that students have a moderate level of confidence in their ability to remember information about the cell. Of the analogy-activated group, 48% of the students indicated that they would be able to remember some or all of the information. The control group indicated similar self-efficacy as well with a total of 48% who responded that they would remember all or some of the information. Self-efficacy is concerned with perceived capability. This question was a general assessment of ability to remember information. Though less sensitive than some measures of efficacy, this open-ended question gave students an opportunity to discuss reasons for their ability to remember information about the cell.

Through the generation of their own analogies, students demonstrated a higher level of reasoning than that indicated by just remembering a suggested analogy (see Table 12). By creating their own analogies by drawing on their life experiences, students demonstrated that shows that they understood the strategy and were able to use it to understand new concepts in science.

Table 11

Posttest Percent Responses of Students to the Question: "Do You Feel Confident that You will be Able to Remember the Information About the Cell Because of What you Read and Studied in the Booklet?"

Conditions:	Response Categories			
	Yes	Some	Maybe	No
Analogy Activated Instructions				
Elaborate Analogy Text	30%	18%	12%	39%
Simple Analogy Text	36%	9%	12%	42%
Control Text	39%	12%	9%	36%
% Total Group	35%	13%	11%	39%
Control Instructions				
Elaborate Analogy Text	52%	18%	9%	21%
Simple Analogy Text	30%	6%	9%	52%
Control Text	36%	3%	9%	48%
% Total Group	39%	9%	9%	40%

Note. Responses were placed in categories based on expressed confidence in ability to remember information about the cell over a period of time.

Table 12

Examples of Responses to the Question, “What does a cell remind you of?”

Analogy Activated Condition

Nick’s Factory analogy: A factory reminds me of a cell. The mitochondria produce power just as a power plant. The golgi bodies carry things out of a cell. The nucleus is the control center just as a control center for a plant. The cell membrane acts like a security guard only letting the right things in. The cytoplasm is like the air in a plant. The endoplasmic reticulum carries things inside just like a canal.

Laura’s Factory analogy: It reminds me of a factory. The cell membrane is like the factory wall, the nucleus like the manager, and the ribosomes like the machines that make stuff.

Linda’s Factory analogy: A factory, all the cell’s parts symbolize something in a factory that helps you remember it better. The book helped me remember when it gave examples of the factory.

Matthew’s Factory analogy: It reminds me of a factory. The nucleus is like the control center, the mitochondria are like the power generators, the wall is like the cell membrane, and so on.

Edna’s Factory analogy: A factory because each part has a certain job, just as everyone in a factory has a certain job.

Control Condition

Robert’s Human Body analogy: Our bodies. Our brain is like the nucleus, and our organs are like the Golgi body, Mitochondria, and E. Reticulum.

Andrew’s sports team analogy: The cell works like any kind of sports team. During a game, the team won’t perform as well if each part of the team is not doing its job.

Saundra’s government analogy: A cell reminds me of government. There are very important jobs and some not so important jobs. You need all of those jobs for it to work.

David’s Computer analogy: A cell reminds me of a computer. CPU = nucleus, different components = ribosomes, mitochondria, etc., motherboard = cytoplasm.

Josh’s Assembly line analogy: It reminds me of an assembly line. The nucleus is like a control center. Mitochondria = electricity (power), cell membrane = walls, cytoplasm = walkways, endoplasmic reticulum = conveyer belt, ribosomes = packages.

CHAPTER V

DISCUSSION AND IMPLICATIONS

In this experiment, eighth grade students read and studied biology text material about the human cell. The students were in one of two instructional groups. One group received an analogy-activated text that instructed them to think of the cell as a factory in which all the parts had a job. The other group received text with no analogy activation. Each of these groups was also divided into smaller groups who read and studied three different text treatments: elaborate analogy, simple analogy, and a control text. The elaborate analogy group received a text with pictorial components and with an explicit comparison of an analog (a factory) with a target concept (the cell). The simple analogy group received a text that generally compared the cell to a factory. The control group had a text with no analogy.

Students who received analogy activation instructions and an elaborate-analogy text were able to explain cell functions better on the posttest than students in a no-analogy control condition. Students who received analogy activation instruction and an elaborate-analogy text were also able to draw cell structures better on the posttest. These findings, taken together, provide strong support for the view that elaborate analogies can promote conceptual understanding. The simple-analogy text fell in between the elaborate analogy text and the control text in effectiveness, not differing significantly from either. The present study did not provide evidence that elaborate analogies stimulate students' perceived interest, understanding, and self-efficacy, Jacqueline's No analogy response: There is nothing besides a cell that reminds me. Possible reasons for this lack of evidence will be discussed in this chapter. The present study did provide greater insight, however, into students' study strategies and their self-generated analogies.

The analogy helped students retain information about the cell immediately after the treatment and three weeks later. The familiar concept of the factory helped students understand and remember the function of cell parts because they were able to map an abstract idea to a more familiar concrete analog. The familiar concept is called the analog and the unfamiliar one is the target. The effect of the analogy was stable because students were able to remember information three weeks later. Though these students benefited from the concrete support of this analogy they were also able to generate their own analogies connected to other familiar analogs. Analogies generated from students in the elaborate analogies group were of better quality than those of the other treatment groups, as evidenced by more correct features.

There seem to be at least two important factors that may have influenced the results of this study. Instructional use of analogies in text does enhance recall when learners are able to use elaborate analogies or are able to generate their own analogies. Almost all the eighth grade students in the analogy activated group thought of analogies to the cell. Some of these analogies exhibited a well-developed ability to link prior knowledge to new information. These findings are consistent with those of other studies in which analogies contributed to the understanding of scientific concepts (Duit, 1991; Glynn & Duit, 1995; Venville and Treagust, 1997).

The other factor is related to the developmental stage of eighth grade students. Glynn and Takahashi (1998) found that both eighth grade students and sixth grade students benefited from the use of analogies in text, and were even able to create their own analogies. This is consistent with the view that students of this age have begun the stage in which they are able to reason at a higher cognitive level (Piaget, 1964). The children in the Glynn and Takahashi study were able to create analogies based on real experiences and relate them to new ideas they were trying to understand. This was also the case in the present study. Students in the elaborate analogy group generated analogies based on the model of the factory and were able to use this analogy to understand and remember information about the cell. More importantly, this study expanded on previous findings by demonstrating that elaborate analogies enhance students' conceptual understanding as indicated by their drawings of cell structures. Elaborate analogies interacted with the imagery process to support conceptual learning.

Students' Strategic Use of Analogies

Pretest responses in the present study indicated that 12% were reminded of a factory when thinking of the cell. It is likely that these students and other students in the classes had previously used the factory analogy, as well as other learning strategies to remember the parts of the cell. Interviews with students following the delayed posttest confirmed that teachers in years past had used the factory analogy when teaching a unit on the cell. The students were using this and other analogies spontaneously, particularly in the elaborate analogy condition.

Answers to two questions indicated that students used analogies spontaneously. The first question, "Does the way a cell works remind you of anything similar?" drew an informative response. Many students mentioned the factory, but others mentioned various other systems (e.g., human body, computer, and sports team) that could describe the way a cell works. The second question asked was, "Was there anything in the text that helped you to remember the functions of the cell parts? Explain what it was." These answers included the analogy of the factory, other analogies, and various learning strategies, such as neumonics and word association. None seemed as helpful as the elaborate analogy. Of these students, 18% used some sort of analogy to remember the information. These analogies were reasonable in that they represented systems with interrelated parts that work together. More than 30% of the total group also used an additional learning strategy to remember the functions of the cell, however, none were as effective as the elaborate analogy.

When specific features of the analogies were examined, it was found that some students included more parts of the cell than their classmates. For example, in the analogy-activated condition a student named Nick correctly mapped five features of the cell: Mitochondria/power plant, nucleus/control center, membrane/security guard, cytoplasm/air, endoplasmic reticulum/canal. The richness of detail in this analogy demonstrates a relatively deep understanding of the concept. Edna, on the other hand, gave a less detailed answer when she stated that the factory is like the cell because,

“. . .each part has a certain job, just as everyone in a factory has a certain job.”

Fewer analogies were generated by students in the control group, but even among those, some show a very detailed mapping of cell features to the target. Consider David’s computer analogy: CPU = nucleus, different components = ribosomes, mitochondria, etc., and motherboard = cytoplasm. Josh also made a very detailed analogy to an assembly line: nucleus/control center, mitochondria/electricity, membrane/walls, cytoplasm/walkways, endoplasmic reticulum/conveyer belt, ribosomes/packages. These student-generated analogies indicate that, even when not prompted, some eighth grade students are familiar with the analogy as a learning strategy. In general, however, these analogies were not as effective for conceptual understanding as the elaborate analogy that compared the cell to a factory. The development of a cognitive learning strategy such as generating spontaneous analogies is a primary goal of effective instruction (Pressley & Woloshyn, 1995).

Duckworth (1987) described the construction of knowledge as “Meaning not given to us in our ***encounters***, but (the meaning) is given ***by us***, constructed ***by us***, each in our own way, according to how our understanding is currently organized.” (p. 112). Students may be given analogies to use in understanding scientific concepts, but the analogy must be one that is familiar to the students themselves so that they may build a “conceptual bridge” between what they know and what they are trying to learn (Glynn, 1995).

Students’ Cognitive Development

In the study by Glynn and Takahashi (1998) eighth grade students systematically generated a wide variety of analogies to compare to the animal cell. These findings indicated that the cognitive development of middle school students plays an important role in their spontaneous generation of analogies during learning. Almost all the eighth graders in this study, regardless of treatment condition, were reminded of an analogy. This is consistent with the view (Carey, 1985; Metz, 1995; Piaget, 1964) that children from age 7 to 11 tend to reason logically about tangible objects and events better than about abstractions. Later, by age 11 or 12, many children begin to think and reason about hypothetical situations and events that have no basis in reality. The eighth grade students in the present study, as well as in the Glynn and Takahashi study, had moved from concrete thinking into more abstract, reflective thinking. Children who move from concrete operational thought to formal operations have more sophisticated thought processes, and they are able to generate their own learning strategies.

In the present study, the analogy provided a bridge of understanding for the students in the elaborate analogy text group. They were able to understand the concept of the cell and the functions of the cell parts. The diagram helped the students remember the cell parts and they were able to successfully record information about cell structure in their own drawings. Though it is apparent that these eighth grade students are capable of generating their own analogies, it was clear that the analogy of the factory helped them remember specific facts about the cell.

Another interesting finding from this present study is that students apparently continued to use the analogy over an extended period to help them remember what the cell parts do. After a delay of three weeks, a significantly higher percentage of the students in the elaborate analogies groups continued to cite the use of the factory analogy as an aid in remembering the material compared to the other text treatment groups.

Interest and Understanding

Concerning students' expressed interest and their conceptual understanding of the cell, the mean scores for all treatments indicated no statistically significant effects for any of the treatment groups. Thus, the findings from the posttest and delayed posttest measures did not support the hypotheses posed. Interest and understanding were not affected in treatments where students were given elaborate analogies. Prior research suggested that there would be a positive relationship between analogies and intrinsic motivation (Deci, Vallerand, Pelletier, & Ryan, 1991; Lepper & Hodell, 1989). It was expected that students who received the elaborate analogy text treatment would have a greater desire to build new knowledge than the other treatment groups. This was not the case. Interest and understanding were higher after the posttest compared to the delayed posttest, but the groups did not differ significantly from each other.

Interviews with students following the delayed posttest revealed that they participated in units on the cell in fifth grade, sixth grade, and seventh grade. To build understanding in the science classroom, it is necessary for students to construct a personal idea of the concept, link it to what they already know and test their ideas through experimentation and conversation (Bussis, Chittenden, Amarel, and Klauser, 1985). It may be that interest and understanding would be increased through activities and experiments designed to extend these initial ideas. Alternatively, it may be that a "factory," while conceptually helpful, is not a particularly interesting environment and, therefore, is not perceived as particularly useful. In future research, a sports team analogy might be a better choice.

Self-efficacy

Following the delayed posttest, students were given an opportunity to respond openly to the question, "Do you feel confident that you will be able to remember the information about the cell because of what you read and studied in the booklet? Why?" About one third of the students in both the analogy activation group and the control group responded "yes".

Self-efficacy develops through successful experiences. Children evaluate the effectiveness of their own actions, compare it to the actions of others, and are told by others how their behavior meets certain standards (Bandura, 1986). It may be that the students in this present study were disappointed that they did not remember more information about the cell on the delayed posttest and felt less confident that they would remember information about the cell in the future. Lower scores on the delayed posttest may also explain the lower measures for interest and understanding.

These findings could indicate that some students need a higher level of "scaffolding" than that provided in these text treatments (Vygotsky, 1978; Wood, Bruner, & Ross, 1976). Students who learn new strategies in processing information often benefit from extended use of the strategy in classroom experiences. Both individual and group guidance may be needed to provide a greater level of support and build confidence in the students' ability to use the strategy as well as remember the targeted information.

Implications for Theory and Practice

The results of this study clearly indicate that elaborate analogies are effective in the learning of science concepts from textbooks. It is important that these analogies be presented in an organized and systematic fashion, such as that suggested by the Teaching With Analogies model. Previous findings have been inconclusive and provide little support for teaching with analogies because students may become confused if analogies are not carefully written and presented (e. g., Bean, Searles, Singer, & Cowen, 1990).

Perhaps the most interesting finding from this present study was the ability of these students to spontaneously create their own analogies. When faced with a situation in which they needed to learn and remember new information, most of these eighth grade students were able to use the analogy of the cell to a factory, but were also able to create their own analogies to remember information about the cell.

From a theoretical perspective, it seems that these findings support the idea that analogies play an important role in the meaningful learning of science text. As students adopted the elaborate analogy and generated spontaneous analogies of their own, they began to make connections with knowledge. It is encouraging that the elaborate analogies text group had higher mean scores on function and structure of the cell. Some students were able to connect familiar schema with new ones, constructing their own mental models to help them remember and recall information more effectively. From this perspective, learning from text was meaningful and more constructive in nature (Glynn & Muth, 1994; Holliday, Yore, & Alvermann, 1994).

In terms of practical implications, some students indicated that the analogy helped them recall key concepts both immediately after text treatment and three weeks later. With these students, the effect of the analogy was a durable one. Other students did not recognize the analogy as helpful in remembering information, but used other learning strategies. Many students in the control group said that "simply" reading and studying the text was most helpful in their understanding of the cell. These students provided little information about their cognitive processes, either during the treatment or three weeks later. It may be that they were less metacognitive in their learning; they were using less effective learning strategies and may benefit from instruction in the use of elaborate analogies.

Though students in the elaborate analogy text treatment group seemed to benefit from the elaborate analogy, the other students were able to remember almost as much information by developing their own spontaneous analogies. These spontaneous analogies by students in the control text groups were reasonable as well as insightful as they related the information about the cell to other systems with interacting parts (e.g., the human body, an assembly line, and a computer). They drew upon experiences from their own daily lives to make the concepts meaningful.

The present study had at least four limitations that should be addressed in future studies. One concerns the familiarity of the students with the analog concept, a factory. This analogy is one that is frequently used by science teachers as they teach students about the cell. It would be useful in future studies to construct other elaborate analogies for a variety of concepts. Additional elaborate analogies (e.g., the heart is like a pump, electricity flows like water through a circuit) could be developed using the Teaching With Analogies model to determine how well students are able to process information.

The second limitation was the amount of information provided about the way in which students were processing information. While it was encouraging that students created their own analogies, it was not clear whether or not students were using these analogies metacognitively to process information about the cell. In the future, it would be useful to design measuring instruments that are more precise and which can specifically assess techniques that students may use to remember information.

A third limitation is that the elaborate analogy improved retention immediately after text study, but not three weeks later. It may be that students should have more active involvement and experience with the analogy (e.g., a field trip to a factory). In future research, the analogy could be made more meaningful and powerful by involving students to a greater degree with it.

A fourth limitation is that the sample of the study may not representative of that in public schools in general. The sample was from a school with limited diversity. In future research, samples with greater diversity that are more representative of public schools nation wide should be employed.

We all use analogies to understand new ideas from childhood through adolescence and into adulthood. Analogies are clearly beneficial to learning. The key to their effectiveness seems to hinge on the position of students on the learning curve for a particular concept and their degree of conceptual development. When analogies are accurate, student generated analogies are preferable to instructor generated analogies because students are constructing their own knowledge and understanding of a concept. The analogies presented in a textbook can be a bridge linking prior knowledge to new ideas. They may also be effective in helping students formulate learning strategies for remembering other information in science, encouraging them to create more links to personal experience.

Directions for Future Research

Directions for future research in the use of elaborate analogies should progress in at least three ways. First, the role of elaborate analogies in learning concepts in science should be further investigated for younger students in middle school. This study showed that eighth grade students had developed their own cognitive strategies for remembering information. Future research should investigate the usefulness of elaborate analogies in text to help younger students understand concepts in science. Second, researchers should assess students' familiarity with the analogy prior to treatment conditions. It appeared that most students were familiar with the factory because it had been used when students studied the cell in previous years. It would be helpful to use analogies that are less familiar to students in order to measure the effectiveness of analogy instruction. And finally, future research should investigate the usefulness of elaborate analogies created by students themselves on the understanding and retention of key concepts in science.

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APPENDIX A

TEXTS AND DIAGRAMS FOR THE CONTROL TEXT TREATMENT

Students in the control condition will receive the following base text and diagram accompanied by the following instructions:

Analogy Activated:

AC-ID Grade C-ID Name

Animal Cells and Their Parts

Instructions:

In the next 20 minutes, please study this booklet carefully and learn the parts of cells and the functions of these parts. When you study, you may notice analogies between cells and other things with which you are more familiar (e.g., a cell could be like a factory). When you finish reading the booklet one time, please continue to review it and study it until the time is up. After 20 minutes is up, the booklets will be collected and you'll be asked to recall, as best you can, the cell parts and their functions. Please study quietly. Different people have different booklets, so don't worry if yours is different than someone else's booklet.

Control:

C-ID Grade C-ID Name

Animal Cells and Their Parts

Instructions:

In the next 20 minutes, please study this booklet carefully and learn the parts of cells and the functions of these parts. When you finish reading the booklet one time, please continue to review it and study it until the time is up. After 20 minutes is up, the booklets will be collected and you'll be asked to recall, as best you can, the cell parts and their functions. Please study quietly. Different people have different booklets, so don't worry if yours is different than someone else's booklet.

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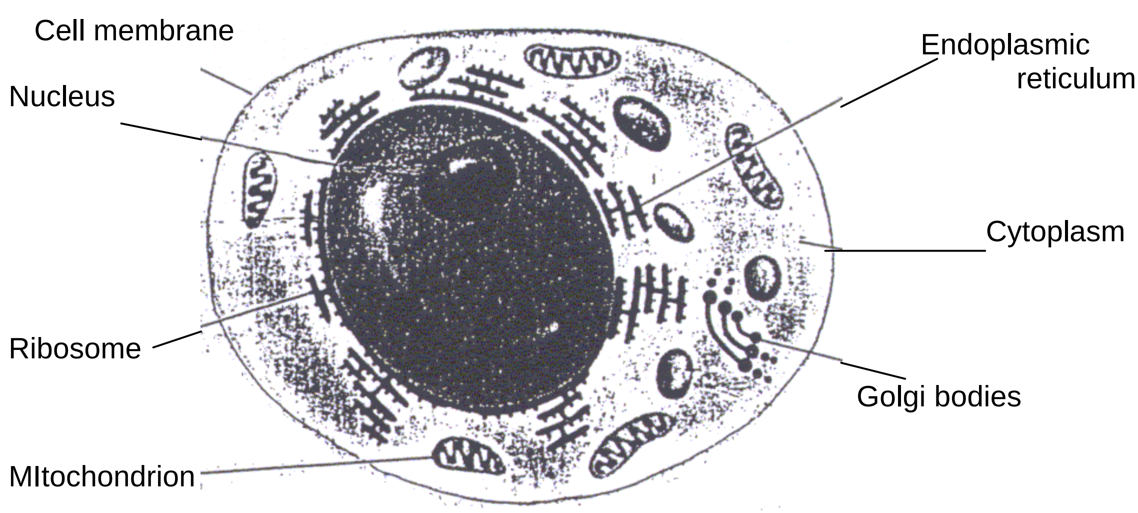
Animal Cells and Their

The first time that you look at animal cells under the microscope is very exciting. All animals are made of very tiny cells. Each cell functions along with the other cells to keep the animal alive and healthy. But the cell,. although extremely small in size, is not the smallest structure in an animal. Within a cell are different structures that help the cell to carry out its functions.

The parts of the cell make it possible for each cell to grow, to release energy from food, and to get rid of wastes, and to divide to create new cells. Some of the most important parts of cells are: the cell membrane, the nucleus, the chromosomes, the cytoplasm, the ribosomes, the endoplasmic reticulum, the Golgi bodies, and the mitochondria. All of these cell parts and their functions will be described in the following sections.

SOME OF THE PARTS OF A TYPICAL ANIMAL CELL



Cell Membrane

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 keeps 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.

Continued on Next Page

Nucleus

The nucleus is usually round or oval shaped, and near the middle of a cell. The nucleus also appears darker than the rest of a cell. The **nucleus** controls the cell's activities. The instructions for all of the cell's activities are in the material that is found inside the nucleus. Around the nucleus is a special covering called the nuclear envelope. Like the cell membrane, this envelope controls the movement of materials into and out of the nucleus.

Cytoplasm

The material between the cell membrane and the nucleus is called cytoplasm (SY tuh plazuhm). Cytoplasm surrounds all the cell parts. Cytoplasm is a jelly-like material, made up mostly of water, that constantly moves within the cell.

Organelles

Organelles are structures within a cell that have certain jobs to do for the cell, much like each organ in your body ha's a job to do. So organelles can be thought of as .the "organs" of the cell. The parts of the cell that will be described in the following sections are all organelles.

Ribosomes

Most of the cell and much of our bodies are made of proteins. The tiny, round dark organelles that make proteins are the ribosomes (RY buh sohmz). Ribosomes take raw materials from the cytoplasm to make the proteins. Ribosomes assemble proteins, which the cell uses for growth, repair, and control. Some ribosomes are attached to the endoplasmic reticulum, while others float freely in the cytoplasm.

Endoplasmic Reticulum

The largest organelle in the cytoplasm is the **endoplasmic reticulum** (ehn duh PLAZ mhk rih TIHK juh luhm). This organelle is a network of tubelike canals that run through the cytoplasm. It stores and transports materials from place to place in the cell. Some of these materials will be sent to the **Golgi Bodies.**

Continued on Next Page

Golgi Bodies

Materials that are transported by the endoplasmic reticulum usually stop first at Golgi (GOHL jee) bodies, where they are "packaged" and stored before they are sent to destinations inside and outside of the cell. **Golgi bodies** Golgi bodies look like stacks of flattened sacs or balloons in the cytoplasm. After a protein is made by a ribosome, the endoplasmic reticulum moves the protein to the Golgi bodies which package it and move it outside the cell.

Mitochondria

The organelles that release energy are **mitochondria** (myt uh KAHN dree uh). Both structures provide energy. Food molecules are broken down inside these organelles, and energy is released. This energy is used to keep the cell working properly. Energy from trillions of mitochondria in billions of cells keeps the body working properly.

Conclusion

A animal cell is a collection of smaller, essential parts that interact and perform important functions that support life. It's important to know the parts. of cells and their functions because all living things are made of cells. Because of this, all living things are related to each other.

The End

Please re-read and study the booklet quietly until the time is up. Then you will be asked to explain what each part of the cell does.

APPENDIX B

TEXTS AND DIAGRAMS FOR SIMPLE ANALOGY TEXT TREATMENT

Students will receive one of the following simple-analogy text treatments with accompanying diagram.

Analogy Activated:

AS-ID Grade S-ID Name

Animal Cells and Their Parts

Instructions:

In the next 20 minutes, please study this booklet carefully and learn the parts of cells and the functions of these parts. When you study, you may notice analogies between cells and other things with which you are more familiar (e.g., a cell could be like a factory). When you finish reading the booklet one time, please continue to review it and study it until the time is up. After 20 minutes is up, the booklets will be collected and you'll be asked to recall, as best you can, the cell parts and their functions. Please study quietly. Different people have different booklets, so don't worry if yours is different than someone else's booklet.

Control:

S-ID Grade S-ID Name

Animal Cells and Their Parts

Instructions:

In the next 20 minutes, please study this booklet carefully and learn the parts of cells and the functions of these parts. When you finish reading the booklet one time, please continue to review it and study it until the time is up. After 20 minutes is up, the booklets will be collected and you'll be asked to recall, as best you can, the cell parts and their functions. Please study quietly. Different people have different booklets, so don't worry if yours is different than someone else's booklet.

Animal Cells and Their

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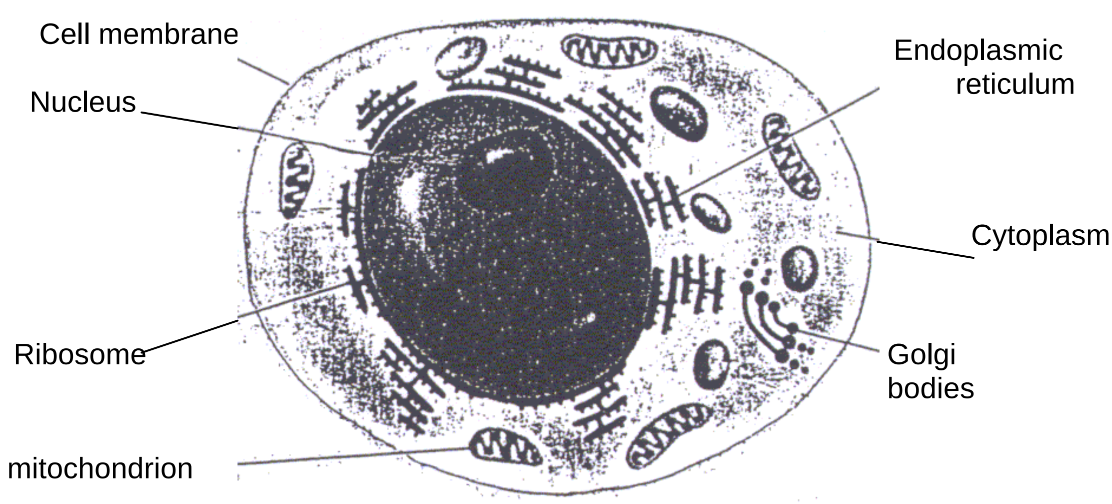
The parts of the cell make it possible for each cell to grow, to release energy from food, and to get rid of wastes, and to divide to create new cells. Some of the most important parts of cells are: the cell membrane, the nucleus, the chromosomes, the cytoplasm, the ribosomes, the endoplasmic reticulum, the Golgi bodies, and the mitochondria. All of these cell parts and their functions will be described in the following sections. You might think of a cell as a tiny factory that takes in raw materials, performs many tasks, and makes products.

SOME OF THE PARTS OF A TYPICAL ANIMAL CELL



Cell Membrane

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 keeps 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.

Nucleus

The nucleus is usually round or oval shaped, and near the middle of a cell. The nucleus also appears darker than the rest of a cell. The **nucleus** controls the cell's activities. The instructions for all of the cell's activities are in the material that is found inside the nucleus. Around the nucleus is a special covering called the *nuclear envelope.* Like the cell membrane, this envelope controls the movement of materials into and out of the nucleus.

Cytoplasm

The material between the cell membrane and the nucleus is called cytoplasm (SY tuh plazuhm). Cytoplasm surrounds all the cell parts. Cytoplasm is a jelly-like material, made up mostly of water, that constantly moves within the cell.

Organelles

Organelles are structures within a cell that have certain jobs to do for the cell, much like each organ in your body has a job to do. So organelles can be thought of as .the "organs" of the cell. The parts of the cell that will be described in the following sections are all organelles.

Ribosomes

Most of the cell and much of our bodies are made of proteins. The tiny, round dark organelles that make proteins are the **ribosomes** (RY buh sohmz). Ribosomes take raw materials from the cytoplasm to make the proteins. Ribosomes assemble proteins, which the cell uses for growth, repair, and control. Some ribosomes are attached to the endoplasmic reticulum, while others float freely in the cytoplasm.

Endoplasmic Reticulum

The largest organelle in the cytoplasm is the **endoplasmic reticulum** (ehn duh PLAZ mhk rih TIHK juh luhm). This organelle is a network of tubelike canals that run through the cytoplasm. It stores and transports materials from place to place in the cell. Some of these materials will be sent to the **Golgi Bodies.**

Continued on Next Page

Golgi Bodies

Materials that are transported by the endoplasmic reticulum usually stop first at Golgi (GOHL jee) bodies, where they are "packaged" and stored before they are sent to destinations inside and outside of the cell. Golgi bodies Golgi bodies look like stacks of flattened sacs or balloons in the cytoplasm. After a protein is made by a ribosome, the endoplasmic reticulum moves the protein to the Golgi bodies which package it and move it outside the cell.

Mitochondria

The organelles that release energy are mitochondria (myt uh KAHN dree uh). Both structures provide energy. Food molecules are broken down inside these organelles, and energy is released. This energy is used to keep the cell working properly. Energy from trillions of mitochondria in billions of cells keeps the body working properly.

Conclusion

A animal cell is a collection of smaller, essential parts that interact and perform important functions that support life. It's important to know the parts. of cells and their functions because all living things are made of cells. Because of this, all living things are related to each other.

The End

Please re-read and study the booklet quietly until the time is up. Then you will be asked to explain what each **part of the cell does.**

APPENDIX C

TEXTS AND DIAGRAMS FOR THE ELABORATE-ANALOGY

TEXT TREATMENT

Students will receive one of the following elaborate analogy texts with accompanying diagram.

Analogy Activated:

AE-ID Grade E-ID Name

Animal Cells and Their Parts

Instructions:

In the next 20 minutes, please study this booklet carefully and learn the parts of cells and the functions of these parts.- When you study, you may notice analogies between cells and other things with which you are more familiar (e.g., a cell could be like a factory). When you finish reading the booklet one time, please continue to review it and study it until the time is up. After 20 minutes is up, the booklets will be collected and you'll be asked to recall, as best you can, the cell parts and their functions. Please study quietly. Different people have different booklets, so don't worry if yours is different than someone else's booklet.

Control:

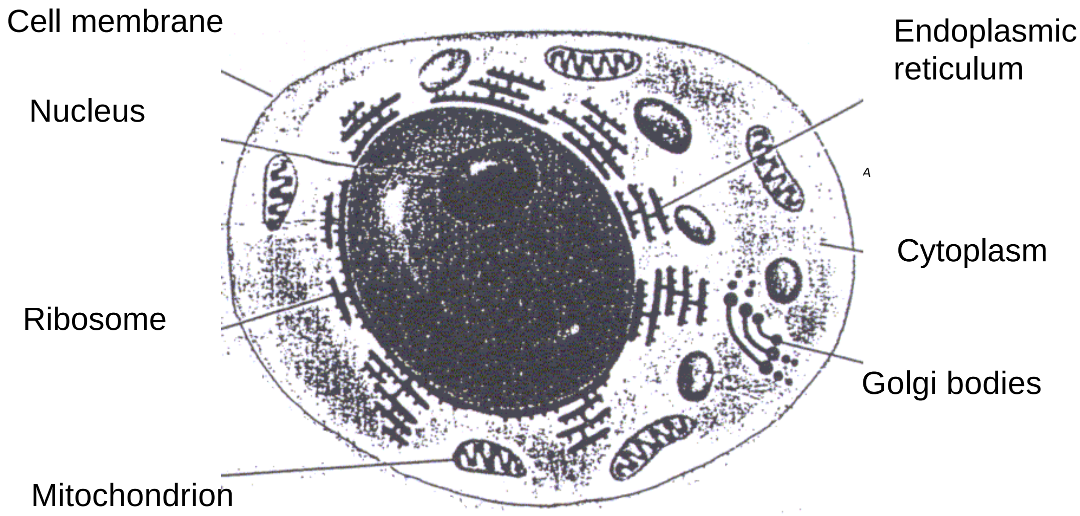
E-ID Grade E-ID Name

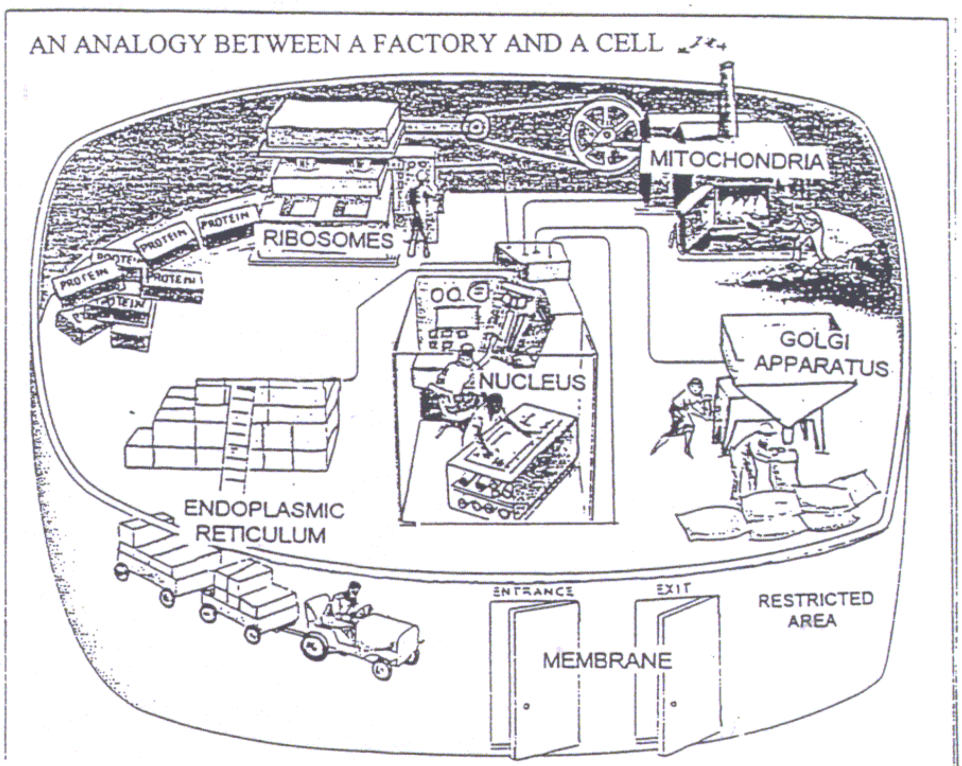
Animal Cells and Their Parts

Instructions:

in the next 20 minutes, please study this booklet carefully and learn the parts of cells and the functions of these parts. When you finish reading the booklet one time, please continue to review it and study it until the time is up. After 20 minutes is up, the booklets will be collected and you'll be asked to recall, as best you can, the cell parts and their functions. Please study quietly. Different people have different booklets, so don't worry if yours is different than someone else's booklet.

SOME OF THE PARTS OF A TYPICAL ANIMAL CELL





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Animal Cells and Their Parts

The first time that you look at animal cells under the microscope is very exciting. All animals are made of very tiny cells. Each cell functions along with the other cells to keep the animal alive and healthy. But the cell, although extremely small in size, is not the smallest structure in an animal. Within a cell are different structures that help the cell to carry out its functions.

The parts of the cell make it possible for each cell to grow, to release energy from food, and to get rid of wastes, and to divide to create new cells. Some of the most important parts of cells are: the cell membrane, the nucleus, the chromosomes, the cytoplasm, the ribosomes, the endoplasmic reticulum, the Golgi bodies, and the mitochondria. All of these cell parts and their functions will be described in the following sections.

You might think of a cell as a tiny factory that takes in raw materials, performs many tasks, and makes products. Different people in the factory work at machines doing different jobs. Likewise, each part of the cell has a special job. Together, the parts keep the cell working properly. Here are some similarities between factory parts and cell parts:

FACTORY	CELL
1. restricted entrance/exit	membrane
2. control center	nucleus
3. air inside the factory	cytoplasm
4. production machines	protein-making ribosomes
5. inside delivery and storage	endoplasmic reticulum
6. packaging and outside delivery	Golgi apparatus
7. power generators	mitochondria

Think carefully about the above similarities and study the factory illustration. But remember that this "factory-cell" analogy, like all analogies, breaks down in places. For example, the membrane envelops the entire cell and has many tiny openings, whereas the factory has only a few entrances in specific locations. In general, however, if you remember how a 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 parts that interact and perform important functions that support life.

Continued on Next Page

Cell Membrane

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 keeps other materials out, just like a security guard at the entrance and exit of a factory. 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.

Nucleus

The nucleus is usually round or oval shaped, and near the middle of a cell. The nucleus also appears darker than the rest of a cell. The **nucleus** controls the cell's activities, just as the factory manager controls the operations of a factory. The instructions for all of the cell's activities are in the material that is found inside the nucleus. Around the nucleus is a special covering called the *nuclear envelope.* Like the cell membrane, this envelope controls the movement of materials into and out of the nucleus.

Cytoplasm

The material between the cell membrane and the nucleus is called cytoplasm (SY tuh plazuhm). Cytoplasm surrounds all the cell parts, just as air surrounds all the people in a factory. Cytoplasm is a jelly-like material, made up mostly of water, that constantly moves within the cell.

Organelles

Organelles are structures within a cell that have certain jobs to do for the cell, much like each organ in your body has a job to do. So organelles can be thought of as the "organs" of the cell. The parts of the cell that will be described in the following sections are all organelles.

Ribosomes

Most of the cell and much of our bodies are made of proteins. The tiny, round dark organelles that make proteins are the **ribosomes** (RY buh sohmz). Ribosomes are like small machines that take raw materials from the cytoplasm to make the proteins. Ribosomes assemble proteins, which the cell uses for growth, repair, and control. Some ribosomes are attached to the endoplasmic reticulum, while others float freely in the cytoplasm.

Continued On Next Page

Endoplasmic Reticulum

The largest organelle in the cytoplasm is the **endoplasmic reticulum** (ehn duh PLAZ mhk rih TIHK juh luhm). This organelle is a-network of tubelike canals that run through the cytoplasm. Just as a factory uses carts and conveyor belts for transporting materials, the cell has the endoplasmic reticulum to do this job. It stores and transports materials from place to place in the cell. Some of these materials will be sent to the **Golgi Bodies.**

Golgi Bodies

Materials that are transported by the endoplasmic reticulurn usually stop first at Golgi (GOHL jee) bodies, where they are "packaged" and stored before they are sent to destinations inside and outside of the cell. **Golgi bodies** Golgi bodies look like stacks of flattened sacs or balloons in the cytoplasm. After a protein is made by a ribosome, the endoplasmic reticulum moves the protein to the Golgi bodies which package it, put it in a sort of "mail bag," and move it outside the cell.

Mitochondria

The organelles that release energy are mitochondria (myt uh KAHN dree uh). For this reason, the mitochondria are often called the "powerhouses" of the cell. You ran compare the mitochondria to the power plant in a factory. Both structures provide energy. Food molecules are broken down inside these organelles, and energy is released. This energy is used to keep the cell working properly. Energy from trillions of mitochondria in billions of cells keeps the body working properly.

Conclusion

A animal cell is a collection of smaller, essential parts that interact and perform important functions that support life. It's important to know the parts of cells and their functions because all living things are made of cells. Because of this, all living things are related to each other.

The End

Please re-read and study the booklet quietly until the time is up. Then you will be asked to explain what each part of the cell does.

APPENDIX D

MEASURE OF PRIOR KNOWLEDGE OF CELL FUNCTION

The following knowledge instrument will be used to measure students' prior knowledge as well as interest and understanding of the cell.

ID Grade ID Name

Date Preliminary Questions: All Students

Instructions:

Think about what you have learned about the cell. You may remember a lot of the information, or only a little-that's fine, just do the best you can.

Turn the page and answer the questions about the cell parts and their functions.

9

Please explain, as best you can, what the following cell parts do. It's ok to explain in your own words and it's ok to guess. Try to explain as much as you can, and be as specific as you can. Write complete sentences. If you need extra paper, please ask the teacher. Think about what you read and saw in the booklet.

1. The Cell Membrane

2. The Nucleus

3. The Cytoplasm

Continued on Next Page

4. The Ribosomes

5. The Endoplasmic Reticulum

6. The Golgi Bodies

7. The Mitochondria

8. Does the way a cell works remind you of anything similar? In a few sentences, please explain what it is that cell reminds you of.

APPENDIX E

KNOWLEDGE MEASURE OF CELL FUNCTION

The following knowledge instrument will be used to measure students' learning as well as interest and understandability of the text immediately after text treatment.

4

ID Grade ID Name

Date Follow-Up Questions: All Students

Instructions:

(1) Please answer the first 2 questions below by making a circle with your pen or pencil. Think about what you read and saw in your booklet about the cell when you answer the questions. You don't have to put the same answers that you put before-it's okay to change your mind.

(2) Then, answer the remaining questions about the cell parts and their functions. Think about what you read and saw in your booklet about the ceIl--that will help you to explain what each part of the cell does.

1. How interesting a topic do you think the **cell** is, compared to other topics in life science? (Please circle one choice below.)

Not Interesting	A Little Interesting	Somewhat Interesting	Interesting	Very Interesting
1	2	3	4	5

2. How well do you understand the cell, compared to other topics in life science? (Please circle one choice below.)

Not Well	A Little Bit	Somewhat	Well	Very **Well**

Continued on the Back of this Page

Please explain, as best you can, what the following cell parts do. It's ok to explain in your own words and it's ok to guess. Try to explain as much as you can, and be as specific as you can. Write complete sentences. If you need extra paper, please ask the teacher. Think about what you read and saw in the booklet.

1. The Cell Membrane

2. The Nucleus

3. The Cytoplasm

Continued on Next Page

4. The Ribosomes

5. The Endoplasmic Reticulum

6. The Golgi Bodies

7. The Mitochondria

Continued on Back of this Page

8. Does the way a cell works remind you of anything similar? In a few sentences, please explain what it is that a cell reminds you of.

9. Explain in a few sentences how you remembered what the parts of the cell do. Was there anything in the booklet that helped you to remember the functions of cell parts? Explain what it was.

APPENDIX F

DELAYED KNOWLEDGE MEASURE

The following knowledge instrument will be used to measure students' retention of information three weeks after treatment. It also includes questions designed to measure self-efficacy and interest in the topic.

9

ID Grade ID Name

Date Follow-Up Questions (Long Term): All Students

Instructions:

(1) Please answer the first 2 questions below by making a circle with your pen or pencil. Think about what you read and saw in the booklet about the cell, when you answer the questions. You don't have to put the same answers that you put before-it's ok to change your mind.

(2) Then, answer the remaining questions about the cell parts and their functions. Think about what you read and saw in your booklet about the cell--that will help you to explain what each part of the cell does.

1. How interesting a topic do you think the cell is, compared to other topics in life science? (Please circle one choice below.)

Not Interesting	A Little Interesting	Somewhat Interesting	Interesting	Very Interesting
1	2	3	4	5

2. How well do you understand the cell, compared to other topics in life science? (Please circle one choice below.)

Not Well	A Little Bit	Somewhat	Well	Very Well
1	2	3	4	5

Continued on the Back of this Page

Please explain, as best you can, what the following cell parts do. It's ok to explain in your own words and it's ok to guess. Try to explain as much as you can, and be as specific as you can. Write complete sentences. If you need extra paper, please ask the teacher. Think about what you read and saw in the booklet.

1. The Cell Membrane

2. The Nucleus

3. The Cytoplasm

Continued on Next Page

4. The Ribosomes

5. The Endoplasmic Reticulum

6. The Golgi Bodies

7. The Mitochondria

Continued on Back of this Page

8. Does the way a cell works remind you of anything similar?
In a few sentences, please explain what it is that a cell reminds you of.

9. Explain in a few sentences how you remembered what the parts of the cell do.
Was there anything in the textbook that helped you to remember the functions of cell parts? Explain what it was.

10. Do you feel confident that you will be able to remember the information about the cell because of what you read and studied in the booklet? Why?

11. Did you look for any other information about cells or the human body after we read the booklets in class? Where did You rind the information?

The End

APPENDIX G

CONSENT FORM

9

PARENTAL CONSENT FORM

I agree to allow my child to take part in a study titled, "Elaborate Analogies in Science Text," which is being conducted by Mrs. Mary Catherine May, Graduate Student in the Dept. of Educational Psychology, University of Georgia. I understand that this participation is entirely voluntary, I or my child can stop taking part at any time without penalty to his/her grade. I can ask to have the results of the participation related to my child returned to me, removed from the
research records or destroyed.

Mrs. May is a former teacher of the Vestavia School System who is currently working on a doctorate degree in Educational Psychology from the University of Georgia. The reason for the research is to develop a strategy that uses analogies to help middle school students learn from science textbooks. Students who take part may improve their understanding of science. Mrs. May also hopes to learn something that may help other students remember science facts.

Students will be asked to silently read a section ofscience text and then answer questions to show that they understand key concepts. This will occur during regular instruction and involve about 40 minutes. Your child may be asked to think about analogies and use them in the study. Some students may be interviewed about the experience and asked to comment on the effectiveness of this learning strategy.

If you do not want your child to take part then he/she will be given another assignment to read and study from the science textbook. The research is not expected to cause any harm or discomfort. Your child may quit at any time and his/her grade will not be effected.

The results of this participation will be anonymous. Any information collected about your child will be held confidential unless otherwise required by law. All information will be coded. If you have any further questions about the research, at any time during the project, you may contact Mrs. May at (205) 525-9430. You may also contact the professor supervising the research, Dr. Shawn Glynn, Educational Psychology, University of Georgia, (706) 542-4100.

I understand the study procedures described above. My questions have been answered to my satisfaction, and I agree to allow my child to take part in this study. Copies of this form are available from Mrs. May if you wish to keep a copy.

Signature of Researcher Date Signature of Parent Date

Questions or problems regarding your child's rights as a participant should be addressed to Julia D. Alexander, M.A., institutional Review Board, Office ofthe Vice President for Research, University ofGeorgia, 606A Boyd Graduate Studies Research Center, Athens, Georgia 3060/2-7411, Telephotic (706) 542-6514, E-Mail Addrcss: I RB@uga.edu.

APPENDIX H

RAW DATA

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
101	1	1	0	4	3	2	6
102	1	1	2	7	3	5	7
103	1	1	2	6	2	4	7
104	1	1	0	6	4	1	5
105	1	1	1	6	5	2	7
106	1	1	1	5	4	2	6
107	1	1	1	4	1	2	6
108	1	1	2	7	4	3	6
109	1	1	3	4	2	2	4
110	1	1	1	5	1	3	7
111	1	1	0	5	1	1	3
113	1	1	4	7	7	7	7
114	1	1	2	5	4	4	7
115	1	1	0	3	3	5	5
116	1	1	0	3	3	3	7
117	1	1	1	5	4	2	7
118	1	1	1	6	1	2	5
119	1	1	0	4	2	0	5

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
120	1	1	0	2	1	3	6
121	1	1	0	3	0	2	4
122	1	1	3	7	7	6	7
123	1	1	4	7	6	4	7
124	1	1	1	6	2	1	7
125	1	1	2	4	4	4	6
126	1	1	0	4	1	3	4
128	1	1	3	7	6	4	6
129	1	1	2	5	4	4	5
130	1	1	0	4	2	2	3
131	1	1	3	7	6	5	7
132	1	1	1	6	5	3	6
133	1	1	1	6	6	1	6
134	1	1	2	7	4	3	7
135	1	1	4	7	6	6	7
201	1	2	1	3	2	1	7
202	1	2	1	3	2	4	5
203	1	2	1	5	1	3	4
204	1	2	1	1	1	6	6
206	1	2	0	3	3	2	4
207	1	2	2	2	2	6	6
209	1	2	1	6	4	3	5

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
210	1	2	4	7	6	3	7
211	1	2	4	7	7	6	7
212	1	2	0	1	2	2	4
213	1	2	2	6	5	5	7
214	1	2	4	5	6	3	6
215	1	2	6	7	7	4	6
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217	1	2	1	3	3	4	5
218	1	2	0	2	1	2	7
219	1	2	4	6	6	3	7
220	1	2	1	3	2	4	5
221	1	2	2	2	1	4	6
222	1	2	1	3	1	1	2
223	1	2	5	7	6	5	7
224	1	2	4	7	7	6	7
225	1	2	0	3	1	2	3
226	1	2	0	0	0	5	6
227	1	2	1	7	4	1	7
228	1	2	0	2	0	2	6
229	1	2	2	2	4	2	6
230	1	2	2	7	4	2	6
231	1	2	2	7	3	3	7

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
232	1	2	1	7	6	3	6
233	1	2	0	1	0	0	3
234	1	2	3	7	6	5	7
235	1	2	1	6	2	2	4
301	1	3	0	1	0	1	5
302	1	3	0	1	1	1	5
303	1	3	0	2	2	1	7
304	1	3	4	5	5	6	7
305	1	3	1	4	1	4	7
306	1	3	0	4	3	2	3
307	1	3	0	5	1	3	7
309	1	3	4	6	5	6	6
310	1	3	1	7	4	2	5
311	1	3	0	6	4	2	7
312	1	3	4	6	6	3	7
313	1	3	0	3	1	1	7
314	1	3	0	2	0	1	3
315	1	3	2	3	2	4	6
316	1	3	0	1	1	1	4
317	1	3	3	7	4	1	5
318	1	3	1	2	1	3	7
319	1	3	0	4	3	3	3

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
321	1	3	1	5	4	2	6
322	1	3	1	4	2	1	6
323	1	3	1	7	5	3	5
324	1	3	0	7	2	2	5
325	1	3	1	7	3	3	7
327	1	3	1	3	2	2	3
328	1	3	0	3	1	1	5
329	1	3	2	7	7	4	6
330	1	3	2	3	1	3	6
331	1	3	1	4	4	4	5
332	1	3	2	7	4	3	7
333	1	3	1	2	1	3	4
334	1	3	1	2	1	1	2
335	1	3	1	2	1	2	5
337	1	3	3	7	7	6	7
401	2	1	2	5	4	0	5
402	2	1	1	6	4	3	7
403	2	1	3	5	6	6	6
404	2	1	4	6	6	6	6
405	2	1	2	6	6	5	7
407	2	1	1	2	2	2	3
408	2	1	0	1	0	0	4

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
409	2	1	0	2	0	2	5
410	2	1	1	2	0	1	4
411	2	1	4	7	7	3	7
412	2	1	2	7	5	2	4
413	2	1	0	6	1	2	3
414	2	1	3	7	7	7	7
417	2	1	0	1	0	0	6
418	2	1	3	6	5	4	6
419	2	1	1	2	2	3	6
420	2	1	1	4	2	3	4
421	2	1	2	6	5	3	5
422	2	1	2	7	6	4	6
423	2	1	3	6	6	2	7
424	2	1	2	7	6	4	6
425	2	1	1	2	2	3	5
426	2	1	0	2	0	3	2
427	2	1	2	5	4	4	5
428	2	1	0	1	2	2	6
429	2	1	5	7	7	6	6
430	2	1	2	4	3	3	5
431	2	1	1	5	4	2	6
432	2	1	0	6	6	2	7

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
433	2	1	0	1	1	2	5
435	2	1	2	6	4	5	5
436	2	1	1	7	5	2	7
437	2	1	2	7	5	5	6
502	2	2	2	6	4	3	7
503	2	2	3	6	3	3	6
504	2	2	0	0	0	2	5
505	2	2	2	6	4	3	6
506	2	2	3	6	3	3	6
507	2	2	1	4	3	2	4
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509	2	2	0	1	0	1	4
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514	2	2	3	4	4	6	7
515	2	2	0	5	1	3	5
516	2	2	1	0	0	1	3
517	2	2	1	4	3	1	5
518	2	2	0	3	1	0	7
519	2	2	0	7	2	4	7

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
520	2	2	4	7	7	4	7
521	2	2	0	5	4	5	7
522	2	2	1	7	1	1	4
523	2	2	0	2	0	0	4
524	2	2	0	0	0	3	4
525	2	2	4	7	6	4	7
526	2	2	2	6	4	2	4
527	2	2	1	6	4	5	7
528	2	2	3	5	5	5	6
529	2	2	0	6	2	1	5
531	2	2	0	2	1	3	3
532	2	2	0	1	1	1	2
533	2	2	1	4	1	2	5
534	2	2	2	7	4	2	5
535	2	2	2	5	3	3	5
601	2	3	0	0	0	0	1
602	2	3	0	1	1	1	4
603	2	3	1	3	2	2	6
604	2	3	0	3	0	1	1
606	2	3	1	7	5	5	7
607	2	3	2	6	6	2	4
608	2	3	0	3	3	2	5

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
609	2	3	0	4	4	2	3
610	2	3	2	5	1	3	7
611	2	3	0	5	2	3	6
612	2	3	2	4	2	2	5
613	2	3	3	7	4	2	6
614	2	3	0	1	0	2	3
615	2	3	0	5	5	2	7
616	2	3	3	7	5	4	7
617	2	3	1	2	3	4	6
618	2	3	1	6	5	3	5
619	2	3	2	7	5	1	5
620	2	3	0	2	0	2	5
621	2	3	0	2	1	3	5
622	2	3	1	5	4	4	7
623	2	3	2	4	3	4	6
624	2	3	0	4	0	1	7
625	2	3	2	7	6	5	7
626	2	3	0	1	0	1	2
627	2	3	3	5	2	1	4
629	2	3	0	7	2	1	6
630	2	3	0	0	0	1	6
631	2	3	1	1	2	2	5

Student	textinstr	texttreat	knowpre	knowpost	knowdel	predraw	posdraw
632	2	3	0	3	3	2	4
633	2	3	1	5	3	3	4
634	2	3	0	7	4	1	5
635	2	3	2	7	5	3	7

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
101	4	3	3	2	2	2	2
102	3	2	2	2	3	4	2
103	5	3	3	3	2	3	3
104	5	1	1	1	3	3	3
105	5	2	2	1	3	2	1
106	3	3	3	3	4	3	4
107	3	2	3	2	2	3	2
108	4	1	3	3	1	3	3
109	2	4	2	3	4	5	3
110	5	3	2	3	2	2	2
111	3	2	2	2	4	1	1
113	6	4	4	4	4	5	4
114	5	2	3	2	3	4	3
115	6	1	2	1	1	3	2
116	5	3	4	2	3	4	3
117	5	3	3	2	2	3	2
118	5	3	3	1	4	4	3
119	4	2	1	1	1	1	1
120	4	1	2	2	2	1	2
121	2	3	3	1	3	2	1
122	5	2	2	2	4	4	3
123	6	3	5	4	4	4	4

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
124	4	2	4	2	4	5	2
125	4	2	2	1	4	4	4
126	3	4	4	3	4	3	2
128	5	3	4	2	3	4	3
129	4	4	4	4	4	4	3
130	2	2	2	1	1	2	2
131	7	3	4	3	3	4	3
132	4	3	3	3	3	3	3
133	6	2	2	2	3	3	3
134	5	3	3	3	3	3	3
135	7	4	3	3	3	4	3
201	4	1	1	2	4	4	3
202	3	3	2	2	4	4	3
203	2	1	1	1	2	3	2
204	4	2	4	3	4	5	3
206	2	5	5	5	5	1	1
207	5	2	1	1	1	1	2
209	4	3	3	3	2	2	2
210	6	3	3	3	3	3	4
211	6	3	4	3	3	4	4
212	2	3	3	3	4	4	2
213	5	3	4	3	3	4	4

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
214	7	5	5	1	5	5	5
215	4	2	2	1	4	4	3
216	6	3	2	2	4	4	3
217	4	3	3	3	3	3	3
218	5	3	2	3	2	2	3
219	6	4	3	3	3	5	5
220	6	3	2	3	3	3	2
221	4	2	2	2	1	2	1
222	2	2	1	2	1	2	2
223	7	2	2	1	5	5	5
224	6	3	3	3	4	4	3
225	2	1	1	1	1	3	2
226	3	2	2	2	2	3	2
227	3	2	3	2	3	4	2
228	2	3	3	3	4	4	3
229	5	2	4	3	3	3	2
230	1	1	2	3	3	3	3
231	4	2	1	2	3	4	3
232	7	4	2	3	5	4	4
233	1	3	3	2	2	3	2
234	7	3	3	3	4	3	4
235	3	3	4	3	3	4	4

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
301	2	3	3	2	3	3	2
302	1	1	2	2	2	2	1
303	5	3	2	3	3	3	4
304	7	4	3	4	4	4	4
305	4	4	2	3	4	3	3
306	4	3	3	3	5	5	4
307	4	2	2	2	3	3	3
309	6	4	4	4	4	5	4
310	4	4	4	4	4	5	4
311	6	3	2	2	3	3	4
312	5	2	1	1	3	3	3
313	3	3	3	3	2	3	3
314	2	2	2	2	2	2	3
315	5	4	3	3	2	3	2
316	2	1	1	2	1	1	3
317	4	4	3	2	3	3	3
318	4	1	1	3	4	3	3
319	3	1	2	2	3	3	4
321	3	2	2	3	2	3	2
322	3	1	1	2	2	4	4
323	2	2	2	2	5	4	4
324	2	2	2	2	3	2	2

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
325	4	3	3	3	3	3	3
327	3	2	1	1	3	3	2
328	2	3	3	2	4	4	4
329	7	3	4	3	3	3	3
330	2	3	3	3	3	3	2
331	4	3	3	3	2	3	3
332	6	3	3	3	3	4	4
333	2	2	3	3	1	3	3
334	2	3	2	1	2	3	2
335	4	1	1	1	1	3	2
337	7	4	4	3	4	5	4
401	5	3	3	3	3	4	4
402	5	3	4	3	4	4	3
403	7	3	2	3	3	4	4
404	7	4	4	4	4	4	4
405	6	2	3	2	2	4	3
407	3	3	3	2	2	3	3
408	2	1	1	1	3	3	3
409	2	4	3	4	3	3	3
410	1	3	4	3	3	4	3
411	6	2	2	3	3	3	3
412	4	3	4	3	3	4	4

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
413	4	4	4	3	3	4	3
414	7	2	2	2	4	4	4
417	2	1	1	1	1	3	2
418	6	3	2	2	4	4	4
419	2	3	3	2	3	3	2
420	3	1	1	1	1	2	3
421	4	2	3	3	3	2	2
422	5	2	4	3	3	3	4
423	4	4	3	3	4	4	3
424	4	3	3	2	3	3	3
425	5	2	2	2	2	2	2
426	3	2	3	3	3	2	2
427	4	4	4	3	4	4	4
428	3	3	4	3	3	3	3
429	5	4	3	4	4	4	4
430	5	3	3	3	3	3	3
431	6	3	3	3	4	4	5
432	3	3	4	4	1	4	4
433	5	2	2	2	2	2	2
435	4	4	4	4	3	3	3
436	4	5	5	5	2	3	3
437	5	3	2	2	4	4	3

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
502	6	4	3	3	3	3	3
503	3	3	3	3	4	4	4
504	3	3	1	2	2	2	3
505	5	3	3	3	3	3	3
506	4	3	3	3	3	3	2
507	5	2	2	2	3	3	2
508	1	2	2	1	2	1	1
509	2	2	2	5	3	5	5
510	5	4	4	4	4	4	4
511	7	2	3	2	3	4	4
512	4	3	4	4	2	4	3
513	1	3	3	4	4	4	4
514	5	1	2	1	3	4	5
515	3	3	3	3	3	3	3
516	0	1	1	1	2	3	2
517	3	1	3	3	2	5	4
518	2	2	2	2	1	2	2
519	4	4	1	1	4	3	3
520	7	4	4	4	2	4	5
521	5	3	4	4	2	4	4
522	1	3	3	3	4	3	4
523	2	2	3	2	2	3	2

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
524	2	1	1	1	1	1	1
525	7	1	2	3	3	4	4
526	3	2	3	2	3	4	3
527	7	5	4	1	2	3	4
528	5	2	2	1	5	4	4
529	3	3	3	3	2	3	3
531	2	1	2	1	2	3	3
532	2	2	2	2	2	2	2
533	2	1	3	3	2	3	3
534	4	3	3	2	5	5	4
535	4	4	4	3	5	4	4
601	1	2	2	3	3	3	2
602	1	3	4	2	3	3	3
603	2	2	3	2	3	5	3
604	2	1	1	1	3	3	2
606	3	3	2	3	1	4	3
607	6	2	3	3	2	5	3
608	3	2	3	2	3	4	3
609	3	2	2	2	4	2	2
610	2	3	3	3	3	4	3
611	4	5	2	3	4	3	4
612	3	3	3	3	4	3	2

Student	deldraw	interest: pre/	post/	delay	understanding: pre/	post/	delay
613	5	1	1	1	3	3	3
614	1	3	3	3	3	4	4
615	5	4	4	4	4	5	3
616	6	2	3	3	3	4	4
617	5	1	1	1	4	4	4
618	4	2	3	3	4	4	2
619	5	3	3	3	2	4	3
620	4	1	2	2	3	3	3
621	3	3	2	3	3	3	2
622	3	2	2	1	3	3	2
623	3	3	2	3	4	4	4
624	1	1	3	3	4	4	3
625	5	3	3	3	3	4	2
626	1	4	2	1	3	3	1
627	2	2	2	1	4	4	3
629	3	2	2	2	3	3	3
630	0	3	3	3	4	3	3
631	3	2	3	3	2	3	2
632	1	3	3	3	3	3	3
633	3	1	2	3	4	4	4
634	2	1	2	2	2	3	3
635	7	3	3	3	2	4	4