METACOGNITIVE STRATEGY USE AND ITS EFFECT ON COLLEGE BIOLOGY STUDENTS' ATTITUDE TOWARD READING IN THE CONTENT AREA

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

2001

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2005

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AKNOWLEDGEMENTS

I would like to thank the members of my committee for their assistance with this project. I have enjoyed knowing all of you.

Dr. Pam Brown opened the doors of educational theory to me and introduced to me to the wonderful work of so many curriculum theorists. Early on, she encouraged my writing and helped me cultivate my own self-confidence. For that I am always grateful.

Dr. Kouider Mokhtari taught me about the beauty and complexity of reading, without which I never would have considered this project. Thank you for your unending patience and the many spur-of-the-moment meetings.

Dr. Richard Bryant, my graduate advisor, was always available for assistance and encouragement. Your sense of humor was always a bright spot during this process. Thank you for being open to this project. Thank you for everything.

During this project, I received assistance, support, and encouragement from many different people. I would like to thank all of them for their contribution.

My mom, for her SPSS wisdom; my dad and my sisters for their patience and encouragement; Booke & Mike Disney and Elicia & Day Ligon for opening their lives and their homes (and their chickens) to my daughter and I; Jerad and Ayn Linneman for their patience, support, and encouragement; and Dr. Donald French for keeping me employed and always looking for ways to help me. I could not have finished this without all of you (and all of that free childcare!).

I would also like to thank the students who participated in this study, for taking the time out of their busy lives to help me.

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Nomenclature

MARSI	Metacognitive Awareness of Reading Strategies Inventory

CHAPTER I

INTRODUCTION

Background

Most science students agree that science texts are challenging to read (Harder, 1989). Research has shown that students receive little instruction on how to read their science text (DiGisi, 1992) or how to use comprehension strategies (Alexander, 2000). Without the use of these strategies, many students read their science texts but do not understand what they read. This difficulty with comprehending science texts may cause students to have trouble comprehending the nature of scientific discussion (Kurland, 1983) and thus increase the population's scientific illiteracy.

Reading instruction in grades 1-3 focuses mainly on decoding words. When students enter fourth grade they are expected to "read to learn" however, there is no explicit instruction to bridge narrative and expository material (DiGisi, 1992). In addition to the shift in reading purpose, science texts contain many new vocabulary words. Without the necessary vocabulary knowledge, students cannot comprehend the text (Pressley, 2000). Pressley found new vocabulary to be one of the greatest challenges for readers (Pressley, 2000). While rapid decoding increases comprehension, problems decoding occupy mental space that could be used for higher order processes (Pressley, 2000). To resolve this problem, Pressley advises vocabulary instruction, which is applicable to all grades (Pressley, 2000).

While acknowledged as extremely beneficial, there are several reasons why comprehension strategies are not taught in content area classrooms. As referenced in DiGisi (1992) many teachers are positive about reading in the content areas (Gillespie & Rasinski, 1989; Yore, 1991); however, most content area teachers are uncomfortable teaching reading (Gillespie & Rasinski, 1989; Shymansky, Yore & Good, 1991; Yore, 1991).

Content area teacher preparation programs focus little on reading and reading instruction, leaving many teachers feeling unqualified. According to Bennett (2003), teachers need instruction for teaching comprehension strategies. Teachers often use these strategies when reading content material, but do not always recognize useful strategies (Bennett, 2003). In addition, teachers are under pressure to teach content (Kurland, 1983) and according to DiGisi (1992) receive little support for integration and reading instruction (Gillespie & Rasinski, 1989; Shymansky, Yore & Good, 1991; Yore, 1991). In the end, students are not receiving strategy instruction in either reading or content area classes.

Pressley (2000) defines reading as more than simply decoding. Comprehension requires lower order (decoding) and higher order (metacognitive) thinking (Pressley, 2000). To perform higher order thinking, readers must interact with text (Pressley, 2000). Alexander (2000) states that interaction, in the form of previous knowledge activation and subject interest positively influences comprehension. Alexander defines two types of readers, *acclimated* and *competent* (Alexander, 2000). Acclimated readers are in the first stage of learning and have little previous knowledge and only temporary interest in the subject (Alexander, 2000). They are extrinsically motivated readers.

Competent readers are more experienced with the subject, have more subject knowledge and usually have personal interest in the material. Alexander (2000) noted that the low or temporary interest of acclimated readers can result in lower comprehension, yet this is not always the case. Alexander (2000) states that greater interest in the subject results in more energy used for comprehension. Acclimated readers who are reading new material because of personal interest will have greater comprehension. Their comprehension will more closely equal students with increased subject knowledge. Therefore, high interest is more beneficial than more subject knowledge (Alexander, 2000). The utilization of reading comprehension strategies compels students to interact with text, and this interaction subsequently increases interest (Alexander, 2000). For students entering introductory science classes at either the secondary or college level with little previous experience, igniting interest is necessary for students' reading achievement.

Using the Metacognitive Awareness of Reading Strategies Inventory (MARSI), Bennett (2003) reports students rarely utilize comprehension strategies when reading texts, if at all. Mokhtari and Reichard (2002) note that unskilled readers focus on decoding, do not monitor their reading, and are unaware when they do not understand. This is supported by responses Bennett (2000) received from her students. When students encountered difficulties reading, they occasionally reread, asked friends or teachers for help, or ignored the problem altogether. Students were largely limited in their strategy use and awareness. DiGisi (1992) found that the use and awareness of metacognitive strategies does not improve with age or grade level. This indicates that unskilled readers with little to no instruction in using comprehension strategies are likely to remain unskilled readers. DiGisi (1992) identified several strategies that are helpful for science students. Among the strategies addressed in the MARSI inventory, DiGisi (1992) states that thinking about information visually, noting the organization of the reading, and asking conceptual questions about the material are most beneficial to science students.

The Problem

With new legislation aimed at meeting standards in education, students' critical understanding of scientific information is vital. In addition to legislation, the National Science Education Standards list scientific literacy as a primary goal. Research has shown that reading comprehension is directly linked to student learning and understanding. Without information on comprehension strategies or practice using them, many students rationalize their reading frustration by claiming a dislike for science. This has led to many students dropping out of science as early as grade 6 and 7. With distaste for science, many students will not continue reading scientific material and will not become scientifically literate. Meanwhile, many will continue to universities and encounter science classes again. In many cases, professors will assume students have mastered scientific reading because the students can decode, unaware that little comprehension of the text is taking place. While a number of researchers have looked into reading comprehension and the use of strategies, very little research has been done in science education. It is fairly well recognized that science texts are often hard to read and understand. It is also recognized that students frequently rank science as their least favorite or hardest class. However, little research has been done to determine whether metacognitive strategies can improve comprehension of science texts and attitudes of science students.

Purpose of the Study

This study is designed to assess the metacognitive strategies used by college students enrolled in an introductory biology class. In addition to assessing the strategies used, the study will focus on several specific strategies to assist students with comprehending the text and try to determine if increased comprehension leads to increased interest or change in attitude towards biology.

Objective of the Study

The hypothesis under investigation in thisstudy was that many college students are unaware of and do not use metacognitive strategies when reading science texts and that the use of specific strategies can improve the students' comprehension and understanding of the material while increasing their interest and improving their attitude toward biology. The study was designed to answer these questions:

- Do students utilize metacognitive strategies and what strategies do students report using while reading biology texts?
- Is there a relationship between student's use of reading strategies and their attitude toward reading biology?
- How does strategy use vary among good and poor readers, gender, and major?
- Does explicit instruction in using metacognitive strategies improve students' attitude toward reading biology texts?

Significance of the Study

This study is significant because it examined the relationship between students' comprehension strategy use and their attitude toward reading biology texts. While many biology classes rely on students to learn on their own from texts, science textbooks are often cited as the most difficult and most unpleasant to read. This study looked at strategies students use to manage these difficult readings and whether or not using strategies contributed to a student's increased likelihood of completing the reading and understanding the material.

Conceptual Assumptions

Throughout this study, several assumptions were made. First, that comprehension strategies are not explicitly taught. Second, that all students used some reading comprehension strategies and were aware of their strategy use. Also, it was assumed that none of the students participating in the small group study had a reading disability that would affect their performance either practicing the reading strategies or completing the post-reading questions.

Definition of Terms

Metacognition **–** First defined as "knowledge that takes as its object or regulates any aspect of cognitive behavior" (Flavell, 1978). Metacognition has been expanded to include conscious awareness of task, topic and thinking, and conscious self-management (Jacobs & Paris, 1987). Students with metacognitive skills possess knowledge about their cognition and the regulation of their cognitive resources during cognitive activities.

Scope and Limitations

This study was conducted using students enrolled in a mixed-majors Introductory Biology class and, therefore, the scope of the study can be extended to cover freshman and sophomores across different majors. Data analysis conducted to look at the differences between males and females, different majors, and differences between self-perceived good, fair, and poor readers presents several limitations. With a broad range of majors present in the study, it was necessary to group them into categories of disciplines. All student-reported majors were grouped into five different categories; Science, Education, Humanities, Business, and Undecided. These categories were subjective and based on the type of courses students would encounter fulfilling their degree, not necessarily the type of career they would pursue after graduation. Gender differences within each major were also analyzed. In most cases, there were relatively equal numbers of males and females. However, in Education, there were significantly more females than males.

Students in the study reported whether they perceived themselves as either good, fair, or poor readers. The majority of students reported that they were good readers. The numbers of reported fair and poor readers were combined so their strategy use could be compared to that of good readers.

Outline of Work

This study was conducted using students enrolled in an Introductory Biology class. Students were asked to complete a survey, indicating the frequency with which they used different reading comprehension strategies. The results of this survey were analyzed to examine differences between male and female students, self-perceived good and fair/poor readers, and different majors. Students were also asked to complete a survey measuring their attitude towards reading their biology text. The attitude survey was analyzed to identify the relationship between strategy use/non-use and positive/negative attitudes toward reading the biology text. Additionally, a small group of students met with the researcher once a week for eight weeks for instruction in and practice with using reading strategies. The attitude of these students toward reading the text was measured at the beginning of the study using the attitude survey. After four weeks of practice, changes in the students' attitudes were addressed during an interview with the researcher. The results of the small group study were analyzed qualitatively to determine the affect of practiced comprehension strategies on attitude toward reading biology text.

CHAPTER II

LITERATURE REVIEW

Introduction

Literacy is taking a prominent role in education. The focus on literacy results from recent legislation and education reform aimed at increasing education achievement in the US. In addition, rapid scientific advancement increases the need for students to develop scientific literacy. The Commission on Adolescent Literacy of the International Reading Association outlined this increased need for literacy. The Commission stated,

> Adolescents entering the adult world in the 21st century will read and write more than any time in human history. They will need advanced levels of literacy to perform their jobs, run their households, act as citizens, and conduct their personal lives. They will need literacy to feed their imaginations so they can create the world of the future. In a complex and sometimes dangerous world, their ability to read will be crucial. (Moore, Bean, Bidyshaw & Rycik, 1999, p.3)

The primary goal of Project 2061, an American Association for the Advancement of Science funded program, is to help Americans become scientifically literate. As an influence in science education reform , Project 2061 renewed momentum for reading in

1985 with an emphasis on communication and critical response (Vacca, 2002). The National Science Education Standards, written in 1996, also identify scientific literacy as a goal for science education (NRC, 1996). One underlying assumption of literacy policy is that once students learn to read, they are capable of learning on their own for the rest of their lives (Vacca, 2002). However, despite the emphasis on literacy in education, institutions promoting scientific literacy are silent in regard to the role that reading and writing have in the classroom (Yore, Bisanz & Hand, 2003).

There are two aspects of scientific literacy, fundamental scientific literacy and derived scientific literacy. Fundamental scientific literacy involves the ability to speak, read and write as a scientist while derived scientific literacy refers to students' knowledge of the body of scientific concepts (Yore, Bisanz & Hand, 2003). Herd (1998) defined scientific literacy as being capable of

> distinguish[ing] experts from the uninformed, theory from dogma, data from myth; recogniz[ing] the cumulative, tentative, skeptical nature of science, limitations of scientific inquiry, need for sufficient evidence, environmental, social and political impact of science and technology; know[ing] how to analyze and process data (Yore, Bisanz & Hand, 2003).

Language is an integral part of science and scientific literacy. Through language, scientists communicate inquiries, procedures, and understandings to other scientists and the public. Through these communications people are able to make informed decisions about social, environment, and health policies. However, to utilize written communication, readers must be able to read, comprehend, and evaluate scientific forms of writing (Yore, Bisanz & Hand, 2003). For this reason, continued literacy development is important for adolescent readers (Vacca, 2002). The instruction on making meaning from text that adolescents receive influences the core strategies they use to negotiate meaning and think critically (Vacca, 2002).

To communicate in science, students must be competent readers with a variety of written forms. Students must be able to read and understand word problems, laboratory reports, and informative materials (textbooks) (Koch, 2001). These comprise a repertoire of scientific documents; they are the basis for communication between scientists, popularizing information generated in the scientific community, and providing formal instruction (Yore, Bisanz & Hand, 2003). Communicating with other scientists can take two forms; it can be formative or integrative. Formative communication shapes a scientist's mind and consists of cutting edge information. Integrative communication is a synthesis of what is already known or widely accepted (Yore, Bisanz & Hand, 2003). Popularizing scientific information to increase the public's awareness or understanding typically consists of media reports or journal articles. Instructional materials comprise textbooks, lab workbooks, and educational websites (Yore, Bisanz & Hand, 2003). With the exception of communicating among scientists, the majority of readers using scientific writing are students.

While students make up the majority of readers for scientific text, instruction for reading these texts is absent from most school curricula. Simpson and Nist (2000) describe strategies used for scientific reading as part of a hidden curriculum. Students are left to develop strategies for dealing with scientific reading on their own, with few students becoming adept at using strategies. This is evidenced by the large number of students unable to comprehend science texts. According to the National Association of

Educational Progress, 30% of US students do not have the reading skills they need when they leave the primary grades, although primary reading teachers are most capable of helping these students. In addition, the NAEP states that 40% of seventh graders do not read fluently enough to read their textbooks and this number increases to 60% by grade 12, with 17-year olds having few developed reading skills for examining ideas they take from reading (Durley, Emlen, Knox, Meeker & Rhea, 2001; Wandersee, 1988). With little evidence that reading comprehension instruction is taking place in elementary and secondary classrooms (Yore, Bisanz & Hand, 2003), there is ample evidence that reading comprehension instruction is not finding its way into content area classrooms (Vacca, 2002). Greenewald and Wolf (1980) concluded that little reading is taking place in secondary content area classrooms and that reading is not used as a primary means of obtaining information. Through observations of reading in classrooms, Smith and Feather (1983a, 1983b) noted that content area class readings were taken directly from the text without the use of other sources; teachers provided no pre-reading strategies, used worksheets to focus student attention on relevant information, and discussions after reading revolved around the worksheets (Rivard & Yore, 1992). This use of text does not encourage higher level thinking in response to text reading and leaves little incentive for students to actively engage in reading. Meanwhile, the renewed debate over phonics versus whole language reading instruction resulted in policy-driven proposals to increase research and development of early reading instruction, leaving adolescent readers behind.

There are several reasons why reading comprehension instruction is not finding its way into content area classrooms. One reason is the content area teacher. With the implementation of standards-based education, content area teachers feel increased pressure to teach content. They view their role in education as preparing students in specific subject areas for high school and college (Vacca, 2002). A second reason is the limited focus on reading in teacher preparation programs and professional development programs. Many content area teachers feel unprepared to teach comprehension instruction (Spence, 1995). As a result, content area teachers suffer from a "poor understanding of science reading theory, make ill-informed instructional decisions," and provide little explicit instruction (Spence, 1995).

Despite the challenges facing content area teachers, students need science reading instruction. According to Baker (1974), 85% of learning comes from independent reading. This indicates students with comprehension difficulties will encounter problems after high school (Nist & Mealey, 1991). After high school, a student's ability to comprehend becomes more important. When reading independently, students do not have a teacher to guide them or assist them with constructing understanding (Koch, 2001). This has serious implications for out-of school reading. Phillips and Norris (1999) found that while reading newspapers or magazines, students are accepting of the information presented in the text and are not critical; they do not measure the information in the text against what they experience and when the find information that contradicts their experience, they accept the new information and disregard what they know. Yet critical reading confers the most promise for life long learning (Yore, Bisanz & Hand, 2003). Research also indicates that as reading becomes more difficult, students' desire to read and enjoyment of reading becomes minimal and is viewed as a task or burden (Serran, 2002). If students are to continue reading after graduation, they must be equipped with the skills they need to comprehend difficult expository texts. Otherwise, students risk becoming scientifically illiterate at a time when literacy is more critical than ever (Vacca, 2002).

Reading

The constructivist philosophy of education views learning as a construction of knowledge taking place in children's minds. Knowledge is constructed through the integration of new experiences with previous experiences. This perspective on learning influenced reading theories and redirected early beliefs about the role of textbooks and reading in science education (Yore, Bisanz & Hand, 2003). Current conceptions of reading parallel constructivist perspectives with the social-constructivist and interactive-constructivist models at the head of reading instruction research (Spence, 1995). The Social-constructivist perspective on reading places the experiences of the student and teacher at the forefront of learning and teaching. Research in this area focuses on beliefs of students and teachers toward learning and teaching, the role of literature in content area classrooms, and the connections between reading, writing, and talking to learn (Vacca, 2002). The interactive-constructivist perspective emphasizes the readers as they construct meaning. This model looks at the interaction between "what is known, concurrent sensory experience, and information accessed from print in a specific context that is directed at constructing meaning" (Rivard & Yore, 1992). The focus of the Interactive-constructivist model is on how previous knowledge interacts with text to make meaning. The emphasis of this model is on the creation of meaning, and not the acquisition of meaning. Both perspectives believe comprehension goes beyond textual information to making logical assumptions, forming pragmatic inferences, and supplying suppositions about the author's intentions (Anderson, 1982).

To learn from a text, readers must facilitate a transaction between themselves and the text. This transaction occurs through the integration of top-down and bottom-up processing. Top-down processing refers to what is already in the readers' heads, their previous experiences and prior knowledge. Bottom-up processing refers to the act of reading text. To create meaning, students create mental models using new information (from bottom-up processing) and testing them against prior knowledge and shared social standards (top-down processing). These models are then put into long-term memory when readers incorporate the new model into their existing knowledge or reorganize existing knowledge to accommodate the new model (Spence, 1995). Therefore, the ability to understand what is read results from combining previous knowledge with new information (Durley et al., 2001). As a result of the interaction between top-down processing and bottom-up processing, comprehension can be seen as negotiation and conflict resolution. To create understanding, readers must solve problems between text, the reader's episodic memory (recollections of concept), the reader's semantic memory (reader's worldview of language structures), and the socio-cultural context (boundaries for acceptable resolution) (Yore, Bisanz & Hand, 2003). Using this model of comprehension construction, a reader's inability to comprehend reading is a result of an inability to integrate new and old information. This inability makes reading meaningless (Rivard & Yore, 1992). The ability to resolve these conflicts is a result of prior knowledge, not skill (Yore, Bisanz & Hand, 2003), and differences in reader's perceptions and engagement with meaning construction effect the outcome of conflict resolution (Slotte, Lonka & Lindblom-Ylanne, 2001).

There are two aspects of reading; cognitive and metacognitive. Decoding, or reading the words on the page make up the cognitive, while thoughts about reading are metacognitive (Eriksson, 2000). Comprehension, as the goal of reading requires mental engagement with the process of reading. To successfully read, readers must utilize both cognitive and metacognitive processes by switching back and forth between what is known and what is presented in the text while simultaneously comparing the new information and what is read with their worldview (Yore, Bisanz & Hand, 2003). At the same time readers are identifying main ideas by delineating supporting information, details, and examples, sorting relevant from irrelevant information, and identifying problems that need extra study (Eriksson, 2000). These processes take place in the short-term memory. For this reason, the benefit of reading comprehension strategy instruction may depend on individuals' short-term memory (Rivard & Yore, 1992).

During meaning construction, the short-term memory acts as an interface between the new information in text and the information stored in long-term memory (Osborne & Wittrock, 1983). The long-term memory stores information in schema, or an abstract framework where related pieces of information are kept together in a neurological network or "slots" containing related parts (Anderson & Pearson, 1984). Schema has six functions in the reading process: organizing and retrieving (scaffolding), selective attention, inference making (filling in gaps), orderly memory searches, editing and summarizing, and inferential reconstruction (hypothesizing about missing information) (Anderson, 1978).

The cognitive and metacognitive aspects of reading take place in the short-term memory; however space in the short-term memory is limited. Kintsch and Van Dijk

(1978) concluded that individuals can only process chunks of seven propositions at a time. The space for working memory and the cognitive demands of processing limit the amount of space for decoding and integrating text (Rivard & Yore, 1992). If readers are not fluent decoders, the short-term memory space is taken up for decoding and there is not space for integrating information. However, if readers are fluent and reduce the amount of short-term memory space used for decoding, the amount of short-term memory used to integrate information increases. Fluent readers use most of their short-term memory for comprehension (Pressley, 2002). As a result good comprehension relies on reading fluency and vocabulary. Research has shown that improving fluency and vocabulary both improve comprehension. Yet skilled reading involves more than fluent word recognition (Pressley, 2002).

Metacognition

The development of cognitive psychology redirected the focus of reading research from reading skills to metacognition. Metacognition was first defined by Flavell in 1978 as "knowledge that takes as its object or regulates any aspect of any cognitive endeavor" (Flavell, 1976). Since then, Flavell's definition was elaborated to include "conscious awareness of one's own knowledge of task, topic and thinking, and conscious self-management" (Jacobs & Paris, 1987). Reading researchers generally accept Metacognition as knowledge about cognition and self-regulation of cognition and cognitive resources (Baker & Brown, 1984; Nist & Mealey, 1991; Pressley, 2002). Brown (1980) specifically defined metacognition and its relationship to reading as "evaluation of the comprehension process while reading and ability to take action when comprehension fails." Metacognition is composed of three factors: metacognitive knowledge, metacognitive skill, and metacognitive experience (Eriksson, 2000). Metacognitive knowledge is also composed of three factors - the person, the task, and the strategies. A reader with metacognitive knowledge is aware of his/her abilities and limitations as a reader, what is required to complete a task and how to meet the requirements, and methods useful towards reaching the goal (Eriksson, 2000). Eriksson (2000) defines metacognitive skill as the reader's knowledge of what he/she is currently doing. Eriksson (2000) also defined metacognitive experience as "experience accompanying an intellectual task," such as knowing you do not understand, using previous experience to solve a problem, or feelings of success or failure. Regulation during reading happens when a reader monitors his/her comprehension to detect errors and separates important and unimportant information. Self-regulation involves planning (selecting particular actions to reach a goal), monitoring, and evaluating strategy use while reading (Nist & Mealey, 1991; Paris & Jacobs, 1984; Baker & Brown, 1984). To demonstrate metacognitive awareness, readers must have declarative knowledge (knowing the information you need is in your head), procedural knowledge (knowing how to connect what is in your head to what you read), and conditional knowledge (when and why to use the information in your head while reading) (Craig & Yore, 1992).

Reading researchers see metacognition as the "foundation upon which comprehension is built" (Nist & Mealey, 1991). Results of research in metacognition show a significant positive relationship between metacognitive awareness and comprehension ability (Spence, 1995). Simpson and Nist (2000) found that students who practice deeper levels of processing perform better on assignments and tests. Students who practice deeper levels of processing access and integrate old and new information to create understanding. In unstressful reading situations, metacognition proceeds without the reader's awareness. It is when reading becomes difficult that metacognition becomes overt and conscious (Jacobs & Paris, 1987).

Pressley (2002) defined metacognition as "knowledge of the thinking process, thinking in the here and now, and thinking in the long-term." According to Pressley, the most important thinking in the here and now is whether or not a text is being understood. This is especially true in science reading. Without metacognition, many science misconceptions go unnoticed. Long-term metacognition pertains to knowledge of reading strategies; however, without knowledge of the thinking process or thinking in the here and now, comprehension strategies are useless. If students are not aware when comprehension breaks down, the comprehension strategies will not work (Nist& Mealey, 1991).

Metacognition is a process that gradually develops (Eriksson, 2000). Several studies indicate that comprehension evaluation improves with age (Jacobs, 1982; Otero & Campanario, 1990). Jacobs and Paris (1984) found significant differences in the metacognitive abilities of eight and ten-year olds. Nist and Mealey (1991) agree that metacognitive skills increase with age, but suggest that as students become older, their reasons for not using metacognitive skills change. Among these reasons are a lack of motivation, a lack of prior knowledge, and competing demands on time (Barnett, 1997).

Research Background

Reading research has changed significantly over the last few decades. Behaviorists and logico-mathematical perspectives dominated much of the research before 1978 (Yore, Bisanz & Hand, 2003). These researchers viewed reading as unidirectional, from the text to the reader. Most research studies were bottom-up studies, focusing on decoding skills and increasing reading rate (Rivard & Yore, 1992). These studies disregarded reader's prior knowledge and experience, viewing the reader as a passive participant in the reading process.

By the 1960's there was increasing awareness that comprehension was more than simply the percent correct on a comprehension test (Kingston, 2003). Researchers began to look at reading as a more complex process. In the 1970's cognitive psychology recognized reading as a process, not a product, and research was redirected (Nist & Mealey, 1991). Cognition and learning research replaced research on reading and study skills (Vacca, 2002). Between 1980 and 1990, the cognitive constructivist vision of learning emerged and readers were seen as active participants in the reading process (Simpson & Nist, 2000).

After the science education reform of the 1960's, explicit science reading instruction was unpopular, the criticism resting on the split between active and passive learning experiences. Science learning needed to be active learning and science reading did not fall into the model of hands-on science (Spence, 1995). As a result, many of the studies in science reading attempted to identify one specific strategy that would improve reading comprehension, the style and content of textbooks, student reading skills, and teachers' use of textbooks in the classroom (Pressley, 2002; Yore, Bisanz & Hand, 2003). Reading research recently refocused again, this time on interactions between the reader and the text, metacognition, and explicit instruction. Research on schema theory, text structure, metacognition, and strategic learning had major impacts on content area reading processes (Vacca, 2002; Yore, Bisanz & Hand, 2003).

Recent research focused on classroom application of metacognition and strategy use. Results of research on strategy use demonstrate that children with high awareness of reading strategies score higher on comprehension tests than children with low awareness (Jacobs and Paris, 1984). Taraban, Rynearson, and Kerr (2000) found strong, consistent relationships between reading goals, strategy use and GPA. Students with higher GPAs knew more strategies and had more reading goals than students with lower GPAs. In addition to knowing more strategies, these students used more strategies than students with low GPAs (Taraban et al, 2000). Garner and Alexander (1982) surveyed college students about their use of questioning while reading. Half of the participating students used questioning and those who did outperformed their non-questioning peers (Rinehart & Kingston, 2003). Wandersee (1988) studied the strategy use of freshmen reading textbooks and found that students alter their strategies more in response to the expected method of evaluation than the type of text content (Wandersee, 1988). Wandersee also found that increasing the attempts at a passage correlated with higher GPAs, only six percent of students in the study tried to connect new information to prior knowledge, and that only 30% of women and 17% of men focused on the value of reading (why is this important? How does this information apply to me?) (Wandersee, 1988). Despite the findings of other researchers regarding the development of metacognition with age, Wandersee (1988) did not a find relationship between college level and specific strategy use.

Studies on metacognition can be grouped into three different categories: cross-cultural, expert-novice, and manipulation studies (Nist & Mealey, 1991). Cross-cultural studies look at the effect of socio-cultural perspectives on reading comprehension. During these studies, participants read several passages that contain familiar and unfamiliar cultural references. Researchers then compare the participant's reading processes. Results of these studies show that participants spend more time on passages that contain unfamiliar references and made more distortions when recalling the unfamiliar passage. In contrast, readers were able to recall more important propositions from the culturally familiar passage (Nist & Mealey, 1991).

Expert/novice studies look at the differences in metacognition between readers with knowledge about a subject and readers without content-specific knowledge. Results of these studies show that readers with content-specific prior knowledge were able to remember more and synthesize more than “novice” readers (Nist & Mealey, 1991). Schema theory contributes to the explanation of these results. “Expert” readers were able to learn more because they already possessed the necessary knowledge structures. To learn from the text, experts' knowledge structures needed to be organized and expanded, while the novice readers needed to create new knowledge structures.

Most of the research in science education focuses on methods of teaching subject matter and problem solving skills with little attention to reading comprehension. The limited research on science text, science reading, and science reading strategies suggest limited strategy use by students, differences between expert and novice readers, domain specific influences, text/structure influences, conceptual change difficulties, and interpretive framework influences (Spence, 1995). The most prominent type of research on science reading comprehension is manipulative studies. During manipulative studies, participants read passages that have been manipulated to contain inconsistencies or contradictions. These studies measure readers' ability to activate proper schema while reading (Nist & Mealey, 1991). The results of these studies are based on individual abilities to identify the inconsistencies or contradictions. An inability to identify inconsistencies or contradictions indicates a lack of control over comprehension (Otero & Campanario, 1990). In many of these studies students failed to identify the inconsistencies or contradictions (Nist & Mealey, 1991). In one study, Baker (1979) reported that 62% of the inconsistencies were not reported and less than 25% of the readers noticed inconsistencies while reading. Many of the unreported inconsistencies were attributed to “fix-up” strategies. While reading, students deliberately omitted or altered the inconsistencies or made inferences without being aware they had done so (Baker, 1979). In another study, Baker and Anderson (1982) introduced main point inconsistencies, detail inconsistencies, or no inconsistencies to reading passages. They found that students spent more time on sentences that were inconsistent with prior knowledge and looked back at inconsistent sentences more often. Explanations for this include regulation failures or the construction of an explanation that satisfied prior knowledge (Rinehart & Platt, 2003). Anderson (1982) concluded that during these studies, large numbers of readers failed to identify inconsistencies or contradictions due to “fixing” the problem with regard to prior knowledge or creating alternative interpretations. Otero and Campanario (1990) conducted a similar manipulation study with science reading. They introduced contradictions into a science text and then asked students to rate the text’s comprehensibility. They found four categories of responses: adequate evaluation and regulation, basic difficulties, absence of evaluation, and adequate evaluation with inadequate regulation. Students with adequate evaluation identified text inconsistencies and rejected the text as incomprehensible. Students with basic difficulties did not identify the inconsistencies, but were aware of a problem while reading; however, they did not reject the text. Students with an absence of evaluation did not detect the inconsistencies and possessed an “illusion of knowing.” Students with an illusion of knowing believed they had a good understanding of the text and were unaware of any incomprehension. Students with adequate evaluation and inadequate regulation identified inconsistencies, but attributed them to advances in science or exceptions to the rule and did not reject the text (Otero & Campanario, 1990). Otero and Campanario (1990) also found that students with more prior knowledge about the content of the passage gave the text higher comprehensibility scores (even though it was incomprehensible) than students without prior knowledge.

Science Texts

Although science education has moved toward hands-on and inquiry-based learning, Ratekin, Simpson, Alvermann, and Dishner (1985) found that science classes are still dominated by science texts (Rivard & Yore, 1992). Textbooks are used to determine and organize content material in science classes, but students are not expected to learn from independent reading. Instead they are used as safety nets to supplement lectures (Rivard & Yore, 1992).

Until recently schools relied heavily on textbook readability (Nist & Mealey, 1991). Text readability is determined by the number of syllables per word and number of words per sentence in a text passage. In attempts to decrease readability, textbook publishers use shorter words and shorter sentences, inadvertently increasing the difficulty of the text by disregarding connectiveness and elaboration (Rivard & Yore, 1992). It is currently recognized that text readability is only part of the problem, with other issues including style, interest level, inconsiderate texts, and the utilization of texts in the classroom (Rivard & Yore, 1992).

Text coherence refers to the relationships between ideas in the text. There are two levels of text coherence. Global coherence refers to the arrangement of concepts throughout the text. Tierney and Mosenthal (1982) described local coherence as the "linguistic mortar that holds the ideas together" (Nist & Mealey, 1991). In a coherent text, relationships are explicitly stated; they are not missing or implied. When publishers focus solely on readability, text coherence can be lost. Discussing more concepts in shorter, easier to read paragraphs reduced students' ability to recall information (Kintsch et al. as cited in Nist & Mealey, 1991).

Unfamiliarity with text structure is one of the most difficult problems readers encounter when reading science texts. Most of students' information about text structure is based on narrative text (Rivard & Yore, 1992). Cook and Mayer (1988) found that many skilled readers are not aware of common science text structures and that college readers do not have fully developed category concepts for expository text structures commonly found in science texts (Cook & Mayer, 1988). Scientific texts differ from narrative with their use of content-specific language, visual aids (graphs, diagrams, and charts), and mathematical symbols (Rivard & Yore, 1992). Because science texts are different from narratives, the strategies students are taught for narrative texts do not transfer effectively to expository text reading.

Most students are not aware that science texts have an underlying structure (Cook & Mayer, 1988). Scientific texts utilize five different structures: description, listing, compare/contrast, problem/solution, and cause/effect (Rivard & Yore, 1992). Textbooks often include cues to help readers focus their attention on important information. Textbooks are unique in the cues they include; some include a variety while others rely on a select few (Goetz, Alexander & Schallert, 1987). In addition to unfamiliarity with common text structure, students are not necessarily aware of what aids textbooks offer. Students often skim chapters without noticing organizational aids such as charts, diagrams, tables, pictures, summaries, etc. (Tomlinson, 1987). Tomlinson (1987) suggests that all students should be aware of aids texts offer. The presence or absence of text cues helps students select comprehension strategies.

While cues can help students, authors provide few cues that encourage meaningful processing of information (Goetz, Alexander & Schallert 1987). Cues provided generally require minimal effort; pictures and summaries are provided, students are never asked to imagine or construct their own image or write their own summary (Goetz, Alexander & Schallert, 1987). Through cues, textbook authors and publishers attempt to mark important information for students, but offer no suggestion for studying the information (Goetz, Alexander & Schallert, 1987). Goetz, Alexander and Schallert (1987) conclude that although text cues are provided, they are ineffective and that if students are to learn from texts they will have to do it on their own.

Although they are skilled narrative readers, many science and technology students have trouble reading science texts (Koch, 2001). Wandersee (1988) stated

> Teachers think that if science content is accurate, up to date,
> and presented in a lively manner, learning will occur. Researchers, however,
> disagree, saying the assumption that students will

> comprehend fully an attractive and accurate text just by starting at the beginning and reading through to the end needs to be challenged. (p. 69)

Different types of texts and different writing styles require different reading processes and therefore different strategies (Koch, 2001). The reading skills students acquire using narrative texts in early grades are ineffective when transitioning to expository texts (Spring, 1985). The limited research in science reading results in the science reading process being poorly understood (Spring, 1985). It is known, however, that science reading by scientists is an active process. The scientist "sits down with pencil and paper and slowly works through the article, making notes along the way. Unclear points are pondered over, references are looked up, calculations are checked" (Mallow as cited by Spence, 1995). While the process is poorly understood, it is acknowledged that science reading involves more cognitive demand than narrative text. When reading science text, students must have knowledge of "scientific enterprise, concepts under consideration, scientific language, patterns of argumentation, canons of evidence, science text, and science reading strategies" (Spence, 1995; Koch, 2001). Due to the unique nature of scientific texts, the interaction of prior knowledge while reading is more important (Rivard &Yore, 1992) and the lack of prior knowledge can derail a reader. Students with limited prior knowledge need to construct their own interpretation or may have misconceptions that impede learning (Alexander& Kulikowich, 1994). Alexander and Kulikowich (1994) identified ten assertions about learning physics from a text. They found:

1. limited knowledge negatively impacts understanding
2. out-of-school knowledge may impede understanding

3. individual interest linked to understanding
4. bilingual character of text increases processing demands
5. situational interest directs readers' attention from important information
6. individual perspective alters comprehension
7. analogies do not always help comprehension
8. instructional importance has greater impact than structural importance
9. teacher explanations can help or hinder student learning
10. technological advances can introduce greater complexity to processes of learning

While their assertions are specific to physics, they may be generalizable to include all scientific learning from texts.

Learning to read is a major goal of the primary grades. Much of the instruction that young students receive is based on narrative. Part of the difficulty students have with science texts is the lack of instruction and their lack of experience (Armbruster as cited by Rivard & Yore, 1992). Cook and Mayer (1988) found that even skilled readers lack a complete awareness of expository text structure and benefit from even modest instruction. Knowledge of text structure benefits student comprehension in a number of ways. Structure awareness guides students and assists them in creating mental representations of information in text (Cook & Mayer, 1988). Structure awareness also helps readers identify important information in a passage (Cook & Mayer, 1988). Both strategies, identifying important information and creating mental representations, engage students in the reading process and increase comprehension.

Awareness of a text's structure helps readers determine which strategies would be beneficial. Barnett (1984) conducted a study investigating the effect of text structure identification on student performance. Barnett found that students who received instruction performed better than students who did not receive instruction. A study by Tomlinson (1987) instructed students in text structure identification. Results of this study show that students who receive instruction in text structure increase their use of active reading strategies and decrease their use of passive strategies.

In a second study conducted by Cook and Mayer (1988), students were trained to identify text structure and pre-test and post- test scores of trained and untrained students were compared. Cook and Mayer (1988) found that trained students gained 30% between pre-test and post- test for high conceptual information and experienced a 14% decrease in low conceptual information. Untrained students gained 12% between pre-test and post-test for low conceptual information and experienced no change for high conceptual information. The trained students showed substantial pre-test to post-test gain in application questions and a lesser gain for literal questions. Untrained students demonstrated a loss in application questions and a slight gain in literal questions.

When students are unaware of text structure they experience comprehension difficulties. In an interview study by Smith (1992), college students reported several problems related to text structure. One student said that “large amounts of information under the headings and subheadings made it difficult for her to know what to focus on” and that “multiple perspectives under each heading and subheading confused her to the point where she understood nothing” (Smith, 1992). Another student said that the “excessive amount of dates, examples and name references distracted her from identifying main ideas” (Smith, 1992).

Cook and Mayer (1988) suggest that when students are unaware of text structure they treat reading as a list of facts. Yore, Bisanz, and Hand (2003) support this idea, stating difficulties with comprehension reduce reading to memorization of expected exam material. If this is the case, students unaware of text structure are blindly accepting information in texts without critical examination and not integrating the textual information into their long-term memory. With six thousand years of science history stored in scientific and sometimes inconsiderate print, Rivard and Yore (1992) believe it is much more productive to focus on readers and what they can do to help themselves.

Strategies

The methods used to teach reading convey attitudes about reading that influence student beliefs. In his interview study Smith (1992) found that many students approach reading half-heartedly because they view reading as a transmission of information that is regulated by the teacher. Smith also found that many students related reading with correctness (Smith, 1992). These two views minimize the role individual learners play in the reading process and stress the accumulation of information. As emphasized by the interactive-constructivist model, learners should play the primary role in getting meaning from text (Smith, 1992).

Despite the prevalence of the interactive-constructivist model, students are not taught how to create meaning from expository text and the development of reading comprehension in content areas is neglected (Koch, 2001). It is recognized that there are many skills common to different subject areas; however, many of these skills have special relationships with achievement in specific subject areas (Vacca, 2003). In this vein, Yore (1986) stated “few inferences from content area reading research utilizing social studies or language arts can be comfortably applied to science and mathematics reading" (Rivard & Yore, 1992). Science, as a different specialty, requires the use of specific reading strategies.

Pressley (2002) observed fourth and fifth grade classrooms and found that comprehension strategies for expository texts were not being taught. Instead of teaching comprehension, teachers were simply testing it (Pressley, 2002). Tests taken after reading asked students to summarize, identify difficult parts of the reading, generate questions, and make predictions. These tests were attempting to initiate active processing; however, processing was stimulated after students finished reading and provided little evidence that students were becoming self-regulated readers (Pressley, 2002). The use of the tests suggest that students were expected to become self-regulating, yet the teachers were not instructing students to come to that level of regulation on their own while reading.

It is recognized among researchers that strategy knowledge and use are crucial for science students' success (DeLisi, 2001; Koch, 2001; Rinehart & Platt, 2003). As a result, strategy instruction is also crucial. Many students view reading as happening automatically, without the need for active intervention (Saumell et al as cited by Taraban et al, 2000) and these students often cannot differentiate between what they know and what they don't or what they do or do not comprehend (Koch, 2001). While Simpson and Nist (2000) argue that the process underlying strategy use is more important than the actual strategy, Eriksson (2000) claims that metacognitive consideration effects behavior. That is, if students are asked to do something they are unfamiliar with, like comprehending science texts, they will be uncomfortable completing the task. This has implications for in- and out-of class reading.

Anderson, Spior, and Anderson (1978) identify schemata as the primary determinant of what will be learned while reading (Anderson, 1982). As such, teacher scaffolding is extremely important. Rivard and Yore warn that without teacher guided scaffolding that without teacher guided scaffolding that

> confronts conceptual differences and encourages integration of old and new information, students will selectively process new information to support their present conceptions or develop dual conceptions (Rivard and Yore, 2003).

Vacca (2002) promotes the use of visible and invisible dimensions of reading instruction. Visible aspects of teaching emphasize explicit development of strategies that enable students to think and learn with texts. During visible instruction, teachers engage in explicit instruction of reading comprehension strategies. At the other end, the use of reading strategies should be the "invisible dynamic underlying subject matter learning" (Vacca, 2002).

Explicit strategy teaching involves several factors; explanation, demonstration, practice, and application (Vacca, 2002). During the first phase of explicit instruction teachers provide students with a direct explanation of the strategy – what it is, how it is used, when it is used, and why it is used. During the second phase, teachers demonstrate the strategy. Demonstration often involves think-alouds or read-alouds so students can witness what is happening in the teacher's head. The third phase is strategy practice. This is when students practice using the strategy while receiving guidance and feedback from the teacher. The final phase, strategy application, comes when students use the strategy as a component of self-regulation. Invisible instruction occurs during well-planned literacy lessons. Strategy use takes place during three points of invisible instruction: before reading, while reading, and after reading (Vacca, 2002).

The use of explicit instruction and well-planned literacy lessons teaches children declarative (what), procedural (how), and conditional (when) knowledge that increases their comprehension and their motivation to read (Paris & Jacobs, 1984). Research on strategy instruction shows that explicit instruction reduces gaps between high and low ability readers and between male and female readers, and increases self-confidence of low-ability readers. Comprehension strategies were assigned to one of three theoretical bases; metacognition, schema theory, and text structure (Nist & Mealey, 1991). Pressley, Johnson, Symons, McGoldrick, and Kurita (1989) and Duffy, Roehler, and Pearson (1991) identified underdeveloped reading strategies that responded to instruction: assessing the importance of text-based information and prior knowledge, questioning to set purpose, summarizing, inferring meaning, monitoring comprehension, utilizing text structure, reading and reasoning critically, self-regulating to fix comprehension problems, skimming, elaborating, and sequencing (Spence, 1995). These strategies are teachable and if used appropriately before, while, or after reading, they increase reading comprehension.

Before students read, they must prepare themselves for the task of reading. Preparation involves identifying the task, setting a goal or purpose, skimming the text to determine length and organization, and activating prior knowledge (Pressley, 2002). Students begin with task identification, this allows students to assess which strategies are useful and which strategies will help them meet their goal. Noting text organization and length also helps students select useful strategies. Activating prior knowledge is essential and provides that framework for creating comprehension. While some readers bring rich experiences to their reading, some students do not (Spence, 1995). For this reason, teachers are instrumental in providing scaffolding for students. This can be done using previews, anticipation guides, or K-W-L charts.

Previews are similar to class discussions in which teachers stimulate previous experience, offer information about the topic, and ask purpose-setting questions (Nist & Mealey, 1991). Anticipation guides were designed in the late 1970's to assess students' prior knowledge. When completing an anticipation guide, students respond to true/false questions before reading and after reading, students check to see if their predictions are correct (Nist & Mealey, 1991). Anticipation guides are useful tools to help teachers determine the level of knowledge students have about specific topics and identify where students may run into trouble. The K-W-L chart activates students' prior knowledge, creates questions to set purpose, and allows students to reflect on comprehension (Spence, 1995). The K-W-L- chart consists of three columns. Before reading, students list what they already know (K) about the topic in the first column. In the second column, they identify what they want (W) to know. The final column is completed after reading and students list what they learned (L) during reading.

Regardless of which method content teachers use to prepare their students to read, they must scaffold using a variety of cognitive and metacognitive strategies (Vacca, 2002). In addition to using previews, anticipation guides, and K-W-L charts, teachers might also scaffold pre-reading by having students brainstorm, create questions, study pictures, or survey titles and subheadings (Vacca, 2002).

As important as the use of prior knowledge is to comprehension, it alone does not guarantee improved comprehension (Rivard & Yore, 1992). To improve comprehension, students must remain active readers by employing strategies while reading. The strategies students use while reading help monitor comprehension, calling to attention areas where comprehension drops. Several strategies used during reading include rereading, taking notes, making predictions, identifying important information, identifying topic sentences and topic paragraphs, integrating ideas to get main ideas, paraphrasing, evaluating, and maintaining metacognitive awareness by asking questions such as “Is the text relevant to my goals?” and “How are different parts of the text related to each other?” (Pressley, 2002). Students can use reading guides, pattern guides, or a Directed Reading Thinking Activity (DRTA) to remain active while reading. While there is little research on the use of guides, they are determined to modestly affect comprehension (Nist & Mealey, 1991). Reading guides pose questions aimed at different levels of thinking and provide students with warnings about sections that may contain comprehension problems. Pattern guides focus on the structure of the text. Commonly, students identify the text structure and fill in missing parts of the text. The DRTA is most effective with students having trouble learning from text. When using the DRTA, students survey the reading and make predictions. Students then read a section of the material and refine their predictions and define unknown vocabulary. Students continue to read another passage and stop to refine and define again. This process is repeated through the end of the text (Nist & Mealey, 1991).

Once students have read, it is important that they reflect back on their comprehension. There are several strategies students can use to do this. Among them are selective re-reading, thinking about how to use the information, and questioning (Pressley, 2002). Through selective re-reading, students go over difficult and important sections of text again. Thinking about how they will use the information in the text relates the information back to their purpose or goal for reading. Questions, however, are the most popular method of reflection in content classrooms.

The use of questions and the type of questions affect reading comprehension. Teaching students to generate main idea questions increases their retention of information (DeLisi, 2001) and the use of pre-reading questions activate schemata, while the use of questions during reading help students focus their attention on important information (Nist & Mealey, 1991). The use of questioning after reading facilitates information retrieval and checks comprehension of the material (Nist & Mealey, 1991). Reader generated questions are most effective for increasing reading comprehension (Rivard & Yore, 1992); however, the nature and the placement of the question is important (Nist & Mealey, 1991).

There are three types of questions: textually explicit, in which the answer is stated in the text; textually implicit, in which the answer is implied in the text but not explicitly stated; and scriptually implicit, in which the reader must relate text information to previous experience (Nist & Mealey, 1991). Textually explicit questions require lower level thinking, while textually implicit and scriptually implicit questions require higher levels of thinking. Higher-level questions are more effective in increasing comprehension. Nist and Mealey (1991) found that unless students are trained to ask higher-level questions, they tend to ask literal or textually explicit questions. One method of teaching students to ask higher-level questions is ReQuest. Developed by Manzo in

1969, ReQuest is a method of reciprocal questioning between teachers and students (Nist & Mealey, 1991). During ReQuest, students ask the teacher questions about the text and then the teacher asks the students questions and then the students predict what is next in the text. During this process the teacher is able to model higher-level questions.

Organizers are a commonly used strategy to connect ideas within a text and are most effective with expository texts (Simpson & Nist, 2000). Organizers include advance organizers and graphic organizers. These are tied to schema theory and text structure theory (Nist & Mealey, 1991). Through using organizers, students activate knowledge, cue awareness of knowledge, and focus attention on important information (Nist & Mealey, 1991) while identifying main ideas, making connections, and visually representing information (Simpson & Nist, 2000). This helps students make predictions and draw conclusions about text (Durley et al., 2001). Berkowitz (1986) investigated the effectiveness of graphic organizers and found that the construction of organizers, such as concept maps, increased the recall of expository texts (Rivard & Yore, 1992). Nist and Mealey (1991) found that organizers created by students are the most effective. Although advance organizers are widely used as a pre-reading strategy to activate prior knowledge and provide teacher directed scaffolding, Nist and Mealey (1991) found that graphic organizers are more effective than advance organizers. Graphic organizers hierarchically arrange concepts and illustrate relationships between concepts (Nist & Mealey, 1991). Graphic organizers are most effective and relevant when created by students in content area classes as a post-reading activity (Nist & Mealey, 1991).

Summaries are another popular method of assessing students' comprehension of reading material. Defined by Harris and Hodges (1981), a summary is "a brief statement which contains the essential ideas of a longer passage or selection" (Spence, 1995). Often students have trouble writing summaries of scientific text because they have difficulty identifying important information and many paragraphs in texts do not include traditional, specific topic sentences (Spence, 1995). Brown and Day (1983) investigated the use of summary writing of students in fifth grade through college. They found that most students encountered problems when they needed to invent topic sentences (Rinehart & Platt, 2003). Yet, explicit instruction on identifying important information and writing summaries improves comprehension (Spence, 1995). In their study, Brown and Day (1983) identified the rules of summarizing: selection, inventing, and superordination. To write an effective summary, student must find the main idea of the passage, infer the main idea if one is not stated, and put details into larger categories (Henrichs, 2003). Hare and Borchard (1984) found that students taught to write summaries through direct instruction improved their summary writing (Nist & Mealey, 1991) and the effective use of summarizing enhanced the recall of unfamiliar text (Taylor & Beach as cited by Rivard & Yore, 1992). Most importantly, Simpson and Nist (2000) state that for summaries to be most effective, students must use their own words, connect concepts, and relate their previous knowledge to the text.

To effectively use strategies before, during, and after reading, teachers must explicitly teach procedural and conditional knowledge (Simpson & Nist, 2000). Explicit instruction involves students' using strategies and receiving feedback while under the guidance and supervision of the teacher (Spence, 1995). Explicit instruction is half of the process; students make up the other half by practicing strategies while they read and study (Simpson & Nist, 2000). There are two models of direct instruction, the self-control model and the teacher-to-learner model (Nist & Mealey, 1991).

The self-control model, developed by Campione and Day (1981) consists of four overlapping and interacting components; characteristics of the learner, tasks, nature of the material, and the learning activities used (Nist & Mealey, 1991). When using the teacher-to-student model developed by Nist and Kirby (1986) the teacher demonstrates and guides students, slowly turning responsibility over to them (Nist & Mealey, 1991). The teacher-to-student model begins with the teacher's focusing students' attention on the topic, then giving students a general overview of the material and introducing new vocabulary. The teacher then describes the procedure, telling students what, how, and when the strategy is used. The teacher models the strategy and guides students as they practice the strategy. The last step of the procedure is independent practice by students. At this point, the teacher re-demonstrates the strategy if necessary (Nist & Mealey, 1991). Durley et al. (2001) emphasizes the importance of prior knowledge activation and vocabulary introduction during direct instruction. This instruction model gradually shifts responsibility from the teacher to the students.

Within the two models of direct instruction, there are two different instructional methods; direct instruction and functional instruction (Vacca, 2002). In direct instruction, strategies are taught separately from content, in perhaps a language arts class, and strategy transfer to content material is assumed. In functional instruction, students are taught to use strategies using content material in content classrooms. Due to the difficulty of transferring strategies from different content areas and the specificity of successful strategies to content areas, strategy instruction should take place in authentic situations

(Vacca, 2002), or within the content area classroom. Regardless of method, researchers conclude that strategy instruction should be explicit and intensive, while the most important role of the teacher is encouraging students to monitor their own comprehension (Koch, 2001).

Good and Poor Readers

For students to become scientifically literate, it is important for students to become proficient and mature readers. Gray and Rogers (1956) defined the proficient and mature reader as one who is competent, has a knowledge of purpose, an ability to comprehend, a positive attitude, good reader judgment, a breadth of interest, and continues to read beyond school (Henrichs, 2003). Henrichs (2003) defined reading proficiency as the use of efficient reading strategies in a variety of texts.

To create proficient and mature readers, research indicates a need to incorporate explicit comprehension strategy instruction into school curriculum. However, the effectiveness of explicit instruction may vary with the grade level, reading level, and ability of the students (Spence, 1995). Spence (1995) adds that explicit instruction may differentially impact younger, low prior knowledge, low reading ability, male students more than older, high prior knowledge, high reading ability, female students. While Eriksson (2000) suggests that metacognition is a skill that gradually develops with age, Nist and Mealey (1991) identified metacognitive differences between younger and older readers and skilled and unskilled readers. Among those differences, mature readers recognize when comprehension fails. Henrichs (2003) states that mature readers are aware when comprehension fails because they engage in comprehension monitoring. This suggests that older students may need less instruction than younger students to develop metacognitive awareness (Spence, 1995). Henrichs (2003) recognizes that readers may be proficient, but not mature and this supports the suggestion that mature readers are in the minority (Nist & Mealey, 1991).

Younger and poor readers view reading differently than more experienced readers. While older, mature readers read for comprehension, Garner and Kraus (1981) found that younger and poor readers are less aware of the need to make sense of what they read and instead focus on decoding the words on the page (Rinehart & Platt, 2003). Craig and Yore (1992) investigated the strategy use of elementary and secondary students. They found that younger students see reading as an active process, in that it requires physical activity, such as reading, re-reading, or taking notes, but do not view reading as an interactive process; in other words, they do not connect their prior knowledge to the text. The students described themselves as technical strategy users, as opposed to spontaneous strategy users. Their approach to using strategies was formulaic, and they did not adjust their use of strategies according to their purpose. Craig and Yore (1992) found the strategy use of these students as purposeful; they used strategies for finding out words, learning, remembering, or understanding, but at the same time did not differentiate between remembering and understanding (Craig & Yore, 1992). These students viewed reading as a form of problem solving, but again, did not understand the role of prior knowledge in solving problems. While the students understood that the text represented someone else's ideas, when confronted with discrepancies between their experience and the text, they assumed the text's position was correct. This indicates that younger students have a strictly text-based view of reading (Craig & Yore, 1992). They believe that information is in the book and they merely transfer it to themselves. Instead of constructing knowledge, they are consuming it (Craig & Yore, 1992). Viewing the text as the source of information places the responsibility for learning, or the problems with learning, upon the text.

Rivard and Yore (1992) found that poor readers are more passive readers, not integrating new and prior knowledge or constructing understanding. Poor readers do not identify a goal or purpose for reading, have inefficient use of visual aids, and are unaware of text structure differences between narrative and expository texts (Craig & Yore, 1992). With a text-based view of reading, when poor readers have comprehension difficulties, they look to the text to resolve the problems. They rely on re-reading or reading more slowly (Craig & Yore, 1992). The use of ineffective strategies results in frequent self-regulation failures among poor readers.

Poor comprehenders may also be poor decoders, using more short-term memory space for decoding (Kaufman & Randlett, 1983). This is supported by the tendency Craig and Yore (1992) found among poor readers to emphasize word identification over word meaning. With text-focused views on reading, for younger and poor readers, planning must be deliberate, while more experienced readers perform strategies without reflection (Paris & Jacobs, 1984).

Wittrock (1974) found that good readers are more active in their reading than poor readers. Paris and Jacobs (1984) also found that skilled readers engage in more deliberate activities that require planful thinking, flexible strategies and periodic self-monitoring. Taraban (2000) determined that behaviors related to setting and monitoring reading goals discriminate between good and poor readers. Kaufman and Randlett (1983) divided strategies into one of three groups: setting the tone, aiding performance, and “inside the head.” In their study of student strategy use, good readers reported using 1/3 more strategies than poor comprehenders. Also, good readers reported using more “inside the head” strategies (Kaufman & Randlett, 1983). While Rivard and Yore found that good readers use more types of strategies than poor readers, Spring (1995) reported instead that good readers differed in their reported understanding of strategies, not their reported use of strategies. This would suggest that poor readers may be relying on strategies to aid comprehension, but without the interaction of prior knowledge, the strategies are useless. Smith (1982, 1984) found that experienced readers proceed on a trial and error basis, shifting their use of strategies as necessary, and are not confined to their text, but search out other sources as needed (Henrichs, 2003). In regard to text structure, Nist and Mealey (1991) found that even skilled readers were inconsistent with their use of text structure strategies. Spence (1995) defined the efficient science reader. This reader knows that reading is interactive, has the abilities necessary for reading as task and pleasure, can shift from automatic to conscious strategy use when reading becomes difficult, knows that words are labels for ideas, knows science text is not absolute truth, evaluates science text, identifies purpose, uses retrieval strategies, uses specific knowledge input strategies, uses knowledge construction strategies, applies critical thinking strategies, uses monitoring strategies, and uses strategies to regulate effort (Spence, 1995).

The major difference between good and poor readers is their approach to reading. While good readers understand that reading is a process of creating understanding, poor readers focus on decoding. A major weakness of poor readers is their inability to monitor comprehension. They do not have problems just comprehending, but also recognizing when they do not comprehend (Otero & Campanario, 1990). Younger and poor readers are less able to select appropriate reading strategies and correct comprehension problems when they arise (Rivard & Yore, 1992; Rinehart & Platt, 2003). Craig and Yore (1992) speculate that the limited experience younger students have with expository text delays their metacognitive development. Based on these differences between younger, poor readers and older, mature readers, Pressley (2002) suggests that reading comprehension strategies should be taught in the primary grades.

Reading at the College Level

Since the 1930's there have been an increased number of reports on college reading. This is due to a constant revision of understanding about reading. The beginning of college reading programs is attributed to a combination of factors resulting from World War II. At this time, significant numbers of draftees were deemed unfit for service, due to illiteracy. At the same time, the GI bill made it possible for large numbers of soldiers to attend college. As a result, college reading programs were initiated to assist these reading deficient students (Kingston, 2003). At the time, there were few experts knowledgeable about college or adult reading and most professors were uninterested in teaching reading. Professors knowledgeable about reading instruction were training primary reading teachers and did not understand adult reading issues (Kingston, 2003). As a result, the college reading programs of the 1940s and 1950s were highly varied among universities and shallow in their focus. Most programs identified increased reading rate as the goal and emphasized vocabulary instruction. These programs employed a number of mechanical methods and machines to achieve these goals (Kingston, 2003). The use of motion pictures and tachistoscopes were common in an attempt to provide perceptual training and reduce eye movements, both of which were believed to increase reading rate. When reading and study skills were taught in these programs, it was primarily through blind instruction (Kingston, 2003). During blind instruction, students are instructed to use strategies, but are not taught how to use them. Many programs used the SQ3R to increase memory while reading. The SQ3R is a series of steps, Survey, Question, Read, Recite, and Review that was developed in 1946 (Kingston, 2003). As personnel services at many universities expanded between 1950 and 1960, reading programs became more individualized. During the 1950's, the number of college reading programs mushroomed and several organizations dedicated to college reading were formed as a result of the need to share information. During this time the Southwest Reading Conference (renamed National Reading Conference), the College Reading Association, and the International Reading Association were formed, and Purdue began publishing the Journal of Reading Development (later renamed the Journal of Reading) (Kingston, 2003). Subsequently, during the 1960's, college-reading programs underwent a major change. Realizing that vocabulary instruction was not enough and the recognition that reading was more than decoding, the new college-reading programs included more individualization, no emphasis on reading rate, and identified active readers as their goal. During the 1970's and 1980's, universities altered their traditional acceptance policies and began admitting nontraditional students. Recognizing that special students often need additional help, college reading programs have flourished (Kingston, 2003).

Reading at the college level is demanding (Taraban et al., 2000). At the college level, print is the primary source of information (Orlando, Caverly, Swetnam & Flippo, 2003), with 85% of all learning coming from text (Baker, 1974). In college, students are required to read and study texts on their own (DeLisi, 2001), yet the purpose and demands of reading in college are different from those in high school (Orlando et al., 2003). College presents many challenges for reading, among them material must be processed to be remembered, students must understand what they read, students must identify important information and organize that information to facilitate retrieval, and students must maintain their effort to do these things for extended periods of time (Goetz, Alexander & Schallert, 2003). Success in college demands that students meet these challenges to learn from textbooks to complete assignments, understand material, and prepare for exams (Goetz, Alexander & Schallert, 1987). Yet, Hallowell and Holland (1998) claim, "scientific illiteracy among college students is a persistent problem" (Yore, Bisanz & Hand, 2003). This is supported by research that demonstrates that college students lack metacognitive skills (Baker, 1974; Rinehart & Platt, 2003). According to Simpson and Nist (2000) and Pressley (2002) found that high school graduates and college freshmen are immature with respect to reading.

Most college freshmen are passive readers with ineffective high school reading strategies (Simpson & Nist, 2000). In a study by Smith (1992), college students were interviewed about their college reading experiences. One student said he skipped over or skimmed the material and took good notes in class, "It worked in high school, but it doesn't work in college." Another student said she "read college textbooks slowly, and sometimes twice, whereas in high school she read everything once and if she didn't get it, she didn't care." Smith also found that students did not understand textual aids. They "did not see the point of having diagrams, charts, pictures, etc...Students normally skipped these clues, especially tables of contents and guide questions" (Smith, 1992). Rothkopf (1988) found that motivation was one explanation for students' lack of strategy use (Barnett, 1997). This is evident in Smith's study (1992) when one student states "reading was boring because much of what he read didn't appear on tests." Another student said "the job was to finish as quickly as possible and with as little effort as possible." These students view reading as the transmission of facts, and because reading is not viewed as interactive, they are not motivated to do it. Barnett (1997) found that demands on student time were another factor in student non-strategy use. Again, Smith's study (1992) reaffirms this, as one student responds he "didn't like reading because it took up too much time." Research on college student strategy use has found that most strategy use is limited to text-based strategies, like re-reading (Wandersee, 1988).

With high demands on reading, most proficient and ineffective college readers share the common goal of increased reading speed (Henrichs, 2003). However, this is where most of the similarities between good and poor college readers end. Like younger readers, differences between good and poor college readers encompass comprehension of expository and narrative text, attitude, motivation, knowledge of purpose, breadth of reading, interest in reading, personal control over the reading process, and confidence in their reading abilities (Henrichs, 2003). Proficient college readers, in contrast to their peers, are able to clearly describe in detail the relationship between reading and their thought processes. Proficient college readers describe science and math reading as a "slow, focused, step-by step procedure through the text examples – a continuous building on prior knowledge" (Henrichs, 2003).

Like all other students, to be successful college readers, students must understand the characteristics of text and use appropriate strategies when reading (Simpson & Nist, 2000). To determine the scope of the college reading problem, Barnett (1997) studied college students and surveyed how much they read and how they studied. Barnett (1997) reports that students attempted to use strategies they learned in other classes, but were unsuccessful. Simpson and Nist (2000) report that recent research pinpoints identifying a purpose for reading as one common problem among college readers. Orlando et al. (2003) supports this finding. In the Orlando study it became apparent that differences exist between student-perceived instructor goals and actual instructor goals. While college students focused on recall, professors indicated interpretation and application as reading goals (Orlando et al., 2003). Simpson and Nist (2000) found that students earning high grades shared an understanding of the task with the professor, or were flexible in their reading and studying to change focus when they developed a better understanding of the task. Students who performed poorly did not understand the task or were inflexible in their reading and studying strategies. Intervention studies with college students support the teaching of strategies. According to Nist and Mealey (1991) using strategies helps students prepare for tests and monitor their text comprehension.

Despite the idea that metacognitive skills gradually increase with age, adult readers, like college readers, may also lack metacognitive knowledge (Rinehart & Platt, 2003). While college and adult readers may regulate their comprehension, poor readers may be deficient with awareness of task variables and strategy variables. Gambrell and Heath (1981) conducted a study on adult readers and found that adult poor readers lacked sensitivity to both task and strategy aspects of reading. They reported using fewer strategies, had more misconceptions about using strategies, and were not aware of how and when to use strategies (Rinehart & Platt, 2003). In the study, Gambrell and Heath (1981) found that adult poor readers also lacked knowledge about text structure. When asked about text structure, 43% could not relate that paragraphs or stories had order, compared to 96% of good readers. When asked what they did when encountering comprehension problems, only one-third of adult poor readers could answer (Rinehart & Platt, 2003). Like younger readers, adult poor readers view reading as decoding. When asked which was easier, reading for general meaning or reading word-for-word, 57% of adult poor readers said reading word-for-word. Despite the social and political implications of adult reading deficiencies, these readers offer the most promise to reading research (Rinehart & Platt, 2003). Their ability to communicate about their mental processes while reading exceed that of children and for that reason, adult readers are valued participants in reading research.

CHAPTER III

METHODOLOGY

Subjects

The participants in this study were 430 college students enrolled in Introductory Biology, a mixed-majors freshman biology course at a large land-grant state university during the spring semester of 2004. Introductory Biology is an inquiry-based biology class with an emphasis on concept attainment and knowledge application. The class utilizes specific text readings for student reference, but text readings are performed at the student's discretion. Student assessment in Introductory Biology is performed using multiple-choice exams with questions aimed at demonstrating student understanding and correct application of information. To achieve this, exam questions are based on "real life" scenarios described in the exam's reading material. Due to the focus on understanding biological concepts, as opposed to memorizing information, the nature of this class lends itself well to the study of student reading practices. To meet the demands of the course, it is essential that students utilizing the text do more than decode words. To use their text effectively, students must actively engage with the reading and comprehend the material.

Participants were volunteers selected from three sections of the class taught at different times during the week by three different professors. Data collected included age, major, sex, and perceived reading ability. However, not all students supplied all of the requested data, causing the tables to include percentages that equal less than 100. The mean age of the students was 19.6 years old with 252 female (58.6%) and 136 male (31.6%) students in the sample. Students' classification ranged from freshman to senior with the majority of students being freshmen (33.7%) and sophomores (15.6%). Student majors were assigned to one of five categories; Undecided, Science, Humanities, Education, and Business. The majority of students, 51.6%, reported having a major that was science-related while 11.2% declared Education-related majors, 12.6% Business-related, 12.6% Humanities related, and 12.1% were undecided (see Appendix A). Students self-reported their reading ability as either "Good," "Fair," or "Poor" with 90 students (20.9%) reporting their reading ability as "Good," 60 students (14.0%) reporting "Fair," and 7 students (1.6%) reporting their ability as "Poor." These students were asked to complete the Metacognitive Awareness of Reading Strategies Inventory (MARSI).

In addition to completing the MARSI inventory, ten student volunteers from the three Biology classes met with the researcher outside of class to receive instruction and practice using selected reading strategies taken from MARSI inventory. Students participating in the case studies were volunteers solicited from four biology lab sections. Students were approached during their scheduled lab time. The study was explained to the students and those interested in participating submitted their contact information. These students were contacted and received a schedule indicating times they could meet with the researcher. Students met individually with the researcher and the meeting times were based on student availability. The smaller group of students comprising the case studies consisted of eight females and two males, ranging in age from 18-25. The group included six freshmen, two sophomores, one junior, and one senior. The majority of student majors related to science (five students), with two education majors, two humanities majors, and one undecided. To maintain confidentiality, all case study participants were given fictitious names.

Instrument

The data for this study were collected using the Metacognitive Awareness of Reading Strategies Inventory (MARSI). This instrument was designed to measure 6th through 12th grade readers' perceived use of reading strategies while reading academic texts or school-related materials (Mokhtari & Reichard, 2002). The intent of the survey was to assess the reader's awareness of processes involved in reading and learn about the reader's intentions when approaching school-related texts (Mokhtari & Reichard, 2002).

The MARSI inventory consists of thirty statements comprising a five-point Likert scale ranging from 1 (I never or almost never do this) to 5 (I always or almost always do this). Students are asked to read through the statements and circle the number that best described the frequency they use the strategy.

The statements on the MARSI inventory represent different strategies that fall into one of three categories; Global, Problem Solving, and Support. The MARSI inventory contains 13 items corresponding to a global analysis of text. These Global Reading Strategies are generalized, intentional reading strategies aimed at preparing the reader for the act of reading, such as "I have a purpose in mind when I read." The MARSI inventory contains 8 items corresponding to problem solving. Problem Solving Reading Strategies are localized strategies that focus on solving problems that arise during reading, such as "When text becomes difficult, I read aloud to help me understand what I'm reading." The MARSI inventory contains 9 items corresponding to Support Reading Strategies, or strategies that involve outside reference materials or taking notes, such as "I underline or circle information in the text to help me understand it."

The MARSI inventory data provided a score for each subscale by summing the responses to each item in the subscale and calculating the mean. The overall MARSI inventory score was determined by summing responses from all three subscales and calculating the mean. Scores below 2.4 are considered low scores, between 2.5-3.4 are medium, and 3.5 and higher are high.

The MARSI inventory was validated with a population (n=825) representing students with reading abilities ranging from middle school to college (Mokhtari & Reichard, 2002). The internal consistency reliability coefficients for the three subscales were determined by Cronbach's alpha and based on the results of factor analysis. The reliabilities are as follows: Global (0.92), Problem-Solving (0.79), and Support strategies (0.87). The reliability for the overall scale is 0.93 (Mokhtari and Reichard, 2002) (see Appendix B).

Attitude was measured using a scale adapted from work by Shaw and Wright (1967). The bipolar scale consists of ten statements. Students completed the statements by circling the word that best represented how they felt about reading their biology text. Topics addressed included opinions on reading science, comparison of science with non-science, ability to attend to reading, and response to not understanding a passage. The score was calculated by summing the number of positive responses out of 10. Scores between 1 and 4 were considered negative, 4.1- 6 were neutral, and 6.1-10 were positive. There is no available reliability for this scale (see Appendix C).

The reading comprehension of students participating in the case studies was evaluated using text readings taken from the Introductory Biology class and post-reading questions composed of multiple-choice questions taken from previous biology exams. Selected text readings were typically three to four pages in length and consisted of passages from several different chapters (see Appendix D). Post-reading questions were selected based on their relevance to the assigned text reading for each week and were commonly compilations of items from 2-3 different exams. Students received these questions before beginning the reading and their text was available to them as they answered the questions. Post-reading questions were scored by calculating the percent correct each week. The Biology exams used were common exams written by the professors teaching the class during each given semester. There are no reported reliabilities for these exams, or the questions contained within (see Appendix E).

Data Collection

The MARSI inventory was administered at the beginning of individual classes with the help of the instructor and teaching assistants. Students were informed of the purpose of the survey and were told there were no right or wrong answers and were asked to complete the survey with their honest responses. All students finished the survey within ten minutes.

The analyses performed on the data included factor analysis, descriptive statistical procedures, *t*-tests, ANOVAs, and chi-squares to determine the use of reading strategies of all individuals and the difference in strategy usage between groups: students with self-perceived good and fair reading ability, male and female, and different majors.

The students participating were randomly assigned either to receive instruction or not receive instruction using the comprehension strategies. Students in both groups completed the attitude survey and the MARSI inventory. Six reading strategies identified as “infrequently used” by these students were selected for instruction. These strategies were Global 3 (I think about what I know to help me understand what I read), Global 10 (I skim the text first by noting characteristics like length and organization), Problem-Solving 18 (I stop from time to time and think about what I’m reading), Support 20 (I paraphrase to better understand what I read), Problem-Solving 21 (I try to picture or visualize information to help me remember what I read), and Support 24 (I go back and forth in the text to find relationships among ideas in it).

Strategy instruction complied with the four factors outlined by Vacca (2002): explanation, demonstration, practice, and application. Instruction began with an explanation of the strategy, what it was, how it was practiced, and when it should be used. The researcher then demonstrated the strategy for the student and observed the student practicing the strategy. At this point, students were given the selected section of text and asked to practice the strategy as they read. Strategy use application occurred during weeks five through eight, when students were asked to choose a strategy and practice it as they completed the readings.

During the first week of the study, all students read a passage from their text and completed post-reading questions to identify the differences already existing between the two groups. For the next three weeks, students receiving instruction observed demonstrations of and received instruction in using the different reading strategies (two strategies per week for three weeks). Students spent approximately 30-45 minutes a week meeting with the researcher, practicing the strategies, and completing the reading and questions.

During the second week, students received instruction in and practiced using strategies Global 3 (I think about what I know to help me understand what I read) and Global 10 (I skim the text first by noting characteristics like length and organization). Before reading the selected passages from their text over photosynthesis, students previewed the reading, taking note of the length and described the organization of the section. Students individually completed a Know-Want to know-Learned (KWL) chart to help them identify what they knew and what they wanted to learn about photosynthesis.

During week three, students received instruction in and practiced using strategies Problem-Solving 18 (I stop from time to time and think about what I'm reading) and Support 24 (I go back and forth in the text to find relationships among ideas in it). Students received a study sheet containing questions to answer as they moved through the text. At pre-determined points throughout the text, students stopped their reading and answered specific questions on their study sheet that related to what they had read.

During week 4, students received instruction in and practiced using Support 20 (I paraphrase (restate ideas in my own words) to better understand what I read) and Problem-Solving 21 (I try to picture or visualize information to help me remember what I read). Students were instructed to stop at various points throughout the text and paraphrase what they had read. After they completed the reading, students received instruction on making a concept map and were asked to make their own map demonstrating the similarities between mitosis and meiosis, the subject of their selected text reading.

Each week, after instruction, students who received instruction practiced using the strategies while reading selected sections of their biology text. Students who did not receive instruction read the selected text without using any instructed reading strategies. After reading, all students answered post-reading questions over the material they read.

During weeks 5-8, all students revisited the quizzes from weeks 1-4. For new readings, students who received instruction were asked to choose a reading strategy they had practiced and apply it to the selected text reading. As they used the strategy, the students were asked to take notes outlining what they did. Students not receiving instruction completed the reading and questions without using any formalized instructed reading strategies.

During the fifth week, students who received instruction were briefly interviewed about their feelings toward using the reading strategies, whether they felt the strategies were useful, which they liked using the most, and whether they would use the strategies in other classes. Students who did not receive instruction were interviewed about their feelings toward reading the sections of the text and how their feelings about reading the text had changed (see Appendix F)

The analysis performed on these data was qualitative. Due to the small sample size, statistical analysis was not possible. Qualitative analysis focused on changes in student attitude toward reading the biology text and using reading strategies. This analysis was taken primarily from the attitude survey completed by each of the students and their interview during week five.

CHAPTER IV

RESULTS

The purpose of this study was to investigate the strategy use of college biology students reading their biology textbooks. The study attempts to answer four questions:

- Do students utilize metacognitive strategies and what strategies do students report using while reading biology texts?
- Is there a relationship between students' use of reading strategies and their attitude toward reading biology?
- How does strategy use vary among good and poor readers, gender, and major?
- Does explicit instruction in using metacognitive strategies improve students' attitude toward reading biology texts?

A factor analysis was performed on all three subscales of the MARSI inventory and the MARSI inventory as a whole. The reliabilities were determined for Global (0.78), Problem Solving (0.75) and Support (0.70). The reliability for the overall scale was (0.88). While these reliabilities are lower than those reported by Mokhtari and Reichard (2002), these reliabilities determine the MARSI inventory a suitable instrument for use with college level students.

Question 1: Do college biology students use metacognitive reading strategies when reading their biology textbook?

Descriptive analysis was performed to determine the mean and standard deviation of all students completing the MARSI inventory for each subscale and the overall scale (see Table 1.1). The mean score for the overall scale was 3.11 (S.D. = .53). The mean score for Global strategies was 3.11 (S.D. = .61). The mean score for Support strategies was 2.68 (S.D. = .64). The mean score for Problem Solving strategies was 3.56 (S.D. = .63).

Table 1.1 (n = 430)
Reported reading strategy use of college biolgy students

Name	Strategy	*M*	S.D
GLOB 1	I have a purpose in mind when I read.	3.70	1.009
SUP 2	I take notes while reading to help me understand what I read.	2.5	1.188
GLOB 3	I think about what I know to help me understand what I read.	3.47	1.013
GLOB 4	I preview the text to see what it's about before reading it.	2.61	1.218
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	3.1	1.395
SUP 6	I summarize what I read to reflect on important information in the text.	2.77	1.094
GLOB 7	I think about whether the content of the text fits my reading purpose.	2.93	1.151
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.55	1.066
SUP 9	I discuss what I read with others to check my understanding.	2.31	1.083
GLOB 10	I skim the text first by noting characteristics like length and organization.	2.67	1.297
PROB 11	I try to get back on track when I lose concentration.]	4.02	0.906
SUP 12	I underline or circle information in the text to help me remember it.	3.3	1.309
PROB 13	I adjust my reading speed according to what I'm reading.	3.59	1.077
GLOB 14	I decide what to read closely and what to ignore.	3.21	1.131
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.38	1.233
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	3.86	1.05
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.53	1.147
PROB 18	I stop from time to time and think about what I'm reading.	3.04	0.987
GLOB 19	I use context clues to help me better understand what I'm reading.	3.18	1.077
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	2.88	1.164
PROB 21	I try to picture or visualize information to help remember what I read.	3.57	1.085
GLOB 22	I use typographical aids like bold face and italics to identify key information.	3.73	1.182
GLOB 23	I critically analyze and evaluate the information presented in the text.	2.79	0.978
SUP 24	I go back and forth in the text to find relationships among ideas in it.	2.51	1.064
GLOB 25	I check my understanding when I come across conflicting information.	3.25	1.071
GLOB 26	I try to guess what the material is about when I read.	2.71	1.115
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	3.94	0.981
SUP 28	I ask myself questions I like to have answered in the text.	2.41	1.097
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.53	1.143
PROB 30	I try to guess the meaning of unknown words or phrases.	2.93	1.202
GLOBAL	**Overall Global Reading Strategies**	**3.1111**	**0.60964**
SUP	**Overall Support Reading Strategies**	**2.6817**	**0.63519**
PROB	**OverallProblem Solving Reading Strategies**	**3.5643**	**0.62638**
OVERALL	**Overall MARSI score**	**3.1095**	**0.52597**

Descriptive analysis was used to identify the five most commonly and least commonly used strategies (see Table 1.2). The most commonly used strategies in order of use are Problem-solving 11 (I try to get back on track when I lose concentration), Problem-Solving 27 (When the text becomes difficult, I re-read to increase my understanding), Problem Solving 16 (When the text becomes difficult, I pay closer attention to what I'm reading), Global 22 (I use typographical aids like bold face and italics to identify key information), and Global 1 (I have a purpose in mind when I read).

The least commonly used strategies in order of disuse are items Support 9 (I discuss what I read with others to check my understanding), Support 15 (I use reference materials such as dictionaries to help understand what I read), Support 28 (I ask myself questions I like to have answered in the text), Support 2 (I take notes while reading to help me understand what I read), and Support 24 (I go back and forth in the text to find relationships among ideas in it).

Table 1.2 (n = 430)
Reported reading strategies used most and least by college biology students

Top five used

Name	Strategy	*M*	S.D
PROB 11	**I try to get back on track when I lose concentration.**	**4.02**	**0.906**
PROB 27	**When the text becomes difficult, I re-read to increase my understanding.**	**3.99**	**0.981**
PROB 16	**When text becomes difficult, I pay closer attention to what I'm reading.**	**3.86**	**1.05**
GLOB 22	**I use typographical aids like bold face and italics to identify key information.**	**3.73**	**1.182**
GLOB 1	**I have a purpose in mind when I read.**	**3.70**	**1.009**

Bottom five used

Name	**Strategy**		
SUP 24	**I go back and forth in the text to find relationships among ideas in it.**	**2.51**	**1.064**
SUP 2	**I take notes while reading to help me understand what I read.**	**2.50**	**1.188**
SUP 28	**I ask myself questions I like to have answered in the text.**	**2.41**	**1.097**
SUP 15	**I use reference materials such as dictionaries to help me understand what I read.**	**2.38**	**1.233**
SUP 9	**I discuss what I read with others to check my understanding.**	**2.31**	**1.083**

Question 2: Is there a relationship between students' use of reading strategies and their attitude toward reading biology?

A correlation and chi-square test of significance was done between overall MARSI inventory score and attitude (see Table 2.1). The correlation matrix shows a positive relationship between overall MARSI inventory score and attitude. The chi-square results indicate that students who scored low on the MARSI inventory were most likely to have a negative attitude and least likely to have a positive attitude toward reading the text. Students who scored medium on the MARSI inventory were most likely to have a neutral attitude and least likely to have a negative attitude. Students who scored high on the MARSI inventory were most likely to have a positive attitude and least likely to have a neutral attitude.

Table 2.1 (n = 137)
Correlation between MARSI score and attitude toward reading biology

MARSI score		Negative	Neutral	Positive
low (1-2.4)	Count	11.0	2.0	3.0
	Adjusted Residual	2.7	-0.5	-2.3
medium (2.5-3.4)	Count	30.0	19.0	37.0
	Adjusted Residual	-1.0	2.2	-0.7
high (3.5-5)	Count	11.0	2.0	22.0
	Adjusted Residual	-0.9	-2.0	2.4
total		52.0	23.0	62.0

Question 3: How does strategy use vary among good and poor readers, gender, and major?

A *t*-test was performed to identify the differences between self-perceived "good" and "fair" ability readers (see Table 3.1). Due to the small number of self-perceived “low” ability readers, these individuals were included in the group of fair readers. Significant differences were found in the overall MARSI inventory score, the overall Problem-Solving subscale, and the overall Global subscale. Good readers scored higher overall and in both subscales. There was no significant difference in the overall Problem-Solving subscale. Significant differences were found in several of the individual items on the scale; items 3 (I think about what I know to help me understand what I read), 7 (I think about whether the content of the text fits my reading purpose), 13 (I adjust my reading speed according to what I’m reading), 16 (When the text becomes difficult, I pay closer attention to what I’m reading), 19 (I use content clues to help me better understand what I’m reading), 25 (I check my understanding when I come across conflicting information), 27 (When text becomes difficult, I re-read to increase my understanding), and 28 (I ask myself questions I like to have answered in the text). Good readers scored higher on each item.

Table 3.1 (n = 154)
Differences in strategy use by self-perceived good and fair readers

		Good		Fair		
Name	Strategy	*M*	S.D.	*M*	S.D.	Sig.
GLOB 1	I have a purpose in mind when I read.	3.84	0.860	3.55	1.038	0.054
SUP 2	I take notes while reading to help me understand what I read.	2.56	1.200	2.39	1.163	0.396
GLOB 3	I think about what I know to help me understand what I read.	3.69	0.895	3.14	1.014	0.001
GLOB 4	I preview the text to see what it's about before reading it.	2.71	1.154	2.43	1.292	0.158
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	3.09	1.466	3.25	1.321	0.485
SUP 6	I summarize what I read to reflect on important information in the text.	2.82	1.223	2.67	0.927	0.409
GLOB 7	I think about whether the content of the text fits my reading purpose.	3.07	1.159	2.61	1.317	0.024
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.36	1.084	3.58	1.036	0.203
SUP 9	I discuss what I read with others to check my understanding.	2.31	1.098	2.06	1.037	0.159
GLOB 10	I skim the text first by noting characteristics like length and organization.	3.07	1.243	2.75	1.309	0.130
PROB 11	I try to get back on track when I lose concentration.	4.11	0.800	4.02	0.864	0.481
SUP 12	I underline or circle information in the text to help me remember it.	3.27	1.364	3.41	1.256	0.519
PROB 13	I adjust my reading speed according to what I'm reading.	3.81	1.016	3.31	1.052	0.004
GLOB 14	I decide what to read closely and what to ignore.	3.47	1.163	3.14	1.207	0.093
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.39	1.330	2.19	1.242	0.352
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	4.08	0.874	3.45	1.246	0.000
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.62	1.167	3.40	1.212	0.249
PROB 18	I stop from time to time and think about what I'm reading.	3.07	1.042	2.81	1.022	0.134
GLOB 19	I use context clues to help me better understand what I'm reading.	3.37	1.043	2.80	1.086	0.001
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	2.96	1.208	2.61	1.063	0.068
PROB 21	I try to picture or visualize information to help remember what I read.	3.68	1.130	3.44	1.104	0.206
GLOB 22	I use typographical aids like bold face and italics to identify key information.	3.80	1.192	3.72	1.188	0.677
GLOB 23	I critically analyze and evaluate the information presented in the text.	2.88	1.037	2.64	0.897	0.142
SUP 24	I go back and forth in the text to find relationships among ideas in it.	2.52	1.169	2.27	0.913	0.154
GLOB 25	I check my understanding when I come across conflicting information.	3.44	1.040	2.92	1.044	0.003
GLOB 26	I try to guess what is about when I read.	2.86	1.137	2.55	1.097	0.094
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	4.15	0.806	3.73	1.102	0.008
SUP 28	I ask myself questions I like to have answered in the text.	2.53	1.173	2.14	1.037	0.033
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.68	1.216	2.31	1.022	0.052
PROB 30	I try to guess the meaning of unknown words or phrases.	3.13	1.192	2.86	1.052	0.142
GLOBAL	**Overall Global Reading Strategies**	**3.2684**	**0.49762**	**2.9256**	**0.61490**	**0.000**
SUP	**Overall Support Reading Strategies**	**2.7203**	**0.71069**	**2.5556**	**0.60497**	**0.137**
PROB	**OverallProblem Solving Reading Strategies**	**3.6624**	**0.56229**	**3.4048**	**0.66475**	**0.011**
OVERALL	**Overall MARSI score**	**3.2222**	**0.49197**	**2.9395**	**0.53725**	**0.001**

A *t*-test was performed to identify differences in strategy usage between males and females (see Table 3.2). No significant difference was seen in the overall MARSI inventory score, Global or Problem-Solving subscales. There was significant difference in the Support subscale. Females scored higher in overall use of Support strategies. Several significant differences were also found for individual items with females consistently scoring higher than males.

Table 3.2 (n = 366)
Differences in reading strategy use by male and female college biology students

Name	Strategy	Male *M*	S.D	Female *M*	S.D.	*Sig.*
GLOB 1	I have a purpose in mind when I read.	3.60	1.00	3.72	1.03	0.272
SUP 2	I take notes while reading to help me understand what I read.	2.04	1.07	2.77	1.15	0.000
GLOB 3	I think about what I know to help me understand what I read.	3.57	1.03	3.40	1.01	0.122
GLOB 4	I preview the text to see what it's about before reading it.	2.57	1.22	2.64	1.21	0.567
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	2.83	1.38	3.24	1.38	0.005
SUP 6	I summarize what I read to reflect on important information in the text.	2.82	1.14	2.75	1.08	0.534
GLOB 7	I think about whether the content of the text fits my reading purpose.	2.84	1.25	2.95	1.11	0.401
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.38	1.17	3.61	1.02	0.045
SUP 9	I discuss what I read with others to check my understanding.	2.16	1.07	2.39	1.08	0.049
GLOB 10	I skim the text first by noting characteristics like length and organization.	2.59	1.26	2.76	1.33	0.224
PROB 11	I try to get back on track when I lose concentration.]	3.90	0.98	4.09	0.88	0.051
SUP 12	I underline or circle information in the text to help me remember it.	2.71	1.31	3.68	1.16	0.000
PROB 13	I adjust my reading speed according to what I'm reading.	3.53	1.14	3.64	1.04	0.339
GLOB 14	I decide what to read closely and what to ignore.	3.16	1.17	3.25	1.11	0.453
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.22	1.13	2.45	1.26	0.071
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	3.77	1.14	3.89	1.02	0.296
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.52	1.20	3.53	1.12	0.975
PROB 18	I stop from time to time and think about what I'm reading.	3.09	0.95	3.04	1.01	0.641
GLOB 19	I use context clues to help me better understand what I'm reading.	3.10	1.14	3.21	1.04	0.300
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	2.85	1.19	2.90	1.15	0.670
PROB 21	I try to picture or visualize information to help remember what I read.	3.70	1.04	3.50	1.12	0.083
GLOB 22	I use typographical aids like bold face and italics to identify key information.	3.52	1.25	3.85	1.12	0.009
GLOB 23	I critically analyze and evaluate the information presented in the text.	2.86	0.96	2.86	2.15	0.999
SUP 24	I go back and forth in the text to find relationships among ideas in it.	2.61	1.17	2.44	1.00	0.116
GLOB 25	I check my understanding when I come across conflicting information.	3.27	1.14	3.27	1.04	0.957
GLOB 26	I try to guess what is about when I read.	2.75	1.14	2.70	1.11	0.665
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	3.90	1.00	3.95	0.97	0.673
SUP 28	I ask myself questions I like to have answered in the text.	2.48	1.08	2.37	1.10	0.332
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.61	1.18	2.47	1.11	0.239
PROB 30	I try to guess the meaning of unknown words or phrases.	3.03	1.25	2.90	1.17	0.313
GLOBAL	**Overall Global Reading Strategies**	**3.07**	**0.60**	**3.13**	**0.61**	**0.374**
SUP	**Overall Support Reading Strategies**	**2.52**	**0.64**	**2.77**	**0.62**	**0.000**
PROB	**Overall Problem Solving ReadingStrategies**	**3.53**	**0.65**	**3.58**	**0.62**	**0.511**
OVERALL	**Overall MARSI score**	**3.04**	**0.52**	**3.15**	**0.53**	**0.073**

Descriptive statistics were performed on each group of majors. Frequencies for each major including sex, age, classification and perceived reading ability can be seen in Table 3.3.

Table 3.3 (n = 430)
Descriptive statistics for each of five major categories

Sex		Age	Frequency	Classificatior	Frequency	Perception	Frequency
Science n=222							
Male	83	18-19	160	Freshman	76	Good	52
Female	113	20-21	46	Sophmore	25	Fair	24
total	222	22+	16	Junior	14	Poor	6
		total	222	Senior	3	total	82
				total	164		
Education n=48							
Sex		Age	Frequency	Classificatior	Frequency	Perception	Frequency
Male	9	18-19	28	Freshman	10	Good	12
Female	37	20-21	17	Sophmore	13	Fair	8
total	48	22+	3	Junior	6	Poor	0
		total	48	Senior	1	total	20
				total	30		
Business n=54							
Sex		Age	Frequency	Classificatior	Frequency	Perception	Frequency
Male	13	18-19	36	Freshman	18	Good	8
Female	36	20-21	15	Sophmore	13	Fair	11
total	54	22+	3	Junior	3	Poor	1
		total	54	Senior	2	total	20
				total	36		
Humanities n=54							
Sex		Age	Frequency	Classificatior	Frequency	Perception	Frequency
Male	13	18-19	33	Freshman	17	Good	13
Female	39	20-21	10	Sophmore	8	Fair	8
total	51	22+	11	Junior	7	Poor	0
		total	54	Senior	1	total	21
				total	33		
Undecided n=52							
Sex		Age	Frequency	Classificatior	Frequency	Perception	Frequency
Male	19	18-19	42	Freshman	24	Good	5
Female	27	20-21	6	Sophmore	8	Fair	9
total	46	22+	3	Junior	0	Poor	0
		total	51	Senior	0	total	14
				total	32		

A chi-square test of significance was performed to determine the differences in low, medium, and high MARSI inventory scores between different majors. Significant differences were found between education majors and undecided students. Education majors were most likely to score within the medium range of the MARSI inventory and undecided students were most likely to score within the low and high range. There were no significant differences between the other three majors (see Table 3.4).

Table 3.4 (n = 416)
Chi-Square of major and score on MARSI instrument (low, medium and high)

Major		Low	Medium	High	*M* score	S.D.
Science	Count	25	123	67	3.11	0.5644
	Adjusted Residual	0.7	-1.2	0.9		
Education	Count	1	36	9	3.18	0.4014
	Adjusted Residual	-2	2.7	-1.5		
Business	Count	6	30	14	3.05	0.5226
	Adjusted Residual	0.3	0	-0.2		
Humanities	Count	2	28	14	3.2	1.4872
	Adjusted Residual	-1.8	1.7	-0.6		
Undecided	Count	10	23	18	3.03	0.4975
	Adjusted Residual	2.2	-2.3	1		
total		44	250	122	3.11	0.526

One-way ANOVAs were performed to compare the MARSI inventory means and standard deviations of the five major categories. No significant differences were found among the five different majors regarding overall MARSI inventory score or among any of the subscales. There were significant differences found among 2 individual items in the scale. Science majors scored higher on Problem-Solving 16 (When the text becomes difficult, I pay closer attention to what I'm reading), while humanities majors scored higher on Global 23 (I critically analyze and evaluate the information presented in the text) (see Table 3.5).

Table 3.5 (n = 402)
Differences in strategy use between different majors

		Science		Education		Business		Humanities		Undecided		
Name	Strategy	*M*	S.D.	*M*	S.D.	*M*	S.D.	*M*	S.D.	*M*	S.D.	Sig.
GLOB 1	I have a purpose in mind when I read.	3.71	1.025	3.87	0.968	3.70	0.839	3.80	1.040	3.53	1.082	0.546
SUP 2	I take notes while reading to help me understand what I read.	2.47	1.238	2.64	1.090	2.52	1.147	2.63	1.232	2.31	1.122	0.615
GLOB 3	I think about what I know to help me understand what I read.	3.56	1.017	3.44	0.841	3.16	1.037	3.55	0.986	3.39	1.096	0.144
GLOB 4	I preview the text to see what it's about before reading it.	2.55	1.237	2.69	1.083	2.78	1.250	2.61	1.150	2.71	1.208	0.735
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	3.03	1.441	3.44	1.099	3.18	1.380	3.02	1.476	2.94	1.345	0.379
SUP 6	I summarize what I read to reflect on important information in the text.	2.84	1.129	2.56	1.078	2.80	0.969	2.86	1.059	2.71	1.080	0.573
GLOB 7	I think about whether the content of the text fits my reading purpose.	3.01	1.219	2.82	0.960	2.86	1.088	3.00	1.020	2.88	1.092	0.782
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.54	1.113	3.60	0.939	3.46	1.164	3.80	0.960	3.37	1.014	0.316
SUP 9	I discuss what I read with others to check my understanding.	2.23	1.072	2.58	1.118	2.32	1.077	2.31	1.029	2.16	1.179	0.348
GLOB 10	I skim the text first by noting characteristics like length and organization.	2.69	1.345	2.91	1.240	2.64	1.102	2.45	1.331	2.80	1.338	0.493
PROB 11	I try to get back on track when I lose concentration.	4.14	0.856	3.91	0.848	3.88	1.043	4.02	0.927	3.98	0.878	0.253
SUP 12	I underline or circle information in the text to help me remember it.	3.26	1.371	3.78	0.927	3.32	1.347	3.51	1.377	3.06	1.107	0.060
PROB 13	I adjust my reading speed according to what I'm reading.	3.61	1.104	3.60	0.939	3.44	1.163	3.71	0.986	3.65	0.991	0.779
GLOB 14	I decide what to read closely and what to ignore.	3.14	1.195	3.22	1.020	3.34	1.062	3.18	1.034	3.41	1.059	0.534
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.34	1.227	2.24	1.111	2.36	1.208	2.75	1.278	2.24	1.182	0.200
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	4.01	1.029	3.80	0.869	3.48	1.199	3.86	1.040	3.84	0.850	0.023
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.59	1.190	3.53	0.968	3.48	1.165	3.37	1.038	3.53	1.192	0.792
PROB 18	I stop from time to time and think about what I'm reading.	3.03	0.970	3.22	1.020	2.96	1.049	3.20	0.960	2.86	1.021	0.309
GLOB 19	I use context clues to help me better understand what I'm reading.	3.24	1.119	3.24	0.908	3.14	1.107	3.33	0.973	2.90	1.085	0.269
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	2.82	1.187	3.07	1.116	2.90	1.199	3.16	1.065	2.63	1.185	0.151
PROB 21	I try to picture or visualize information to help remember what I read.	3.58	1.133	3.69	1.041	3.34	1.002	3.71	1.006	3.55	0.980	0.451
GLOB 22	I use typographical aids like bold face and italics to identify key information.	3.72	1.205	3.84	1.127	3.54	1.073	3.75	1.129	3.92	1.205	0.561
GLOB 23	I critically analyze and evaluate the information presented in the text.	2.78	1.013	2.80	0.757	2.68	0.891	3.63	1.016	2.73	0.974	0.032
SUP 24	I go back and forth in the text to find relationships among ideas in it.	2.48	1.153	2.73	0.915	2.54	0.952	2.51	1.027	2.41	0.911	0.625
GLOB 25	I check my understanding when I come across conflicting information.	3.30	1.174	3.27	0.751	3.04	1.049	3.33	0.952	3.31	1.004	0.601
GLOB 26	I try to guess what is about when I read.	2.61	1.156	2.78	1.106	2.78	1.036	2.96	1.076	2.61	1.017	0.290
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	4.04	0.992	4.07	0.751	3.60	1.107	3.94	0.925	3.90	0.797	0.051
SUP 28	I ask myself questions I like to have answered in the text.	2.45	1.131	2.40	1.156	2.48	1.092	2.39	1.021	2.27	1.016	0.851
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.56	1.233	2.44	0.967	2.64	1.191	2.55	1.064	2.45	1.042	0.906
PROB 30	I try to guess the meaning of unknown words or phrases.	2.87	1.286	3.11	1.191	3.04	1.049	3.04	1.076	2.90	1.065	0.683
GLOBAL	**Overall Global Reading Strategies**	3.11220	0.62858	3.14360	0.43718	3.06000	0.55867	3.19310	0.66178	3.09	0.63807	0.837
SUP	**Overall Support Reading Strategies**	2.65750	0.67389	2.82720	0.61753	2.71330	0.58927	2.79300	0.56131	2.52610	0.60679	0.125
PROB	**Overall Problem Solving Reading Strategies**	3.60390	0.65840	3.62500	0.43301	3.40000	0.71562	3.65930	0.60108	3.50510	0.49276	0.180
OVERALL	**Overall MARSI score**	3.10690	0.56439	3.17700	0.40138	3.04670	0.52260	3.19740	0.48716	3.03130	0.49751	0.412

T-tests were performed to compare males and females within majors. Within Science majors, several individual items were found to have significant differences between males and females. Females scored higher on Support 2 (I take notes while reading to help me understand what I read), Problem-Solving 11 (I try to get back on track when I lose concentration), Support 12 (I underline or circle information in the text to help me remember it), and Global 22 (I use typographical aids like bold face and italics to identify key information). Males scored higher on item Support 24 (I check my understanding when I come across conflicting information). (see Table 3.6)

Table 3.6 (n = 196)
Differences in strategy use by male and female science majors

		Male		Female		
Name	Strategy	*M*	S.D.	*M*	S.D.	Sig.
GLOB 1	I have a purpose in mind when I read.	3.67	1.001	3.71	1.091	0.827
SUP 2	I take notes while reading to help me understand what I read.	2.00	1.115	2.81	1.177	0.000
GLOB 3	I think about what I know to help me understand what I read.	3.69	1.023	3.46	0.995	0.129
GLOB 4	I preview the text to see what it's about before reading it.	2.54	1.255	2.60	1.250	0.748
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	2.84	1.384	3.19	1.449	0.097
SUP 6	I summarize what I read to reflect on important information in the text.	2.84	1.222	2.82	1.096	0.912
GLOB 7	I think about whether the content of the text fits my reading purpose.	2.83	1.313	3.09	1.177	0.150
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.41	1.240	3.53	1.044	0.459
SUP 9	I discuss what I read with others to check my understanding.	2.12	1.137	2.34	1.027	0.166
GLOB 10	I skim the text first by noting characteristics like length and organization.	2.65	1.292	2.68	1.410	0.876
PROB 11	I try to get back on track when I lose concentration.	3.92	1.002	4.19	0.840	0.042
SUP 12	I underline or circle information in the text to help me remember it.	2.66	1.373	3.65	1.224	0.000
PROB 13	I adjust my reading speed according to what I'm reading.	3.55	1.150	3.63	1.104	0.649
GLOB 14	I decide what to read closely and what to ignore.	3.04	1.271	3.20	1.143	0.338
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.21	1.194	2.50	1.276	0.101
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	3.87	1.166	4.04	1.017	0.285
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.54	1.243	3.64	1.142	0.580
PROB 18	I stop from time to time and think about what I'm reading.	3.14	0.912	3.02	0.973	0.356
GLOB 19	I use context clues to help me better understand what I'm reading.	3.12	1.193	3.27	1.054	0.341
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	2.77	1.220	2.92	1.151	0.376
PROB 21	I try to picture or visualize information to help remember what I read.	3.74	1.142	3.45	1.126	0.077
GLOB 22	I use typographical aids like bold face and italics to identify key information.	3.46	1.281	3.88	1.151	0.018
GLOB 23	I critically analyze and evaluate the information presented in the text.	2.84	1.018	2.73	1.020	0.425
SUP 24	I go back and forth in the text to find relationships among ideas in it.	2.70	1.302	2.33	1.030	0.029
GLOB 25	I check my understanding when I come across conflicting information.	3.35	1.234	3.30	1.125	0.775
GLOB 26	I try to guess what is about when I read.	2.64	1.143	2.62	1.160	0.909
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	3.90	1.078	4.06	1.011	0.294
SUP 28	I ask myself questions I like to have answered in the text.	2.52	1.141	2.38	1.113	0.399
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.53	1.262	2.55	1.180	0.916
PROB 30	I try to guess the meaning of unknown words or phrases.	2.98	1.325	2.75	1.257	0.230
GLOBAL	**Overall Global Reading Strategies**	**3.0682**	**0.64335**	**3.1429**	**0.63649**	**0.427**
SUP	**Overall Support Reading Strategies**	**2.5171**	**0.66107**	**2.7679**	**0.65345**	**0.010**
PROB	**Overall Problem Solving Reading Strategies**	**3.5716**	**0.68888**	**3.5830**	**0.66325**	**0.098**
OVERALL	**Overall MARSI score**	**3.0466**	**0.55477**	**3.1486**	**0.56944**	**0.231**

Within Business majors, significant differences between males and females were found on items Support 12 (I underline or circle information in the text to help me remember it) and Global 14 (I decide what to read closely and what to ignore). On both items, females scored higher. (see Table 3.7)

Table 3.7 (n = 49)
Differences in strategy use by male and female business majors

		Male		Female		
Name	Strategy	*M*	S.D.	*M*	S.D.	Sig.
GLOB 1	I have a purpose in mind when I read.	3.77	0.725	3.64	0.867	0.631
SUP 2	I take notes while reading to help me understand what I read.	2.08	0.954	2.72	1.137	0.074
GLOB 3	I think about what I know to help me understand what I read.	3.08	1.038	3.14	1.073	0.858
GLOB 4	I preview the text to see what it's about before reading it.	2.62	1.044	2.74	1.291	0.751
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	2.77	1.481	3.17	1.404	0.393
SUP 6	I summarize what I read to reflect on important information in the text.	3.08	0.954	2.61	0.994	0.150
GLOB 7	I think about whether the content of the text fits my reading purpose.	2.85	1.144	2.81	1.142	0.913
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.31	1.251	3.50	1.134	0.612
SUP 9	I discuss what I read with others to check my understanding.	2.46	1.050	2.25	1.052	0.537
GLOB 10	I skim the text first by noting characteristics like length and organization.	2.46	1.050	2.80	1.132	0.353
PROB 11	I try to get back on track when I lose concentration.	3.69	1.109	4.06	0.984	0.276
SUP 12	I underline or circle information in the text to help me remember it.	2.77	1.166	3.64	1.313	0.041
PROB 13	I adjust my reading speed according to what I'm reading.	3.08	1.256	3.61	1.128	0.162
GLOB 14	I decide what to read closely and what to ignore.	2.77	1.013	3.61	1.050	0.016
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.38	1.193	2.31	1.215	0.841
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	3.31	1.316	3.50	1.207	0.633
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.62	1.193	3.25	1.251	0.366
PROB 18	I stop from time to time and think about what I'm reading.	3.08	1.038	2.89	1.116	0.599
GLOB 19	I use context clues to help me better understand what I'm reading.	3.23	1.301	3.06	1.120	0.645
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	3.23	1.301	2.69	1.117	0.162
PROB 21	I try to picture or visualize information to help remember what I read.	3.62	0.870	3.08	1.105	0.124
GLOB 22	I use typographical aids like bold face and italics to identify key information.	3.38	1.044	3.56	1.132	0.636
GLOB 23	I critically analyze and evaluate the information presented in the text.	2.92	0.760	2.49	0.951	0.144
SUP 24	I go back and forth in the text to find relationships among ideas in it.	2.62	0.768	2.47	1.000	0.642
GLOB 25	I check my understanding when I come across conflicting information.	3.08	1.115	3.14	1.125	0.865
GLOB 26	I try to guess what is about when I read.	2.62	0.768	2.89	1.166	0.437
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	3.69	1.182	3.61	1.103	0.824
SUP 28	I ask myself questions I like to have answered in the text.	2.92	0.862	2.33	1.171	0.104
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.85	1.214	2.56	1.206	0.461
PROB 30	I try to guess the meaning of unknown words or phrases.	2.77	1.166	3.17	1.108	0.280
GLOBAL	**Overall Global Reading Strategies**	**3.01780**	**0.69741**	**3.07690**	**0.56559**	**0.758**
SUP	**Overall Support Reading Strategies**	**2.70090**	**0.57267**	**2.68830**	**0.61137**	**0.949**
PROB	**Overall Problem Solving Reading Strategies**	**3.31730**	**0.84874**	**3.42710**	**0.72109**	**0.656**
OVERALL	**Overall MARSI score**	**3.00260**	**0.62738**	**3.06360**	**0.50596**	**0.732**

Significant differences between males and females within Humanities were found on items Support 2 (I take notes while reading to help me understand what I read), and Support 12 (I underline or circle information in the text to help me remember it) with females scoring higher on both. (see Table 3.8)

Table 3.8 (n = 51)
Differences in strategy use by male and female humanities majors

Name	Strategy	Male *M*	Male S.D.	Female *M*	Female S.D.	Sig.
GLOB 1	I have a purpose in mind when I read.	3.25	1.215	3.85	0.961	0.084
SUP 2	I take notes while reading to help me understand what I read.	1.83	0.937	2.85	1.159	0.008
GLOB 3	I think about what I know to help me understand what I read.	3.58	0.900	3.62	1.067	0.925
GLOB 4	I preview the text to see what it's about before reading it.	2.42	1.165	2.64	1.181	0.566
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	2.92	1.505	3.15	1.424	0.621
SUP 6	I summarize what I read to reflect on important information in the text.	2.42	0.669	3.00	1.124	0.095
GLOB 7	I think about whether the content of the text fits my reading purpose.	2.75	0.965	3.05	1.025	0.371
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.83	1.115	3.89	0.894	0.846
SUP 9	I discuss what I read with others to check my understanding.	2.25	1.055	2.44	1.021	0.587
GLOB 10	I skim the text first by noting characteristics like length and organization.	1.92	0.996	2.69	1.341	0.071
PROB 11	I try to get back on track when I lose concentration.	4.17	0.718	4.03	0.959	0.641
SUP 12	I underline or circle information in the text to help me remember it.	2.58	1.443	3.77	1.245	0.008
PROB 13	I adjust my reading speed according to what I'm reading.	3.83	1.115	3.72	0.972	0.730
GLOB 14	I decide what to read closely and what to ignore.	3.08	0.793	3.13	1.105	0.897
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.36	0.924	2.87	1.321	0.239
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	3.75	1.055	3.90	1.095	0.683
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.5	0.905	3.41	1.117	0.801
PROB 18	I stop from time to time and think about what I'm reading.	3.45	1.036	3.18	0.942	0.407
GLOB 19	I use context clues to help me better understand what I'm reading.	2.92	0.793	3.44	1.021	0.113
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	2.92	0.900	3.21	1.128	0.423
PROB 21	I try to picture or visualize information to help remember what I read.	3.83	0.835	3.69	1.104	0.686
GLOB 22	I use typographical aids like bold face and italics to identify key information.	3.25	1.055	3.90	1.142	0.087
GLOB 23	I critically analyze and evaluate the information presented in the text.	2.92	1.084	3.82	4.909	0.532
SUP 24	I go back and forth in the text to find relationships among ideas in it.	2.25	0.866	2.54	1.072	0.400
GLOB 25	I check my understanding when I come across conflicting information.	3.17	0.937	3.31	1.004	0.668
GLOB 26	I try to guess what is about when I read.	3.5	1.314	2.85	1.040	0.080
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	4.25	0.622	3.87	0.951	0.203
SUP 28	I ask myself questions I like to have answered in the text.	2.08	0.996	2.44	0.995	0.288
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.67	0.888	2.44	1.071	0.502
PROB 30	I try to guess the meaning of unknown words or phrases.	3.25	1.055	2.92	1.061	0.355
GLOBAL	**Overall Global Reading Strategies**	**2.9936**	**0.41289**	**3.2406**	**0.71230**	**0.260**
SUP	**Overall Support Strategies**	**2.3434**	**0.40202**	**2.9174**	**0.55656**	**0.003**
PROB	**Overall Problem Solving Reading Strategies**	**3.7169**	**0.51262**	**3.6480**	**0.61777**	**0.741**
OVERALL	**Overall MARSI score**	**3.0267**	**0.27253**	**3.2491**	**0.52823**	**0.207**

Among undecided students, significant differences between males and females were found on items Support 12 (I underline or circle information in the text to help me remember it) with females scoring higher, and Global 14 (I decide what to read closely and what to ignore) with males scoring higher. (see Table 3.9)

No significant differences were found between male and female Education students. (see Table 3.10)

Table 3.9 (n = 46)
Differences in strategy use by male and female undecided majors

Name	Strategy	Male *M*	Male S.D.	Female *M*	Female S.D.	Sig.
GLOB 1	I have a purpose in mind when I read.	3.37	1.012	3.52	1.156	0.651
SUP 2	I take notes while reading to help me understand what I read.	2.05	1.026	2.59	1.152	0.109
GLOB 3	I think about what I know to help me understand what I read.	3.53	1.219	3.11	0.974	0.206
GLOB 4	I preview the text to see what it's about before reading it.	2.37	1.300	2.74	1.130	0.307
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	2.58	1.502	3.33	1.301	0.076
SUP 6	I summarize what I read to reflect on important information in the text.	2.79	1.182	2.62	1.061	0.607
GLOB 7	I think about whether the content of the text fits my reading purpose.	2.89	1.449	2.78	0.892	0.736
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.11	0.937	3.56	1.050	0.142
SUP 9	I discuss what I read with others to check my understanding.	1.95	0.848	2.44	1.340	0.161
GLOB 10	I skim the text first by noting characteristics like length and organization.	2.47	1.429	2.93	1.238	0.259
PROB 11	I try to get back on track when I lose concentration.	3.89	0.994	4.00	0.832	0.699
SUP 12	I underline or circle information in the text to help me remember it.	2.47	0.905	3.59	0.844	0.000
PROB 13	I adjust my reading speed according to what I'm reading.	3.32	1.057	3.81	0.879	0.088
GLOB 14	I decide what to read closely and what to ignore.	3.89	0.875	3.15	1.064	0.016
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.00	1.106	2.19	1.178	0.593
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	3.72	1.074	3.85	0.718	0.629
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.53	1.172	3.52	1.156	0.982
PROB 18	I stop from time to time and think about what I'm reading.	2.63	0.895	2.85	1.099	0.475
GLOB 19	I use context clues to help me better understand what I'm reading.	2.95	1.026	2.81	1.075	0.677
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	2.58	1.216	2.67	1.177	0.807
PROB 21	I try to picture or visualize information to help remember what I read.	3.47	0.964	3.70	1.031	0.448
GLOB 22	I use typographical aids like bold face and italics to identify key information.	4.00	1.333	3.89	1.013	0.749
GLOB 23	I critically analyze and evaluate the information presented in the text.	2.79	0.918	2.67	1.074	0.688
SUP 24	I go back and forth in the text to find relationships among ideas in it.	2.26	0.991	2.41	0.888	0.608
GLOB 25	I check my understanding when I come across conflicting information.	3.16	1.068	3.30	0.953	0.647
GLOB 26	I try to guess what is about when I read.	2.58	1.017	2.67	1.000	0.773
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	3.79	0.855	3.96	0.759	0.472
SUP 28	I ask myself questions I like to have answered in the text.	2.26	0.933	2.19	1.039	0.795
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.63	1.012	2.26	0.984	0.218
PROB 30	I try to guess the meaning of unknown words or phrases.	3.21	1.316	2.89	0.751	0.298
GLOBAL	**Overall Global Reading Strategies**	**3.0891**	**0.63859**	**3.0256**	**0.62529**	**0.739**
SUP	**Overall Support Reading Strategies**	**2.3275**	**0.67125**	**2.6496**	**0.51992**	**0.077**
PROB	**Overall Problem Solving Reading Strategies**	**3.3819**	**0.46271**	**3.3819**	**0.49656**	**0.188**
OVERALL	**Overall MARSI score**	**2.9574**	**0.49663**	**2.9574**	**0.48559**	**0.492**

Table 3.10 (n = 46)
Differences in strategy use by male and female education majors

Name	Strategy	Male *M*	Male S.D.	Female *M*	Female S.D.	Sig.
GLOB 1	I have a purpose in mind when I read.	3.67	1.000	3.86	0.976	0.589
SUP 2	I take notes while reading to help me understand what I read.	2.67	1.000	2.70	1.127	0.930
GLOB 3	I think about what I know to help me understand what I read.	3.22	0.667	3.43	0.899	0.515
GLOB 4	I preview the text to see what it's about before reading it.	3.33	0.866	2.59	1.142	0.077
SUP 5	When the text becomes difficult, I read aloud to help me understand what I read.	3.22	0.833	3.51	1.146	0.478
SUP 6	I summarize what I read to reflect on important information in the text.	2.89	1.054	2.49	1.070	0.316
GLOB 7	I think about whether the content of the text fits my reading purpose.	3.00	0.707	2.68	1.082	0.399
PROB 8	I read slowly but carefully to be sure I understand what I'm reading.	3.11	0.928	3.68	0.915	0.105
SUP 9	I discuss what I read with others to check my understanding.	2.44	1.014	2.59	1.166	0.725
GLOB 10	I skim the text first by noting characteristics like length and organization.	3.33	0.707	2.89	1.329	0.343
PROB 11	I try to get back on track when I lose concentration.	3.67	1.000	3.95	0.815	0.382
SUP 12	I underline or circle information in the text to help me remember it.	3.78	1.093	3.78	0.917	0.987
PROB 13	I adjust my reading speed according to what I'm reading.	4.00	0.866	3.49	0.961	0.151
GLOB 14	I decide what to read closely and what to ignore.	3.33	0.866	3.22	1.058	0.760
SUP 15	I use reference materials such as dictionaries to help me understand what I read.	2.33	0.866	2.19	1.175	0.732
PROB 16	When text becomes difficult, I pay closer attention to what I'm reading.	3.67	0.866	3.84	0.866	0.598
GLOB 17	I use tables, figures, and pictures in text to increase my understanding.	3.22	1.394	3.58	0.841	0.323
PROB 18	I stop from time to time and think about what I'm reading.	3.11	1.054	3.24	1.011	0.729
GLOB 19	I use context clues to help me better understand what I'm reading.	3.22	1.202	3.24	0.830	0.951
SUP 20	I paraphrase (restate ideas in my own words) to better understand what I read.	3.56	0.726	2.92	1.164	0.126
PROB 21	I try to picture or visualize information to help remember what I read.	3.78	0.667	3.72	1.085	0.885
GLOB 22	I use typographical aids like bold face and italics to identify key information.	3.67	1.225	3.95	1.053	0.493
GLOB 23	I critically analyze and evaluate the information presented in the text.	3.00	0.707	2.76	0.760	0.388
SUP 24	I go back and forth in the text to find relationships among ideas in it.	3.11	0.782	2.65	0.919	0.172
GLOB 25	I check my understanding when I come across conflicting information.	3.22	0.667	3.22	0.821	0.984
GLOB 26	I try to guess what is about when I read.	3.33	1.225	2.62	1.037	0.081
PROB 27	When the text becomes difficult, I re-read to increase my understanding.	4.00	0.707	4.00	0.782	1.000
SUP 28	I ask myself questions I like to have answered in the text.	2.44	1.130	2.41	1.166	0.928
GLOB 29	I check to see if my guesses about the text are right or wrong.	2.89	1.054	2.32	0.915	0.114
PROB 30	I try to guess the meaning of unknown words or phrases.	3.22	0.833	3.08	1.256	0.751
GLOBAL	**Overall Global Reading Strategies**	**3.2650**	**0.34425**	**3.1068**	**0.46091**	**0.342**
SUP	**Overall Support Reading Strategies**	**2.9383**	**0.48785**	**2.8048**	**0.64492**	**0.565**
PROB	**Overall Problem Solving Reading Strategies**	**3.5694**	**0.41510**	**3.6354**	**0.44358**	**0.688**
OVERALL	**Overall MARSI score**	**3.2481**	**0.31540**	**3.1676**	**0.42522**	**0.599**

A chi-square test of significance was performed to determine the relationship between major and attitude (see Table 3.11). There was a significant difference in attitude among the different majors. The chi-square identifies science majors as least likely to have a negative attitude and most likely to have a positive attitude. Education majors are most likely to have a negative attitude and least likely to have a neutral or positive attitude, while undecided are most likely to have a neutral attitude.

Table 3.11 (n = 162)
Chi-square of major and attitude toward reading biology

Major		Negative	Neutral	Positive	*M* attitude	S.D.
Science	Count	25	15	45	6.25	2.760
	Adjusted Residual	-3.1	0.6	2.6		
Education	Count	14	1	5	3.90	2.594
	Adjusted Residual	2.8	-1.4	-1.8		
Business	Count	10	4	6	4.40	2.945
	Adjusted Residual	0.9	0.5	-1.3		
Humanities	Count	10	1	10	5.38	2.854
	Adjusted Residual	0.7	-1.5	0.4		
Undecided	Count	7	5	4	5.06	2.294
	Adjusted Residual	0.3	1.7	-1.5		
total		66	26	70	5.50	2.842

Question 4: Does explicit instruction in using metacognitive strategies improve student attitude toward reading their biology text?

Three students not receiving instruction had slight variations in their initial attitude toward reading the biology text. Becky, a 19-year old student, scored in the medium range on all subscales of the MARSI inventory and demonstrated a negative attitude toward reading at the outset of the study. On the attitude survey she stated that reading her biology text made her feel bad. She reported that while reading her attention would drift and after re-reading a section more than once she became frustrated if she did not understand. At this point Becky would try again, but her difficulties with reading the text resulted in her equating reading the biology text with torture.

Sarah, an18-year old freshman Athletic training major, scored in the medium range on all three subscales of the MARSI inventory. On the attitude survey, she reported having a neutral attitude toward reading her biology text. She did not like reading, but was comfortable with the text. Despite this, Sarah did not feel like she was learning from the text. Her attention also drifted while reading and not understanding after re-reading a section would also frustrate her. However, overall Sarah stated that the reading was informative.

Emma, an 18-year old freshman biochemistry and molecular biology major, scored high on the Global subscale, but medium on the other subscales. On the attitude survey she also demonstrated a negative attitude. Reading her biology textbook also made her feel bad and when confronted with reading problems she would quit reading instead of trying again or trying another approach. Emma also indicated that she avoided reading her textbook whenever possible.

After four weeks of reading, Becky and Emma reported a change in their attitude toward reading the text, while Sarah reported no change in her attitude. When asked "How do you feel about reading every week?" Becky said "I don't dread the reading anymore, but don't necessarily look forward to it either." She also reported a new feeling of satisfaction. She said "[After reading] I feel better. Like I've done something." She added "I think I try to go back and understand things more now." When asked the same question, Emma reported that she felt differently about the readings and said "I feel different now…I understand what I read better." She suggested that the post-reading questions influenced her attitude shift, "the questions after reading help me figure out what I don't understand."

Students receiving instruction began the study with a wider range of attitudes and demonstrated different levels of engagement with the strategies. Jessica, a 19-year old Applied Health freshman, scored within the medium range overall and on the Global and Problem-Solving subscales, but scored low on the Support subscale. On the attitude survey, Jessica indicated that she did not like reading her biology textbook and that it took more time than the texts for her other classes. Additionally, when she read she felt frustrated and like she was not learning. Overall she equated reading her text as torture. Jessica was selectively engaged during the reading strategy instruction and practice. She did not like the KWL charts and did not complete them. When stopping periodically during the reading, Jessica answered the provided questions, but did not generate any questions of her own. When asked to diagram the information in the text, Jessica drew a diagram that illustrated multiple relationships between ideas. During the fifth week, Jessica chose to use summary writing as her strategy of choice. Her strategies, however, consisted of terms, definitions, and single statements. She did not identify a main idea or connect any ideas.

Roy, an older student, also began the study with a negative attitude. Roy scored within the low range overall and on the Support subscale, and scored within the medium range on the Global and Problem-Solving subscales of the MARSI inventory. On the attitude survey he indicated that knowing he has to read for biology makes him feel bad and that while he is reading he feels miserable. Roy avoided reading when he could. Although he felt like he learned, his attention drifted while he was reading and when he encountered problems reading he would quit reading. Roy remained fairly unengaged during the strategy instruction and practice. When stopping periodically to think about what he read, he answered the provided questions with incomplete sentences and did not generate any questions on his own. He also preferred to summarize what he had read, but like Jessica, his summaries lacked main ideas and consisted of nothing more than definitions.

Renee, an 18-year old student, reported a neutral attitude on the attitude survey. Renee scored within the high range on the MARSI inventory overall and the Global and Problem-Solving subscales and in the medium range on the Support subscale. In regards to reading for her biology class, Renee said it took a lot longer than her other classes and she avoided doing it when she could. At the same time, she feels like she learns from reading and after two readings of her text feels encouraged, not frustrated. Overall, she finds the reading informative. Renee remained engaged with the reading strategies during instruction and practice. She completed the KWL, and when stopping periodically during the reading she answered the questions in complete sentences. Her answers illustrated connections between different ideas and generated several questions on her own. She generated both low level (What is a B cell?) and high thinking level questions (How do B and T cells correspond to one another?).

Vicky, a 19-year old elementary education major, scored low on the MARSI inventory overall, and the Global and Support subscales. She scored in the medium range on the Problem-Solving subscale. On the attitude survey Vicky demonstrated a neutral attitude toward reading her text. She indicated that reading the text made her feel miserable and frustrated. Her attention drifted while she read, but she would try confusing passages again. Although she did not like to read the text, overall she found it informative. Vicky also remained engaged during instruction and practice. When Vicky stopped periodically to think about the reading, she answered the questions in complete sentences and generated several low level questions. She also attempted to create her own concept map showing the similarities and differences of mitosis and meiosis.

Amy, a 19-year old pre-veterinary freshman, scored in the medium range overall and the Global subscale and low on the Support subscale, and high on the Problem-Solving subscale. On the attitude survey Amy indicates a positive attitude toward reading the text. Although knowing she had to read for the class made her feel bad, she was comfortable with the text and felt that she learned from it. Even though her attention drifted, she tried confusing passages more than once. Amy was relatively unengaged during instruction and practice. She did not complete the KWL or create a concept map. When answering questions during the reading, she used incomplete sentences, and did not generate any of her own questions.

Phillip, a 22-year old physical therapy sophomore, scored high on all aspects of the MARSI inventory. Phillip also demonstrated a positive attitude on the attitude survey. Knowing he needed to read for class left him feeling good and he was comfortable with the text. Occasionally he felt slowed down, but overall he felt he learned and that the text was informative. Phillip was slightly more engaged than Amy. He completed the KWL, but did not generate any of his own questions during the reading. He created a concept map illustrating the processes of mitosis and meiosis.

Kelly, a 22-year old psychology junior, also scored high on all aspects of the MARSI inventory. Unlike Phillip, Kelly demonstrated a negative attitude toward reading the text. She indicated that the biology text took a lot longer compared to her other texts and that she avoided reading when she could. While reading, her attention would drift and she would feel frustrated. Kelly remained engaged during the instruction and practice. She completed the KWL and answered questions in complete sentences. She generated several low-level questions and attempted a concept map.

During the Week Five interview, students expressed a variety of responses to using the reading strategies. Amy and Phillip, the two students with initially positive attitudes, maintained their positive attitudes throughout the instruction and practice. Phillip, referring to the questions after each reading stated that he understood “a lot better when I read the questions, then do the reading and answer the questions.” Amy felt the questions provided during the reading were most helpful. She said “Questions during reading definitely help…I usually just read to get through, but the [questions] help me to go back and make sure I understand.” When asked if she would use these strategies for other classes Amy responded that she would “if it is class where I really had to read the stuff to know it.”

Renee and Vicky both expressed neutral attitudes at the study outset. After four weeks of strategy practice they both felt the strategies were helpful. At the beginning of the study, Vicky felt that the post-reading questions were unrelated to the readings. During the fifth week interview, Vicky acknowledged that the readings and questions seemed more aligned. In regard to using the strategies Vicky said “I feel like I learned something. [The strategies make me use the information right away …I feel better about reading …I am more aware of what I read.” Renee said “I know [the strategies] are helping me to read, but I don’t enjoy it…Sometimes I read and don’t understand, this helps me get the information…Sometimes [when I read] I assume that I know, now I re-read.”

Kelly, Roy, and Jessica all began the study with negative attitudes toward reading their text. After four weeks, Roy and Jessica still had their negative attitudes, but Kelly experienced a positive shift. During the interview Roy stated “I just don’t figure stuff out reading. [The strategies] are just more work." However, Roy did say that he would use the strategies for his physics and chemistry classes – ones he enjoyed more than biology. When asked how she felt about reading the text, Jessica said that she didn't get anything out of it, "they talk in almost a foreign language." Jessica did say that she practiced the strategies with her chemistry text and "it helps... [the strategies] make me stop and think about what I've read." Kelly was the only student with a negative attitude that experienced a positive shift in attitude. During the interview she said "I like [using the strategies]. It gives me a lot of ways to look at books I don't understand…I don't feel so overwhelmed."

Many of the students reported the use of questions throughout the reading as the strategy they liked most and found most helpful, yet during weeks five through eight when students could choose the strategy they would use while they read, students primarily chose to summarize the readings. All of the students had problems writing summaries of the material. None of the students identified main ideas in the text or connected ideas from different parts of the reading. Five of the seven students using paraphrasing as their strategy of choice listed definitions and/or incomplete phrases. Only two students organized their thoughts into complete sentences and addressed the entire reading.

CHAPTER V

DISCUSSION

Summary

The purpose of this study was to identify the reading strategies used by college biology students when reading their biology text for information. Four hundred-thirty students enrolled in Introductory Biology completed the Metacognitive Awareness of Reading Strategies Inventory (MARSI) to measure their reported use of reading strategies. Ten students participated in the eight-week, qualitative portion of the study and were assigned to either receive instruction or not receive instruction. Students assigned to receive instruction were taught six reading strategies over the course of three weeks. Instruction consisted of an explanation of the strategy, demonstration of the strategy, guided practice, and application of the strategy. Both groups read sections of their biology text and answered questions based on the readings. After five weeks, students in both groups were interviewed about their feelings towards reading biology and whether their feelings changed. Students in both groups reported a positive change in attitude, but this change was associated with a prior value placed on reading.

Findings

The results of this study revealed six findings that are worthy of discussion. These findings are summarized below.

1. Introductory Biology students combined average score fell within the medium range on the Overall MARSI inventory (3.11), Overall Global subscale (3.11), and Overall Support subscale (2.68), and these students scored within the high range on the Problem-Solving subscale (3.56). The five most used strategies were either Global or Problem-Solving strategies and the five least used strategies were all Support strategies. As MARSI inventory score increased, attitude toward reading biology became more positive.

2. Good readers scored significantly higher than Fair/Poor readers on Overall MARSI inventory ($P<0.001$), Global subscale ($P<0.000$), and Problem-Solving subscale ($P<0.011$). Good and Fair/Poor readers did not have significantly different scores on the Support subscale. Males and females did not have significantly different scores on the Overall MARSI inventory, Overall Global, or Overall Problem-Solving subscales, but females scored significantly higher than males on the Overall Support subscale ($P<.000$).

3. When looked at by major, science majors were most likely to have positive attitudes toward reading the biology text, while education majors were most likely to have negative attitudes. Undecided majors were most likely to have neutral attitudes.

4. Education majors were most likely to score within the Medium range of the Overall MARSI inventory, while Undecided majors were most likely to score either high or low. Other majors were distributed across the low, medium, and high ranges. No significant differences in strategy use were found among different majors; however, science students were more likely to pay more attention to reading when comprehension becomes difficult and humanities students were more likely to critically examine and analyze information in the text.

5. Students both receiving and not receiving strategy instruction reported a positive change in attitude toward reading biology; however, students with a neutral attitude were more likely to have positive shifts in attitude than students with negative attitudes.

6. When asked which strategy they found most helpful, students receiving instruction identified “asking questions throughout the reading” as the most useful strategy; however, when left to choose a reading strategy, none of the students generated their own questions during reading.

The results of the MARSI inventory suggest that among Introductory Biology students, college freshmen are somewhat skilled in using reading strategies. The students rely primarily on Problem-Solving strategies and less so on Global strategies and least on Support strategies. The Problem-Solving strategies are actions that the reader engages in when comprehension difficulties arise during reading. Global strategies are actions the reader engages in before reading to prepare for reading. Support strategies are actions readers take to monitor their comprehension and resolve comprehension problems before comprehension fails. The reliance on Problem-Solving strategies suggests that students possess an awareness of comprehension difficulties and use a variety of methods to resolve these problems. The lower Global score suggests that students do not put as much thought into reading before they read as they do into problems that arise while reading. The low Support score suggests that students do not consistently use reference materials to assist in reading comprehension. The result is that students spend the majority of their time correcting comprehension problems without taking measures to prevent them. This is supported by the five most and least used strategies. Of the five most used strategies, the top three were all Problem-Solving strategies and the other two were Global strategies. The five least used were Support strategies. Of the top fifteen strategies used, only two were Support strategies.

A weak positive correlation was found between reading strategy usage and attitude toward reading biology texts. Due to the difficult nature of science texts, many students have negative attitudes about reading science texts. Their attitudes may result from repeated difficulties reading science text. Many students in the study reported trouble maintaining focus on the text and relating what they read to what they know. This leads students to view reading science text as irrelevant and unproductive. The students in this study averaged a neutral to slightly positive attitude toward reading their text. Their attitudes correspond to the medium scores on the MARSI inventory. This relationship indicates that as students use more strategies to monitor and improve their comprehension their attitude toward reading science material improves. Considering that most science classes currently rely heavily on text reading, the use of reading strategies is an important tool to increase the amount of time students are willing to spend reading their text.

When comparing Good and Fair/Poor readers' use of strategies, it is not surprising that Good readers score higher than Fair/Poor readers, suggesting they use more strategies while reading. Good readers scored higher overall and on each subscale than Fair/Poor readers. Their scores mirrored those of the entire sample. The Overall MARSI inventory score, Global score, and Support score fell within the medium range (2.5 – 3.4). Only the score on the Problem-Solving subscale was within the high range (> 3.5). This indicates that Good readers use a wider variety of strategies more frequently than their Fair/Poor counterparts. It is surprising, however, that they are not out-strategizing Fair/Poor readers completely. The Overall MARSI inventory, Global, Problem-Solving, and Support scores of Fair/Poor readers also fell within the average range (2.4 – 3.4). While the differences between the Good and Fair/Poor readers were significantly different, they were not differences between high and low scores, but instead the higher and lower ends of the average range. It is also surprising that there is no statistically significant difference between the Support scale scores of Good and Fair/Poor readers. This suggests that while Good readers are using more strategies, they are using Global and Problem-Solving strategies more and not Support strategies. Among Good readers, there are differences between subscale scores indicating a preference For Problem-Solving, followed by Global and Support strategies. This distinction between strategies also appears in the scores of Fair/Poor readers. Poor readers also rely heavily on Problem-Solving strategies, while using Global and Support strategies infrequently.

The only statistically significant difference found between male and female students was in the use of Support strategies. Females scored higher on the Support subscale than males, indicating that they use more Support strategies than males. This finding is similar to that of Virpi (2001). In that study, female students indicated using different types of reading and study strategies than males. The finding that females use more Support strategies than males contributes to current research that indicates females have better reading comprehension than males (Slotte, Lonka & Lindblom-Ylanne, 2001; Spence, 1995). Their increased use of Support strategies suggests that they would not benefit as much from text structure instruction or metacognitive strategy instruction that focuses on using outside references or textual aids.

When comparing the MARSI inventory scores of different majors, no significant differences were found. However, differences between the different majors did become apparent when scores within each major were grouped as high, medium, or low. When examining the strategy use of different majors, most majors had large score variations. Students identifying themselves within a specific major had MARSI inventory scores that ranged from low to high. The exception to this was Education. The majority of these students scored within the average range. This indicates that Education majors as a group are more consistently using reading strategies than other majors. One reason for this may be related to their choice of major. Students with positive reading experiences may be more likely to become teachers than students who do not have positive reading experiences. Another possible reason for this might be the type of classes they take. Education majors are more likely than other majors to focus on how learning takes place and how to foster good reading and study skills in their future students. This knowledge may translate into their studies. Other majors without this focus would experience a larger range of scores. At the other end of the spectrum, Undecided majors were grouped within the low and high ranges with fewer students falling in the middle. This could be due to a wider range of interest and ability among students who have not yet declared a major.

While there were no significant differences between different majors, there were significant differences between the uses of individual strategies. When text becomes difficult, science students, more than other majors, pay closer attention to what they are reading. This is interesting, but not entirely surprising since science texts are often poorly written, making them difficult to read and comprehend. Their increased exposure to difficult texts gives science students more opportunity to identify and practice using this strategy. It is surprising that this is the only strategy that science students use more frequently, simply because of the recognized difficulty of science texts. It would be expected that students who are exposed to difficult reading material would develop a variety of strategies to cope with comprehension problems. This lack of strategy development could be a result of not explicitly teaching reading strategies during reading instruction and implies that reading strategy skills are not innately developed in response to difficult texts. Another surprising find was that Humanities students were more likely to critically analyze and evaluate information in the text. One possible explanation for this may be the perceived subjective nature of humanities. Students majoring in a humanities discipline investigate areas of interest with smaller bodies of perceived objective knowledge. In opposition, many students perceive science through a lens of objectivity. Viewing science with this perspective would tempt students to accept scientific information as fact, without critically examining it. This finding is particularly interesting due to the increased emphasis on critical thinking skills outlined in the National Science Education Standards. This result suggests that despite the push for scientific literacy, many science classrooms still perpetuate the student belief that science is a collection of facts to be memorized, not questioned. This could be explained by the gap between instructor and student goals, however the results of this study suggests that students need instruction on how to critically analyze what they read. Without critical analysis, science students will not met the national goal of scientific literacy.

Science students were found to have the most positive attitude toward reading biology texts, while Education students had the most negative attitude. The positive attitude reported by science students is expected simply because they chose to pursue an education in science. This implies that they have an increased interest in the material and are more likely to enjoy this type of reading. The negative attitude reported by education students is surprising based on their MARSI inventory scores. As the group most likely to score average on the MARSI inventory, it would be expected that these students would be likely to have a neutral attitude. However, their negative attitude combined with their medium score on the MARSI inventory suggests that unlike most students with negative attitudes, education students place a value on reading and will practice using strategies that will help them understand what they read even if they do not enjoy the material. This can be credited to the current emphasis on reading in public school curriculum, and subsequently, in teacher preparation programs. While many students view reading as merely decoding words, perhaps education majors, as future teachers, see the role reading plays in learning and hold different expectations regarding what reading involves. From this, it can be speculated that education students are aware of reading as an active process rather than a passive experience.

While reading strategy use improves attitude toward reading biology, results from the case studies suggest that reading itself can improve attitude. Two of the three students not receiving instruction reported a positive shift in attitude. This indicates that simply practicing reading science text will have an effect on students' approach to reading. However, just practicing does not seem to be as effective in changing student attitudes toward reading as using reading strategies. Of the seven students receiving instruction, two students maintained a positive attitude toward reading, three students reported a positive shift in attitude, and two students reported no change in attitude. In addition, the study's drop-out rate demonstrates that practice is not enough. When the study began, both groups consisted of ten students. During the first five weeks of the study, the instruction group lost three students, whereas the non-instruction group lost seven. This would indicate that students in the instruction group were receiving a benefit that encouraged their continued participation, while students in the non-instruction group were not.

Differences in attitude shift between the two groups and among students within those groups can be attributed to students' perception of the value of reading. Further examination of the responses on the attitude survey, revealed that all three students in the non-instruction group appeared to disregard reading as a means of obtaining information about biology. The description of their feelings about reading included "bad," "miserable," "frustrated," and "torture." All three students indicated that they did not feel reading their text was informative and indicated that when confronted with difficult passages in the text, they felt frustrated and would quit reading instead of trying to read the passage again.

Students in the instruction group initially reported a wider range of attitude toward reading and students fell into one of four groups; Positive attitude, Neutral attitude/Values reading, Negative attitude/Values reading, and Negative attitude/No Value reading. The positive group consisted of Phillip and Amy. They both felt comfortable reading, saw reading their text as informative, and when confronted with difficult passages were willing to try to read them again. Renee and Vicky made up the Neutral/Value group and reported a neutral score on the attitude survey. They did not enjoy or look forward to reading, but when they did, they felt they had learned. They saw their text readings as informative and when confronted with difficult passages were willing to try again. Kelly demonstrated a Negative-Value approach to reading. She scored negatively on the attitude survey, reporting that she did not like reading for biology and when she read they felt she did not learn, but reported that her textbook readings were informative and when confronted with difficult passages, she would try to read the passage again. Jessica and Roy composed the Negative/No Value group and scored negatively on the attitude survey, indicating that they did not like to read and when they did read they felt that they did not learn. They also reported that their text reading was not informative and when faced with a difficult passage they would quit reading.

Of the students in the experimental group, only the students demonstrating a value for reading reported positive shifts in attitude. Students that were identified as No Value did not experience an attitude change. When practicing strategies there were differences in the level of engagement between students who believed reading was valuable and those who did not. Students who valued reading answered questions more thoroughly, providing more than one word answers. They also attempted to design the concept map, and create questions from the reading. Students who felt that reading is not valuable are not likely to expend much time practicing the strategies. These students typically supplied one word answers to questions, did not attempt the concept map, and did not create questions from the reading. With minimal engagement, students continue to experience reading as a passive activity and do not benefit from strategy usage. This suggests that attitude toward reading can be improved using strategies as long as students feel that reading is worthwhile. This also suggests that motivation and student interest plays a large role in reading comprehension.

During the last four weeks of the study, students in the experimental group were asked to choose the strategy / strategies they liked using most and practice them with the new readings. All students in the experimental group identified the use of questions throughout the reading as the strategy they liked most during the Week Five interview. However, none of the students in the experimental group chose to use this strategy during the last four weeks. Instead, all students indicated that they would paraphrase the reading. When paraphrasing, most students only wrote definitions to unknown or bolded words. Only two students wrote complete sentences and addressed each section of the reading. These students also included terms and definitions. This suggests two things, first that they placed importance on unfamiliar words or words that were identified by the publisher as important, and second, when left to practice summarizing on their own most students fell back into familiar student roles, relying on bolded words and definitions. Both support the results of studies on student problems with summary writing.

Implications

The results of this study provide several implications for reading instruction and teaching science. Students participating in the study used a narrow range of reading strategies while reading their biology text. While students overall scored in the medium range on the MARSI inventory (2.5-3.4), they scored lower on the Support subscale than the Global or Problem-Solving subscale. This implies that college freshmen and sophomores are using some strategies to help them understand what they read, but need more instruction using Support strategies that will help them avoid comprehension problems. To correct this, reading instruction should include reading comprehension strategies, especially Support strategies. Since repeated experiences with comprehension difficulties lead to a diminished value of reading, reading strategies should be taught during elementary reading instruction and reinforced in content area classes through secondary and post-secondary education programs.

The results also indicate that reading comprehension strategies should not be confined to reading classes. Students in science classes need guidance in using their textbook. This study indicates that even minimal instruction in using reading strategies results in a positive attitude shift. These students also found that reading became easier after practicing the strategies and the students using the strategies had a lower drop-out rate than the group of students not using strategies. This implies that science classes that emphasize learning from texts need to spend time practicing comprehension strategies. This would assist students in using their text more easily and efficiently. Discussing strategies in science classes would also help prevent students from becoming too frustrated by text readings and disregarding them all together.

The decision of students participating in the study not to use questions as a reading strategy for the last four weeks is intriguing and hints at a larger problem in science education. When receiving guided instruction using questions, many students were unable to design their own questions and perhaps as a result chose not to practice this strategy on their own during the last four weeks. One aspect of critical thinking that should be encouraged in science education is the formulation of questions. Familiarity with generating and posing questions might help students engage in what they read, rather than passively taking in the words on the page.

Conclusions

College freshmen and sophomores practice reading comprehension strategies while reading their biology text, but not as frequently as expected, and they rely primarily on problem-solving strategies. This is problematic for students in science classes that rely heavily on learning from textbooks. As a result, science texts are generally viewed as difficult to read. To help students use their texts effectively, science classes must also become reading classes and teach reading comprehension strategies that assist students reading science texts. Helping students manage comprehension problems while reading science texts results in a more positive attitude toward reading science text. With a positive attitude toward reading, these students are more likely to attempt readings than students not using comprehension strategies.

Recommendations for Future Research

The limitations of this study leave several areas open to future research. Of highest interest is the relationship between reading comprehension strategies and conceptual understanding and application. Due to the high drop-out rate among students in the control group, this study was unable to determine whether practicing comprehension strategies improves student understanding of material and subsequently their ability to apply the information to novel circumstances.

The qualitative portion of this study was limited in the number of students participating and the amount of time each student received instruction. Students in this study received minimal instruction, 30-45 minutes a week, using the reading strategies. It would be interesting to explore the outcome of more frequent strategy practice and its affect on student attitude and achievement.

Also, the differences between majors and class rank could be investigated in more detail. It would be helpful to know whether students approach reading for other classes the same way they approach reading for biology. In addition, college juniors and seniors may use different strategies for monitoring comprehension than freshmen and sophomores. As more experienced students, upperclassmen may use more strategies than freshmen and sophomores, who may still be adjusting to the increased demands of college and learning the most effective ways to tackle their studies.

The effect of teaching reading comprehension to middle school science students would be of interest to science educators. According to Yore, Craig, and Maguire (1993), teaching strategy use is most effective with students at this level. Teaching these students to monitor their comprehension and solve comprehension problems could help maintain their interest in science.

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APPENDIX A

Student Majors by Category

Science
Allied Health
Animal Science
Athletic Training
Biochemistry
Biology
Biomechanical Engineering
Botany
Cell Biology
Chemical Engineering
Chemistry
Civil Engineering
Dentistry
Engineering
Entomology
Environmental Science
Forestry
Geology
Health Promotions
Horticulture
Math
Mechanical Engineering
Microbiology
Nursing
Nutritional Science
Physics
Physiology
Pre Medical
Pre Pharmacy
Pre Veterinary
Radiology
Turf Mangement
Wildlife Ecology
Zoology

Humanities
Speech Pathology
Sociology
Art
English
Human Development and Family Science
Journalism
Psychology
Broadcast Journalism
Theater
Leisure Services
Graphic Design
Music
History
Political Science
Foreign Languages
Interior Design

Education
Elementary Education
Early Childhood Education
Secondary Education
Physical Education
Agriculture Education

Business
Agricuture Communications
Accounting
Public Relations
Computer Science
Business
Agriculture Business
Marketing
Advertising
Economics
Hotel/Resteraunt Administration

APPENDIX B

Strategies Included in the MARSI inventory

Global Strategies	
1	I have a purpose in mind when I read.
3	I think about what I know to help me understand what I read.
4	I preview the text to see what it's about before reading it.
7	I think about whether the content of the text fits my reading purpose.
10	I skim the text first by noting characteristics like length and organization.
14	I decide what to read closely and what to ignore.
17	I use tables, figures, and pictures in text to to increase my understanding.
19	I use context clues to help me better understand what I'm reading.
22	I typographical aids like bold face and italics to identify key information.
23	I critically analyze and evaluate the information presented in the text.
25	I check my understanding when I come across conflicting information.
26	I try to guess what the material is about when I read.
29	I check to see if my guesses about the text are right or wrong.

Problem-Solving Strategies	
8	I read slowly but carefully to be sure I understand what I'm reading.
11	I try to get back on track when I lose concentration.
13	I adjust my reading speed according to what I'm reading.
16	When the text becomes difficult, I pay closer attention to what I'm reading.
18	I stop from time to time and think about what I'm reading.
21	I try to picture or visualize information to help remember what I read.
27	When the text becomes difficult, I re-read to increase my understanding.
30	I try to guess the meaning of unknown words or phrases.

Support Strategies	
2	I take notes while reading to help me understand what I read.
5	When text becomes difficult, I read aloud to help me understand what I read.
6	I summarize what I read to reflect on important information in the text.
9	I discuss what I read with others to check my understanding.
12	I underline or circle information in the text to help me remember it.
15	I use reference materials such as dictionaries to help me understand what I read.
20	I paraphrase (restate ideas in my own words) to better understand what I read.
24	I go back and forth in the text to find relationships among ideas in it.
28	I ask myself questions I like to have answered in the text.

Taken from the Metacognitive Awareness of Reading Strategies Inventory (Mokhtari & Reichard, 2002)

APPENDIX C

Attitude Survey

I consider myself a GOOD READER FAIR READER POOR READER

1. When I have reading for INTRODUCTORY BIOLOGY I feel:
   GOOD BAD

2. Compared with reading in my non-science courses, the time that I allow for reading INTRODUCTORY BIOLOGY is :
   A LOT LONGER ABOUT THE SAME

3. When I read for INTRODUCTORY BIOLOGY, I feel:
   COMFORTABLE MISERABLE

4. If I'm reading INTRODUCTORY BIOLOGY and another INTRODUCTORY BIOLOGY student calls, I'm eager to talk so that I can:
   AVOID READING SHARE NEW INFO

5. Reading for INTRODUCTORY BIOLOGY leaves me feeling like a have:
   LEARNED NOT LEARNED

6. If I don't understand a passage when reading INTRODUCTORY BIOLOGY, I feel:
   SLOWED DOWN ANGRY

7. While reading INTRODUCTORY BIOLOGY, my attention:
   DRIFTS FROM TEXTS STICKS TO TASKS

8. After two readings of a section in my INTRODUCTORY BIOLOGY text, I feel:
   FRUSTRATED ENCOURAGED

9. If I didn't understand a passage, I:
   TRY AGAIN QUIT READING IT

10. My idea of reading INTRODUCTORY BIOLOGY is a process that's:
    TORTURE INFORMATIVE

APPENDIX D

Sample Text Passage Taken From Life, 4th Ed. (Lewis, 2002)

A food chain can be described as consisting of levels. An organism's **trophic level** is its position in the food chain, relative to the ecosystem's energy source. **Primary producers,** or **autotrophs** ("self-feeders"), form the first link in the food chain and the base of the trophic structure. Primary producers ultimately provide energy for all other organisms; they use inorganic materials and energy to produce all the organic material they require. Familiar primary producers include plants and algae, but many prokaryotes are primary producers, too, deriving energy from the sun or inorganic chemicals.

The other levels in a food chain are **consumers,** or **heterotrophs** ("other eaters"), which obtain energy from the producers. Herbivores (plant-eaters) are primary consumers and form the second trophic level. Carnivores (meat-eaters) that eat herbivores are secondary consumers. Carnivores that eat other carnivores form a fourth trophic level; they are tertiary consumers. These animals expend a great deal of energy capturing their prey. Scavengers, such as vultures, eat remains of another's meal, and **decomposers,** such as certain fungi, bacteria, insects, and worms, break down **detritus** (dead organisms and feces).

Food chains interconnect, forming complex **food webs,** such as the Antarctic web in **figure 43.10.** Webs form when one species eats or is eaten by several other species and when one species functions at more than one trophic level. As Investigating Life 43.1 on p. 863 describes, food webs can unravel if keystone species die out.

Ecological Pyramids Describe Ecosystem Characteristics

The total amount of energy that is trapped, or "fixed," by all autotrophs in an ecosystem is called gross primary production. However, the autotrophs use some of this energy to generate ATP for their own needs. **Net primary productivity** is the amount of energy left over after respiration by the autotrophs; it is the amount of energy that is available to consumers.

Consumers cannot completely digest all the food they eat; they also lose energy to heat. (The second law of thermodynamics, described in section 5.2, explains this process.) Because of these inefficiencies, only about 2 to 30% of the potential energy stored in the bonds of organic molecules at one trophic level fuels growth and reproduction of organisms at the next trophic level (**figure 43.11**). If a food chain consists of four organisms—such as a cat eating a bird that has eaten a beetle, which ate a tomato leaf—the cat can only use a tiny fraction of the energy in the leaf for its growth and development. This inefficiency of energy transfer is why food chains rarely extend beyond four trophic levels. One way to maximize energy obtained from producers is to lower the number of trophic levels. A person can do this by getting protein from beans and grains instead of meat.

If each trophic level is represented by a volume directly proportional to the energy stored in new tissues per unit time, these volumes can be stacked to form a steep-sided **pyramid of energy** (see figure 43.11). Consider a simplified example. In Cayuga Lake in New York, algae store 1,500 kilocalories of energy in a period of time. The algae feed small aquatic animals, which store about 150 kilocalories as new tissues. When a smelt fish eats these small aquatic animals, it derives perhaps 15 kilocalories for growth and development. A human eating the smelt would convert only about 1.5 kilocalories of the original 1,500 kilocalories to new growth.

Other types of pyramids describe other aspects of ecosystems. A **pyramid of numbers** shows the number of organisms at each trophic level. The shape of this type of pyramid reflects the size and number of the producers and consumers. The pyramid of numbers in a grassland community has a broad base because the producers—grasses—are small and numerous (**figure 43.12A**). In

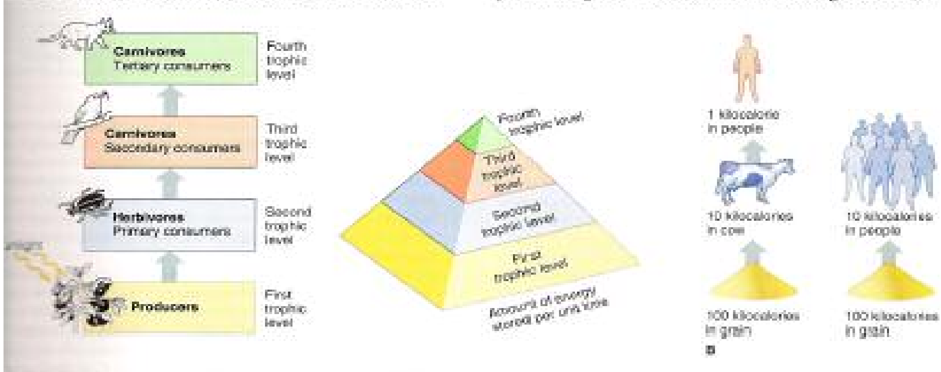
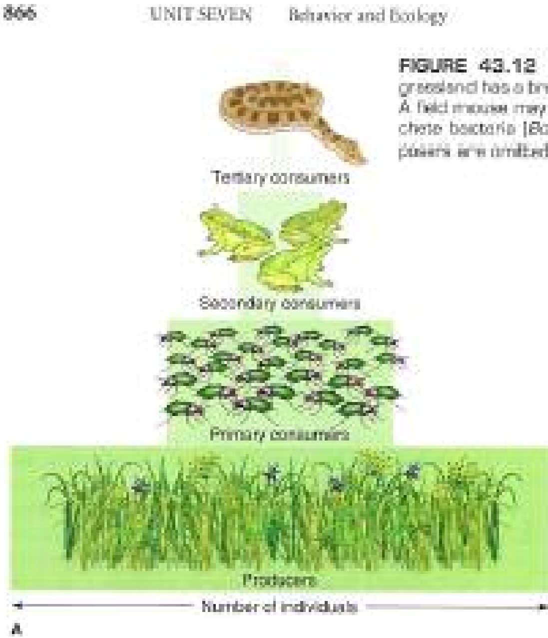


FIGURE 43.11 **Energy Flow Through an Ecosystem.** (A) The cat eats the bird that eats the beetle that eats the tomato plant. The pyramid of energy shows that only a small percentage of the energy stored at one trophic level per unit time is transferred and stored in new growth and reproduction at the next level. Decomposers are omitted in this figure. (B) Humans who derive energy by eating meat are getting only a small fraction of the energy originally present in grain. The example shown assumes an average of 10% of the energy in any trophic level is available to the next. In reality, the value varies from about 2 to 30%, depending on the food source and the consumer.

43.13



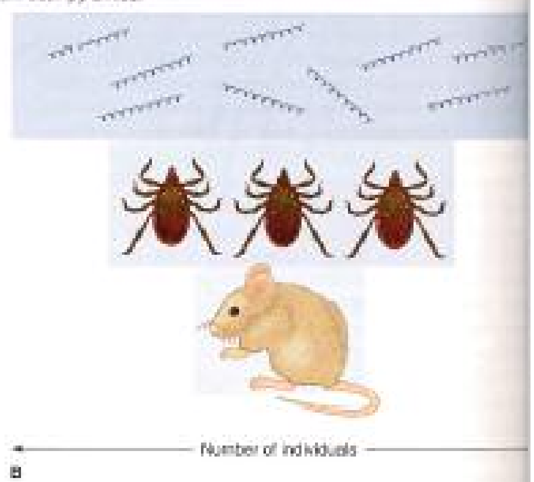


FIGURE 43.12 **Pyramids of Numbers.** (A) A pyramid of numbers that represent grassland has a broad base. (B) Parasitic organisms illustrate an inverted pyramid of numb A field mouse may carry several deer ticks in its fur, which, in turn, each harbor many s chete bacteria (*Borrelia burgdorferi*). The bacteria cause Lyme disease in humans. De posers are omitted from both pyramids.

a forest, in contrast, the pyramid of numbers stands on a very narrow base, because a single tree can feed many herbivores. Such an inverted pyramid can also represent a single animal that supports a large number of parasites, such as the field mouse and its ticks depicted in figure 43.12B.

A **pyramid of biomass** takes into account the weight of organisms at different trophic levels. **Biomass** is the total dry weight of organisms in an area at a given time. Many pyramids of biomass are wide at the bottom and narrow at the top because energy is lost as heat at each trophic level. In some aquatic ecosystems, however, the pyramid is inverted because the biomass of the primary producers (phytoplankton) is smaller than that of the primary consumers (zooplankton). This is because biomass is measured at one time. Phytoplankton reproduce quickly, but zooplankton eat them almost immediately, so few are present at any given time. In contrast, zooplankton live longer, so more of them are present at one time. If we consider the biomass of all the phytoplankton that zooplankton consume during their life span, the pyramid would be upright.

43.3 Mastering Concepts

1. How do ecosystems range in size?
2. Identify the types of organisms that form trophic levels.
3. Distinguish between gross and net primary production.
4. How efficient is energy transfer between trophic levels in food webs?
5. List three types of pyramids that are used to describe ecosystems.

43.4 How Chemicals Cycle Within Ecosystems—Biogeochemical Cycles

Biogeochemical cycles describe how elements move between organis and the physical environment. Elements from the environment ascend food webs and return to the physical environment when an organism decomposes. Some chemicals are concentrated as they ascend food we with toxic effects.

All life, through all time, must use the elements present w Earth formed. These elements continuously recycle through interactions of organisms and their environments. If not for t constant recycling, these elements would have been depleted they became bound in the bodies of organisms that lived e ago. Because recycling chemicals essential to life involves b geological and biological processes, these pathways are cal **biogeochemical cycles.**

Each chemical element in an ecosystem has a characteri biogeochemical cycle, but all cycles have steps in common. Ge erally, an inorganic form of the element is taken from the en ronment and incorporated into the organic molecules autotrophic organisms, such as plants. If an animal eats the pla the element may become part of animal tissue. If another ani eats this animal, the element may be incorporated into the s ond animal's body. All organisms die, and decomposers br their tissues down, which releases the elements back into t environment in inorganic form.

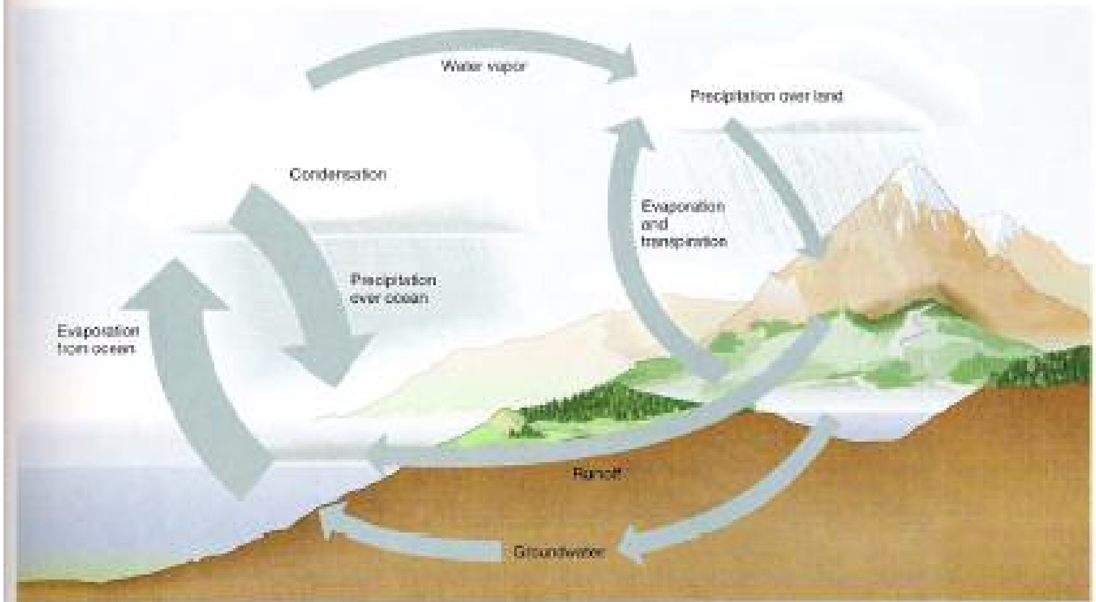


FIGURE 43.13 **The Water Cycle.** Water falls to Earth as precipitation. Organisms use some water, and the remainder evaporates, runs off into streams, or enters the ground. Animals return water to the environment by respiring and excreting, and plants do so by transpiring.

The Water Cycle

Water covers much of Earth's surface, primarily as oceans but also as lakes, rivers, streams, ponds, swamps, snow, and ice. Water is also below the land surface as groundwater. The ability of water to exist in all three states of matter—solid (ice), liquid, and gas (vapor)—in the temperature range of the biosphere allows it to cycle efficiently from Earth's surface to the atmosphere and back again (**figure 43.13**).

The sun's heat evaporates water. Plants absorb water from soil, use it, and release some of it from their leaves in transpiration. Animals return water to the environment through evaporation and excretion. Water vapor may rise on warm air currents, cooling and forming clouds. If air currents carry this moisture higher or over cold water, more cooling occurs, and the vapor condenses into water droplets. Depending on the temperature and atmospheric pressure, the droplets fall as rain, snow, hail, fog, sleet, or freezing rain. ■ **transpiration, p. 542**

Most precipitation enters oceans or other bodies of water, but some also falls on land, where it either soaks into the ground and porous rock to restore soil moisture and groundwater, or it runs along the surface following the natural contours of the land. Rivulets join and form streams that unite into rivers. Most rivers eventually lead back to the ocean, where the sun's energy again heats the surface, evaporating the water and continuing the cycle. Water trapped in porous rock between the ground surface and impervious rock far below creates an aquifer. This underground water supplies wells and feeds springs that many species use. Spring water may evaporate or flow into streams, linking the groundwater system to the overall water cycle.

The Carbon Cycle

In the carbon cycle, autotrophs such as plants capture the sun's energy and use it with atmospheric carbon dioxide (CO_2) to synthesize organic compounds that are incorporated into their tissues (**figure 43.14**). Cellular respiration releases carbon to the atmosphere as CO_2. Dead organisms and excrement also return carbon to soil or water. Invertebrates feed on and fragment the dead, and bacterial and fungal decomposers complete the breakdown of these organic compounds to release simple carbon compounds into the soil, air, and water.

Certain geological deposits contain carbon from past life. Limestone, for example, consists mostly of exoskeletons and shells of ancient sea inhabitants. Fossil fuels, such as coal and oil, form from the remains of long-dead organisms. When these fuels burn, carbon returns to the atmosphere as CO_2.

The Nitrogen Cycle

Nitrogen is an essential component of proteins and nucleic acids, as well as other parts of living cells. Although the atmosphere is

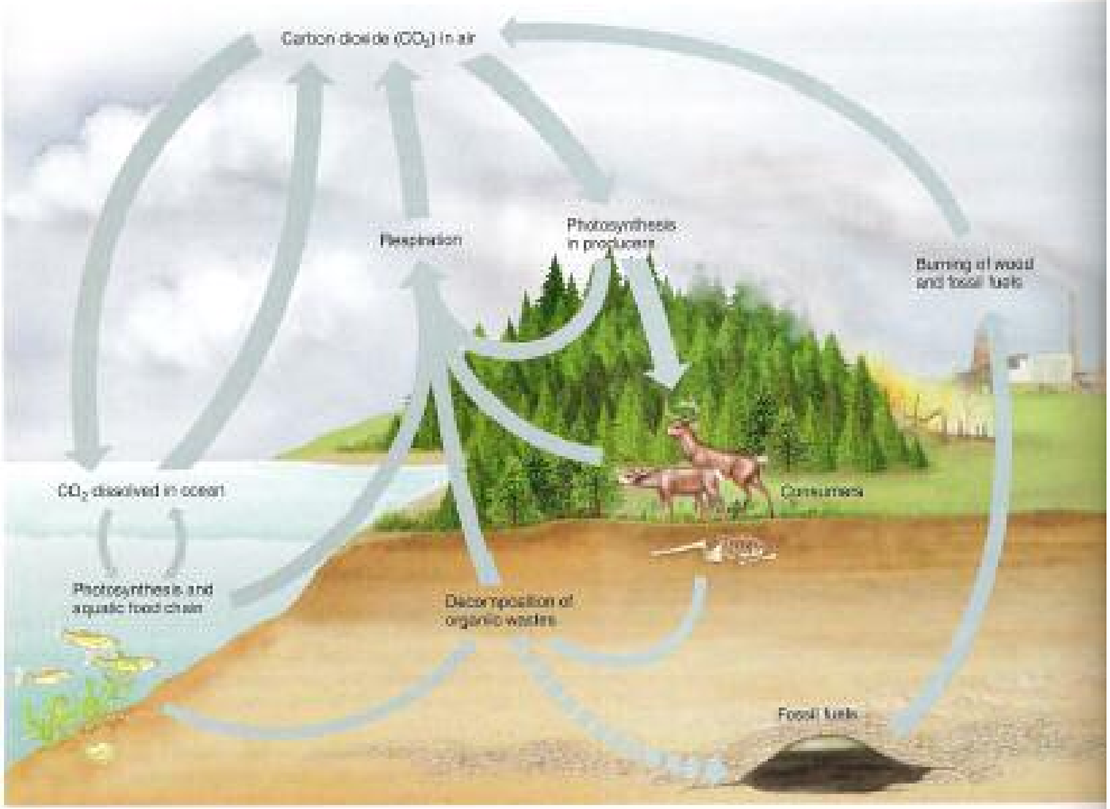


FIGURE 43.14 **The Carbon Cycle.** Carbon dioxide in the air and water enters ecosystems through photosynthesis and then passes alo food chains. Respiration and combustion return carbon to the abiotic environment. Carbon can be retained in geological formations and fossil fu for long periods of time.

79% nitrogen gas (N_2), most organisms cannot use this nitrogen to manufacture biochemicals. They depend on free-living or symbiotic **nitrogen-fixing bacteria** that convert N_2 into ammonia, NH_3 (present as ammonium ion, NH_4^+), which can be incorporated into plant tissue. Decomposers also release some ammonia. **Nitrifying bacteria** convert ammonia to nitrites (NO_2^-) and eventually to nitrates (NO_3^-), which plants can incorporate and then pass to animals. (Some nitrate is also produced when lightning fixes atmospheric nitrogen.) Finally, N_2 returns to the atmosphere when **denitrifying bacteria** convert nitrites and nitrates to nitrogen gas (**figure 43.15**).

The enzyme nitrogenase enables nitrogen-fixing bacteria to convert N_2 to other nitrogen-containing compounds. Because oxygen inactivates this enzyme, nitrogen-fixing microbes are typically anaerobic or shield nitrogenase from oxygen. For example, *Rhizobium* bacteria live in nodules on the roots of legumes such as beans, peas, and clover (see figure 20.1). Farmers rotate legumes with nonleguminous crops, such as corn, so the soil continually enriched with biologically fixed nitrogen.

The Phosphorus Cycle

Phosphorus is a vital component of nucleic acids, ATP, and mem brane phospholipids, and it is a structural component of ma organisms. Unlike the other biogeochemical cycles, that for pho phorus is based mostly in sediments and rocks, rather than t atmosphere (**figure 43.16**). As they erode, these geologic sources gradually release phosphorus, in the form of ino phosphate (PO_4^{3-}), to ecosystems. Organisms assimilate some this phosphorus, but much of it ultimately returns to the ocea and other bodies of water, where it becomes part of sediment Geological uplift eventually returns underwater sedimenta rock to the land. Decomposers return phosphorus assimilated living organisms to soil and water.

43.16

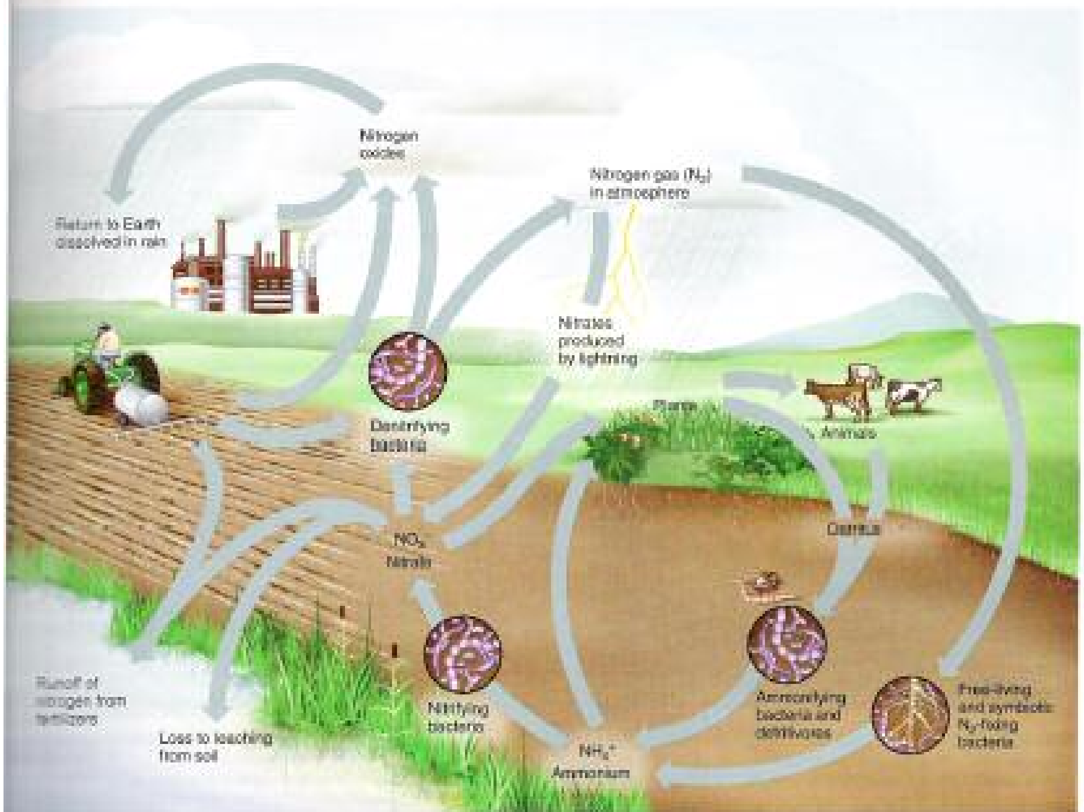


FIGURE 43.15 **The Nitrogen Cycle.** Nitrogen-fixing bacteria convert atmospheric nitrogen gas (N_2) to organic forms and ammonium ion, which plants can use. Plants use nitrogen to synthesize amino acids, nucleic acids, and chlorophyll. They pass these biochemicals along food chains. Nitrogen returns to the abiotic environment in urine and feces and by decomposition of dead organic matter. Specific groups of bacteria convert ammonium ion to nitrate (another form plants can use), and nitrate to nitrogen gas, completing the cycle.

Some Chemicals Become Concentrated as They Ascend Food Webs

Because cells admit some chemicals but not others, certain chemicals become more concentrated within cells than in the surrounding environment. This process, termed **bioaccumulation,** can concentrate particular elements or compounds in cells to thousands or millions of times their concentrations in the environment. Some substances, including certain synthetic compounds not normally found in ecosystems, become increasingly concentrated in organisms at successively higher trophic levels. This process, called **biomagnification,** occurs because the chemical passes to the next consumer rather than being metabolized or excreted. Two classic examples of biomagnification concern the pesticide DDT and mercury contamination of fish.

DDT was once widely used to kill insect pests because it damages their nervous systems, but it soon proved to harm many other species, too. The United States banned use of DDT in 1971, after much evidence showed it to cause cancer, disrupt wildlife, bioaccumulate, and become biomagnified (**figure 43.17**). DDT is still used in some countries, particularly to control the mosquitoes that transmit malaria, and it has touched nearly all life on Earth. DDT and its breakdown products have even been found in the fat of Antarctic penguins, who live where DDT was never used. Most of the DDT entering an animal remains in its fat and then passes through successive trophic levels. The pesticide becomes concentrated with each trophic level and most severely affects organisms at the top of the energy pyramid. By the fourth trophic level, DDT concentrations may be 2,000 times greater than in organisms at the base of the food web (**figure 43.18**).

43.17

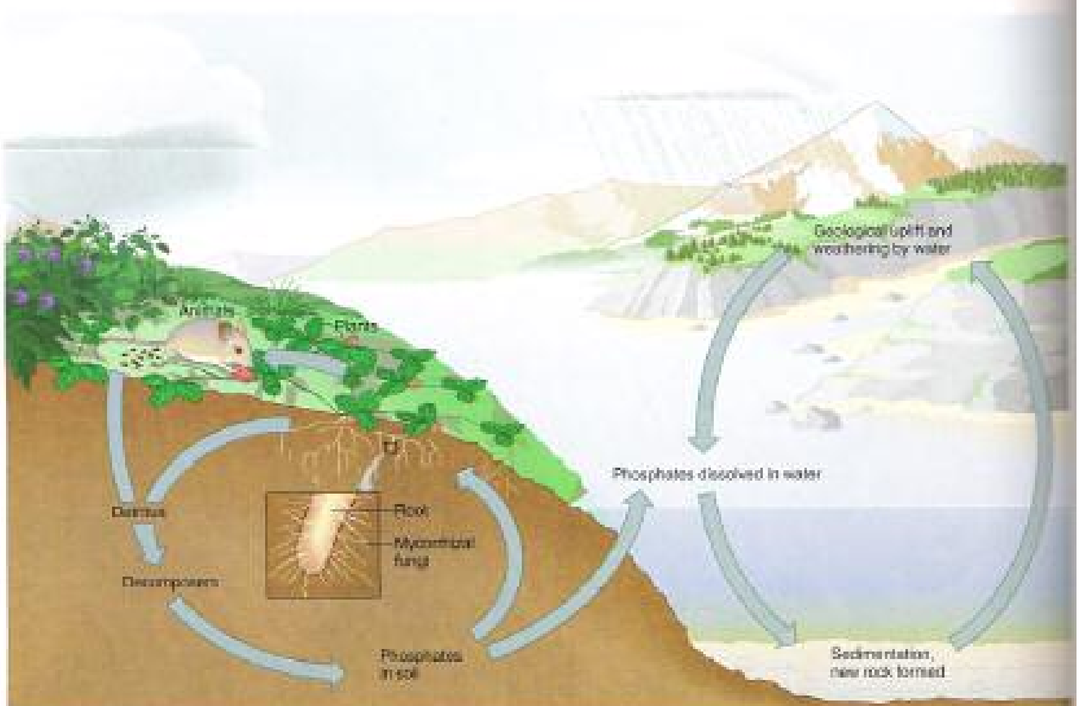


FIGURE 43.16 The Phosphorus Cycle. Phosphorus comes from rock, which slowly erodes. Soluble phosphates are taken up by pla (often with the help of mycorrhizal fungi) and passed up food chains. Decomposers return phosphorus to the abiotic environment. Phosphorus m ing and distribution of the element in fertilizer (not shown) has increased phosphorus availability to both terrestrial and aquatic organisms.

FIGURE 43.17 DDT Accumulates in Top Predators. The corpse of this about-to-hatch peregrine falcon, discovered amidst broken, empty eggs in Scotland in 1971, is testament to the concentration of DDT at the top of the food web, a position the animal occupies as a predatory bird. The pesticide caused birds' livers to abnormally metabolize the hormones required to secrete a firm, calcium-rich eggshell.

Mercury is a naturally occurring element that bioaccumu lates and is biomagnified. Plants growing near volcanoes or the mal springs, such as in parts of California, Hawaii, and Mexic assimilate airborne mercury particles through leaves and me cury in the soil through roots. Phytoplankton bioaccumul mercury from fresh water or ocean water. Mercury can also be pollutant. Biomagnification of mercury along food chains m create levels in fishes that are hazardous to humans and t carnivores such as birds of prey and marine mammals. He 43.1 discusses some effects of the bioaccumulation of mercury.

43.4 Mastering Concepts

1. What are the basic steps of a biogeochemical cycle?
2. Describe the steps of the water, carbon, nitrogen, and phosphorus cycles.
3. What is bioaccumulation?
4. What is biomagnification?

43.18

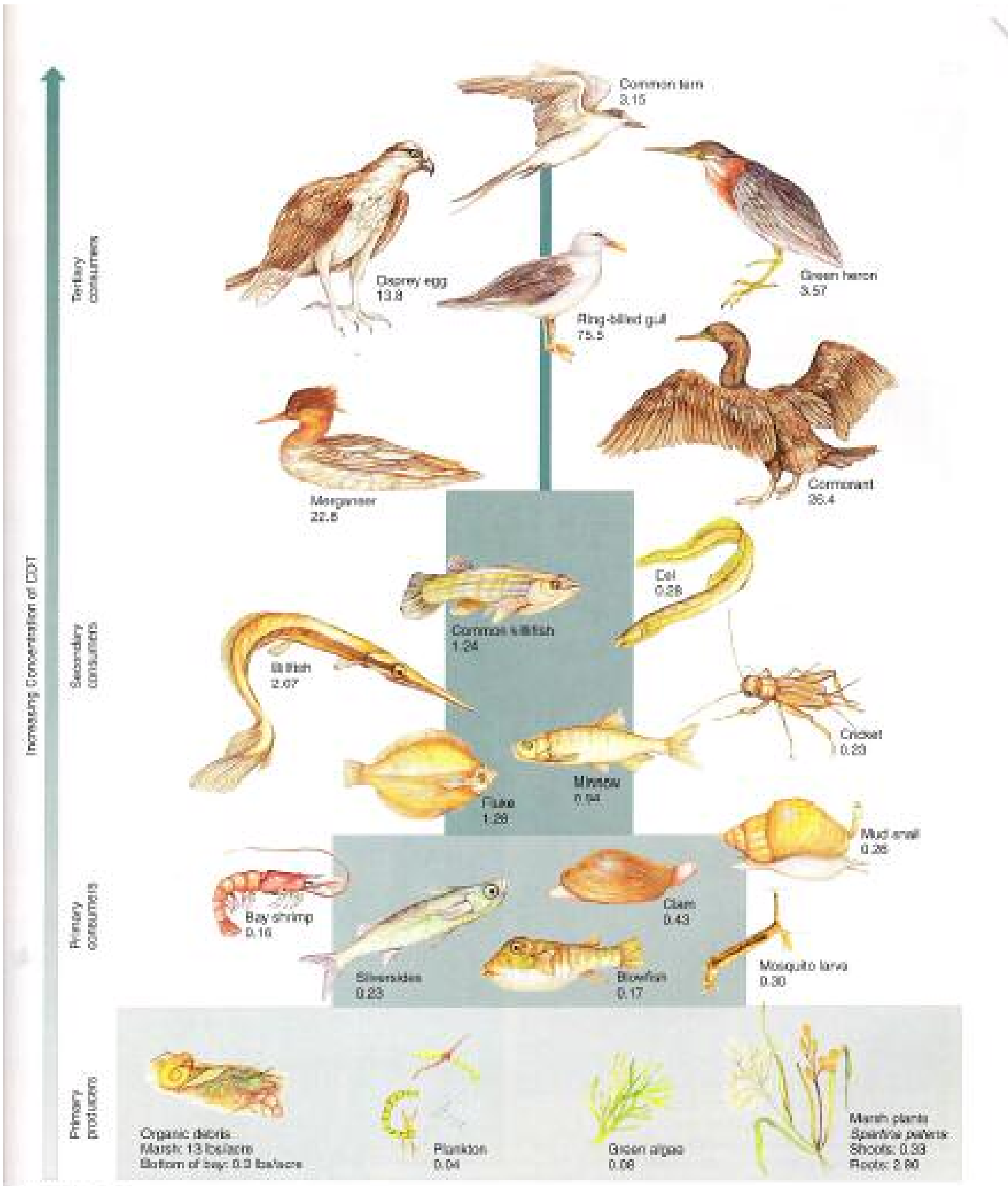


FIGURE 43.18 **Biomagnification in a Sampling of Wetland Organisms.** The concentration of DDT in organisms' bodies increases up the food web. Values represent concentrations of DDT per unit of tissue, measured in parts per million (ppm).

Like plants, the animals of the tundra have adapted to the harsh climate. Both the hunters and the hunted benefit from camouflage. White winter colors make the arctic fox, ptarmigan, ermine, and arctic hare as inconspicuous against snow as their brown summer colors make them against the snow-free landscape. These animals often have short extremities, a form that helps to conserve heat. The snowshoe hare's big feet are natural snowshoes. The shallow soil, short growing season, and slow decomposition of the tundra make it a very fragile environment.

44.1 Mastering Concepts

1. What are the major climatic regions of the world?
2. How do climate and soil composition determine characteristics of biomes?
3. Describe the rainfall and temperature patterns, nutrient cycling, and inhabitants of each of the major terrestrial biomes.

44.2 Freshwater Ecosystems

Life in lakes, rivers, and streams must be adapted to water velocities, changing nutrient and oxygen concentrations, and drought and flooding conditions.

Earth's waters house diverse species adapted to the temperature, light, current, and nutrient availability of their surroundings. Aquatic ecosystems are distinguished by physical and chemical factors such as current pattern and degree of salinity. Two types of freshwater ecosystems are standing water, such as lakes, swamps, and ponds, and running water, such as rivers and streams.

Lakes and Ponds

Light penetrates the regions of a lake to differing degrees. These differences determine the types of organisms that live in particular areas (**figure 44.14**).

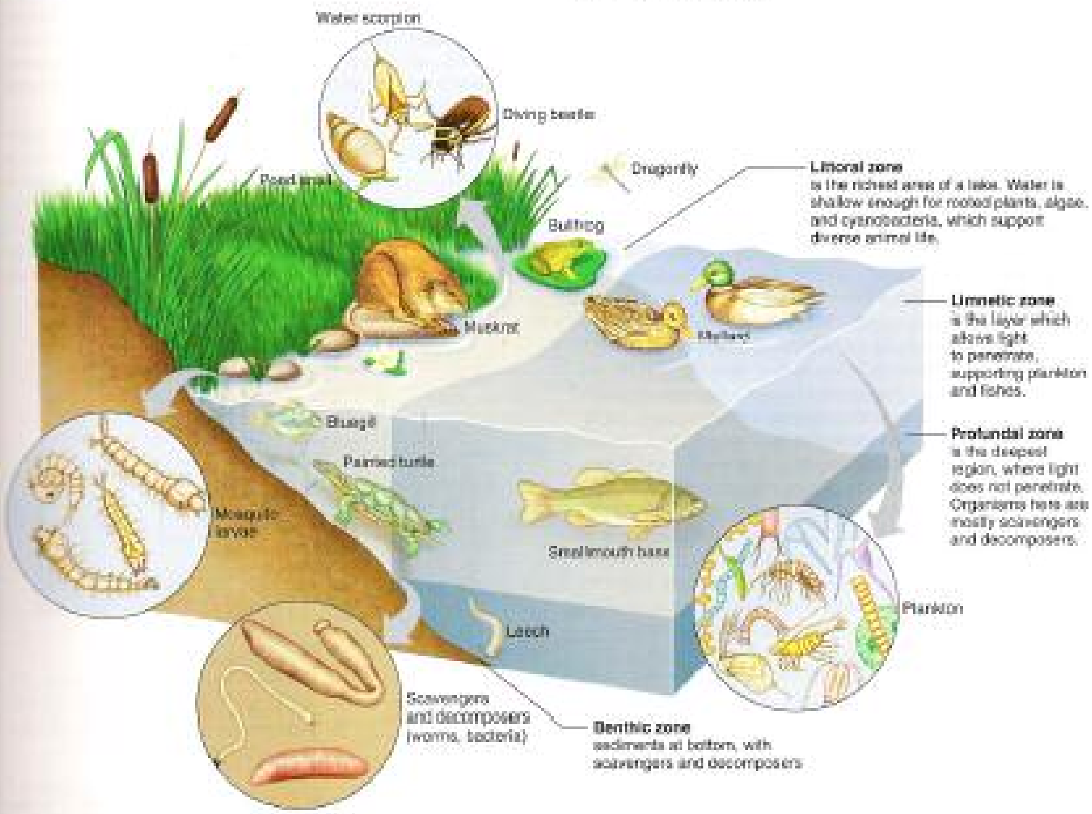


FIGURE 44.14 **Zones of a Lake.** The littoral, limnetic, profundal, and benthic zones of a lake describe where different types of organisms live.

The **littoral zone** is the shallow region along the shore where light reaches the bottom sufficiently for photosynthesis to occur. Some photosynthetic organisms in this region are free-floating; others are rooted to the bottom and have submerged, floating, or emergent leaves. The littoral zone is the richest area of a lake or pond. Producers here include free-floating and attached cyanobacteria, green algae, and diatoms. Floating plants such as water lilies and emergent plants such as cattails, reeds, and rushes are also part of the flora. Animal life is diverse and includes damselfly and dragonfly nymphs, crayfish, rotifers, flatworms, *Hydra*, snails, snakes, turtles, frogs, and the young of some species of deep-water fishes.

The **limnetic zone** is the layer of open water where light penetrates. Plankton (mostly protists, such as diatoms, ciliates, and algae) and fishes inhabit this area. The **profundal zone** is the deep region beneath the limnetic zone where light does not penetrate. Organisms here, which rely on falling organic material from above, include mostly scavengers and decomposers such as insect larvae and bacteria. The sediment at the lake bottom comprises the **benthic zone.**

Oxygen and mineral nutrients in a lake are distributed unevenly. The concentration of oxygen is usually greater in the upper layers, where it comes from the atmosphere and from photosynthesis. As dead organic matter sinks to the bottom, decomposers consume oxygen and release phosphates and nitrates into the lower layers of the lake. In a shallow lake, wind blowing across the surface mixes the water, redistributes nutrients, and restores oxygen to bottom waters.

Deeper lakes in temperate regions often develop layers with very different water temperatures and densities. This thermal stratification prevents the free circulation of nutrients and oxygen in the lake. The degree of thermal stratification varies with the season.

In the summer, the sun heats the surface layer of the lake, but the deepest layer remains cold. Between these two layers is a third region, the thermocline, where water temperature drops quickly. In the fall, the temperature in the surface layer drops as the air cools. Gradually, water temperature becomes the same throughout the lake. Wind then mixes the upper and lower layers, creating a **fall turnover** that redistributes nutrients and oxygen throughout the lake. During winter, surface water cools. When water cools to 39°F (4°C), the temperature at which it is most dense, it sinks. Water colder than this floats above the 39°F layer and may freeze, giving the lake an ice cover. In the spring, when the surface layer warms to 39°F, a **spring turnover** occurs, again redistributing nutrients and oxygen. After the spring turnover, algae thrive in the warming, nutrient-rich surface water.

Lakes age. Younger lakes are often deep, steep-sided, and low in nutrient content. The deep zone of bottom water stores a large quantity of oxygen, which is rarely depleted. These lakes are termed **oligotrophic,** which means they are low in fertility and productivity. They are clear and sparkling blue, because phytoplankton aren't abundant enough to cloud the water. Lake trout and other organisms that thrive in cold, oxygen-rich deep water are numerous.

As a lake ages, organic material from decaying organisms and sediment begins to fill it in, and nutrients accumulate. These lakes are termed **eutrophic,** which means they are nutrient-rich and high in productivity. The rich algal growth turns the water green and murky. Decomposing organisms in the deeper waters deplete oxygen during the summer. Fish and plankton communities change, and fishes that can tolerate low oxygen conditions replace species such as lake trout. In time, the lake becomes a bog or marsh and, eventually, dry land. Discharge of nutrient-rich urban wastewater and runoff carrying phosphate-rich fertilizers from cultivated lands can speed conversion of oligotrophic lakes to eutrophic lakes. This transformation is termed eutrophication. In extreme cases, the nutrients promote excessive algal growth. When the algae die, they sink to the lake bottom, where decomposers deplete the water of oxygen. Fish kills and unpleasant odors often result.

Rivers and Streams

The rivers and streams that flow across the terrestrial landscape carry rainwater, groundwater, snowmelt, and sediment from all portions of the land toward the ocean or an interior basin (such as the Great Salt Lake). The flow is not constant, however. Where the landscape flattens, the water may slow to a virtual standstill, forming pools. Elsewhere, the water flows in shallow runs or bends called riffles. Rapids are fast-moving, turbulent parts. Along the way, rivers provide moisture and habitat to a variety of aquatic and streamside organisms, which are adapted to both flooding and drying.

Rivers change, physically and biologically, as they move toward the ocean (**figure 44.15**). At the headwaters, the water is relatively clear, and the channel is narrow. Where the current is swift, turbulence mixes air with water, so the water is rich in oxygen. In fast-moving streams, some organisms cling to any available stationary surface, such as rocks or logs. Algae, diatoms, mosses, and snails that graze on them, live here. Larval and adult

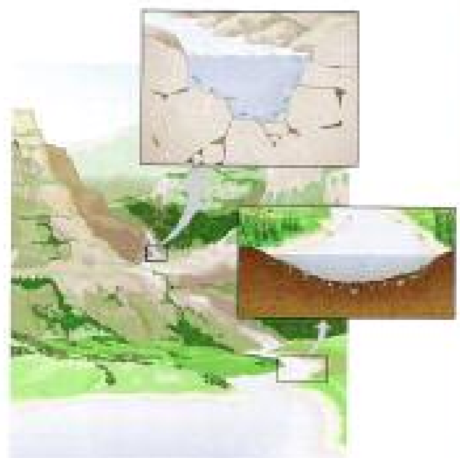


FIGURE 44.15 Rivers Change Along Their Course. A narrow, swift stream in the mountains becomes a slow-moving river as it accumulates water and sediments and approaches the ocean.

insects burrow into sediments or adhere to the undersides of rocks with hooks or suckers. Many of these invertebrates eat decaying plant material that drops in from streamside vegetation, which often provides the bulk of the energy that fuels the headwater stream food chain.

As the river flows toward the ocean, it continues to pick up sediment and nutrients from the channel. Tributaries contribute to water flow, so the river widens, and as the land flattens, the current slows. The river is murky, restricting photosynthesis to the banks and water surface. As a result, the oxygen content is low relative to the river upstream. Such slower-moving rivers and streams support more diverse life, including crayfish, snails, bass, and catfish. Worms burrow in the muddy bottom, and plants line the banks.

Rivers and streams depend heavily on the land for water and nutrients. Dead leaves and other organic material that fall into a river add to the nutrients that resident organisms recycle. Rivers also return nutrients to the land. Many rivers flood each year, swelling with meltwater and spring runoff and spreading nutrient-rich silt onto their floodplains. When a river approaches the ocean, its current diminishes, which deposits fine, rich soil that forms new delta lands. The opener to chapter 45 describes the incredible disruption to ecosystems that occurred when people altered a river's course in southern Florida.

44.2 Mastering Concepts

1. Describe the types of organisms that live in each zone of a lake or pond.
2. How are oxygen and nutrients distributed (and redistributed) in lakes?
3. What is eutrophication?
4. What adaptations enable organisms to survive in moving water?
5. Describe the ways a river changes from its headwaters to its mouth.

44.3 Marine Ecosystems

In areas where salt water meets fresh water, organisms are adapted to fluctuating salinity. In the intertidal zone, the ebb and flow of the tide challenges organisms. Life in the oceans is abundant and diverse, but we know little about it because oceans are vast and mostly inaccessible.

The ocean, covering 70% of Earth's surface and running 7 miles (11.2 kilometers) deep in places, is the largest and most stable aquatic ecosystem. Specific regions are based on proximity to land.

Coasts

Several types of aquatic ecosystems border shorelines. **Figure 44.16** illustrates these coastal areas.

Estuaries At the margin of the land, where the fresh water of a river meets the salty ocean, is an **estuary**. Life in an estuary must be adapted to a range of chemical and physical conditions. The water is brackish, which means that it is a mixture of fresh water and salt water; however, the salinity fluctuates. When the tide is out, the water may not be much saltier than water in the river. The returning tide, however, may make the water nearly as salty as the sea. As the tide ebbs and flows, nearshore areas of the estuary are alternately exposed to drying air and then flood.

Organisms able to withstand these environmental extremes enjoy daily deliveries of nutrients from the slowing river as well as from the tides. Photosynthesis occurs in shallow water. An estuary houses a very productive ecosystem, its rocks slippery with algae, its shores lush with salt marsh vegetation, and its water teeming with plankton. Almost half of an estuary's photosynthetic products go out with the tide and nourish coastal communities.

Estuaries are nurseries for many sea animals. More than half the commercially important fish and shellfish species spend some part of their life cycle in an estuary. Migratory waterfowl feed and nest here as well. Human activities can threaten these important ecosystems. ▪ **endangered estuaries, p. 909**

Mangrove Swamps Another type of aquatic ecosystem where salinity varies is a **mangrove swamp**, which is distinguished by characteristic salt-tolerant plants. The general term "mangrove" refers to plants that are adapted to survive in shallow, salty water, typically with aerial roots. About 40 species of trees are considered to be mangrove. Mangrove swamps mark the transitional zone between forest and ocean and are located in many areas of the tropics. Within them, salinity varies from the salty ocean, to the brackish estuary region, to the fresh water of the forest.

A mangrove swamp is home to a diverse assemblage of species because it provides a variety of microenvironments, from its treetops to deeply submerged roots in its own version of vertical stratification. Life is least abundant in the treetops, where sun exposure is greatest and water availability the lowest. Snakes, lizards, birds, and many insects live here. A hollow elevated mangrove branch may house a thriving community of scorpions, termites, spiders, mites, roaches, beetles, moths, and ants.

Aerial roots of mangroves provide the middle region of the swamp's vertical stratification. Here, roots are alternately exposed and submerged as the tide goes in and out. Barnacles, oysters, crabs, and red algae cling to the roots. Lower down lies the root region of the mangrove swamp, populated by sea anemones, sponges, crabs, oysters, algae, and bacteria. The algal slime that coats roots discourages hungry animals.

Submerged roots form the lowest region of the mangrove swamp. Here live sea grasses, polychaete worms, crustaceans, jellyfishes, the ever-present algae, and an occasional manatee. Ecologists estimate that up to 30% of the resident species here are unknown.

Unfortunately, many mangrove swamps are in prime vacation spots for humans—which means habitat destruction. When people cut down mangrove trees, small shrubs that can tolerate salt grow in the area, and trees cannot grow back. The diverse mangrove ecosystem shrinks and may vanish.

APPENDIX E

Sample Reading Questions

There is a small pond in my backyard and once, while mowing the grass, I let a lot of grass clippings blow from the lawn mower into the pond. Several days later, a few of my goldfish died and the others were swimming near the surface.
Which one of the following hypotheses is the most likely explanation for the situation indicated above?
a. Chlorophyll from the grass clippings acted as a neurotoxin blocking signaling from dendrite bulbs to axons within the fish.
b. Most of the oxygen in the pond was consumed as aerobic bacteria decomposed the grass clippings.
c. Too much oxygen was produced by the grass clippings, therefore poisoning the fish.
d. The grass clippings blocked the sunlight so the fish started having head on crashes with one another.
e. Chlorophyll from the grass clippings stimulated the sodium pump in the fish resulting in paralysis.

One day, we put fertilizer on our back lawn. It was a windy day and some of the fertilizer blew into the pond. A week later we noticed a lot of green scum floating on top of the pond on the side that is not shaded by trees. This green scum was probably made mostly of ______.
a. frog snot
b. moss
c. lichen
d. zebra mussels
e. algae

The green scum on top of our pond probably grew because of what substances from the fertilizer that blew into the pond?
a. glucose and other simple sugars
b. phosphorous-containing compounds
c. compounds rich in oxygen
d. compounds containing sulfates and sulfites
e. both (a) and (c)

Just prior to the fertilizer incident my daughter was planning a class project in which she needed to monitor population growth for a single population of the organism of her choice. She had chosen to monitor a common microscopic animal found in our pond. She had sampled the water two days prior to the application of the fertilizer and estimated the population size. Her experimental design included taking water samples every 2 days for 4 weeks. A week after the green scum appeared on the surface of the pond, she measured a sharp decline in the population size of her study animal.
Given the situation described above, which one or more of the following would be the most reasonable hypothesis(es) for the decline in the microscopic organism my daughter was studying?

a. A decrease in CO_2 levels in the pond.
b. An increase in O_2 levels in the pond.
c. A lack of decomposers in the water and a subsequent increase in O_2 levels.
d. A lethal level of toxin produced by the green scum.
e. Both (b) and (d).

Within any one particular community, which one of the following would have the smallest total biomass ?

a. producers (autotrophs)
b. primary consumers (heterotrophs)
c. secondary consumers (heterotrophs)
d. tertiary consumers (heterotrophs)

You and a 6th grade class design an experiment to study the carbon and nitrogen biogeochemical cycles. You explain to the class that they can safely use a, heavy-form of nitrogen (N-15) to follow or trace the fate of the nitrogen. You mix soil taken from a pasture with some dried, ground up alfalfa that contains N-15 nitrogen. You place the pre-mixed soil (complete with decomposers and other soil microorganisms) into the bottom of a 2 liter clear plastic soda pop bottle, plant some green grass and introduce a few grass-eating bugs. Occasionally you water the soil when the grass appears to be wilting. After 6 months you sample the soil, the grass and the air inside the bottle and measure the concentration of N-15 in each sample.

Where in the ground-up alfalfa plants would you find the N-15 nitrogen?
a. nucleic acids, e.g., DNA and RNA
b. proteins
c. amino acid pool
d. NAD+
e. All of the above.

You would predict that N-15 would be found in _____ when you examine the samples from the soda pop bottle.
a. the bugs only
b. the soil and bugs only
c. the grass and bugs only
d. the soil, the grass and the bugs

After sampling the bottle, you explain to the class that you are going to introduce some carbon dioxide that contains a radioactive form of carbon (C-14) that can be followed or traced. You keep the bottle closed for another six months and then sample the soil, the grass and the air inside the bottle and measure the concentration of C-14 carbon in each sample.
You would predict that C-14 would be found in ______.
a. the bugs only
b. the soil and bugs only
c. the grass and bugs only
d. the soil, the grass and the bugs only
e. the soil, the grass, the bugs and the air

Although rain is rare on the Creosote Islands, the caves that the bats inhabit are periodically subjected to heavy flooding in certain very rainy years and the waters carry the bat guano (bat poop) out of the caves and into some of the low lying, deep ponds. The following data were collected from a water sample taken from one of the ponds on the Creosote Islands.

Year	Nitrogen concentration in water	Phosphorus concentration in water	O_2 concentration	% absorption of red light (630 nm) as measured in a Hach DR2000 spectrophotometer as an indicator of Chlorophyll content.
1997	Low	Low	High	Low
1998	High	High	Low	Low
1999	High	High	Low	high

In which year would you predict that the rainfall was low and insufficient to wash the guano out of the cave into the pond?
a. 1997
b. 1998
c. 1999

The most reasonable hypothesis for the drop in oxygen concentration in 1998 is that ___________.
a. added rainfall diluted the oxygen
b. algae grew on the bat guano
c. aerobic bacteria decomposed the bat guano
d. algae decomposed the bats
e. nitrogen fixation occurred
The most reasonable hypothesis for the increase in chlorophyll content in 1999 is ___________.
a. added rainfall diluted the oxygen
b. algal growth resulting from an increase in bacteria
c. bacterial death resulting from excess bat guano
d. algal growth induced by the release of N and P from decomposition of bat guano
e. nitrogen fixation
If a scientist measured turbidity (how murky the water was), you would predict that it would be ____________.
a. highest in 1997
b. equal all three years
c. lowest in 1997
d. lowest in 1998
e. lowest in 1999

APPENDIX F

Week Five Interview

How do you feel about doing these readings every week? Positive/negative

How do you like practicing the strategies? Useful/not useful

How has awareness of these strategies changed the way you read? Examples?

How have these strategies changed the way you feel about reading biology? Yes/No

Would you use these strategies in the future for other classes?

APPENDIX G

Institutional Review Board Approval

Oklahoma State University
Institutional Review Board

Protocol Expires: 1/19/2005

Date: Tuesday, January 20, 2004 IRB Application No ED0472

Proposal Title: Metacognitive Strategy Use, Instruction and Its Effect on College Students' Attitude Toward Reading Biology

Principal Investigator(s):

Catherine Sonleitner	Richard Bryant
412 S. Burdick	229 Willard
Stillwater, OK 74074	Stillwater, OK 74078

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

Dear PI:

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact me in 415 Whitehurst (phone: 405-744-5700, colson@okstate.edu).

Sincerely,

Carol Olson

Carol Olson, Chair
Institutional Review Board

VITA

Catherine L. Sonleitner

Candidate for the Degree of

Master of Science

Thesis: Metacognitive Strategy Use and Its Effects on College Biology Students' Attitude Toward Reading in the Content Area

Major Field: Teaching and Curriculum Leadership

Education: Graduated from Norman High School, Norman Oklahoma in May 1994; received Bachelor of Science degree from Oklahoma State University, Stillwater, Oklahoma in December 2001. Completed the requirements for the degree Master of Science in the field of Teaching and Curriculum Leadership in May 2005.

Experience: Employed by Oklahoma State University Department of Botany as an undergraduate and by Oklahoma State University Department of Zoology as a graduate Teaching Assistant.

Professional Memberships: National Center for Science Education, National Science Teachers Association, National Association of Biology Teachers

Name: Catherine L. Sonleitner   Date of Degree: May, 2005

Institution: Oklahoma State University   Location: Stillwater, Oklahoma

Title of Study: Metacognitive Strategy Use and Its Effect on College Biology Students' Attitude Toward Reading in the Content Area

Pages in Study: 117   Candidate for the Degree of Master of Science

Major Field: Teaching and Curriculum Leadership

Scope and Method of Study: This research was completed to answer the following questions:

- What metacognitive strategies do students report using while reading biology texts?
- What is the relationship between reading strategies use and their attitude toward reading biology?
- Does strategy use vary among good and poor readers, gender, and majors?
- Does explicit strategy instruction improve students' attitude toward reading biology texts?

During the study, 430 students completed the Metacognitive Awareness of Reading Strategies Inventory and an attitude survey. Ten students volunteered as case study participants. These students received instruction using multiple metacognitive strategies and participated in an interview.

Findings and Conclusions: This research indicated that college freshmen are somewhat skilled using metacognitive reading strategies, but rely primarily on problem-solving strategies. Use of metacognitive reading strategies was positively correlated with student attitudes toward reading science texts. Significant differences were found among good and poor readers, males and females, and different majors.

Advisor's Approval Richard J. Bryant