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Dialogue as a Tool for Meaning Making

Angela Suzanne Dudley Bruni

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The University of Southern Mississippi

DIALOGUE AS A TOOL FOR MEANING MAKING

by

Angela Suzanne Dudley Bruni

Abstract of a Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

May 2013
ABSTRACT

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by Angela Suzanne Dudley Bruni

May 2013

In order to empower citizens to analyze the effects, risk, and value of science, a knowledge of scientific concepts is necessary (Mejlgaard, 2009). The formal educational system plays a role in this endeavor (Gil-Perez & Vilches, 2005). One proposed constructivist practice is the use of social learning activities using verbalized, shared cognition among learners. In an effort to investigate the effects of verbally shared cognition, this project sought to determine if social learning opportunities affect the mastery of content in gateway biology courses and to identify the types of dialogue students engage in during cognitive collaboration. Fifty-seven students enrolled in a small southern community college were randomly assigned into treatment groups for each of nine units of instruction. The treatment variable was participation in verbalized social learning activities. Treatment differences based on a pretest/posttest design were analyzed using various statistical methods and recorded student discussions were analyzed for characteristics of talk based on a model developed by Mercer. Findings support the use of social learning activities as a way to improve content knowledge. Students in the treatment group had higher posttest and gain scores than those in the control group, with statistical significance reached in some cases. Types of talk were examined to support the constructivist method of learning. Findings support the use of non-confrontational talk as the vector of meaning making within the classroom.
The University of Southern Mississippi

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for the Degree of Doctor of Philosophy

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ACKNOWLEDGMENTS

They say it takes a village to raise a child. I say it takes one to write a dissertation. No great and worthy effort is accomplished in isolation. I would first like to thank my committee, Dr. Sherry Herron, Dr. Kyna Shelley, Dr. Kristy Halverson, Dr. Rebecca Fillmore, and Dr. Mac Alford, who have invested so much time in my graduate education and the production of this research. I sincerely thank you and appreciate you for the example you set as instructors, mentors, and individual people.

I would like to acknowledge my education warriors, Kelly Rouse and Lynn Singletary. We have laughed so much, cried so much, stressed so much, worked so much, planned so much, and traveled so much, and we did it all together! What began as Kelly's hair-brained idea that it would be "fun" to get a Ph.D., turned into our dream, and became our reality. We started together, we finished together, and through it all, we were there for each other.

I would like to acknowledge my family, especially my sister-in-law, Tracie, who gladly and willingly took over many of my family duties so that I could pursue this goal. I am also grateful for my parents who instilled in me the value of education, especially for my mom who has always believed I could accomplish whatever I set my mind to. Lastly, and most importantly, I would like to thank my husband and children, Jeff, Catie Lee, Jeff, and Christopher. You have allowed me to be absent from your lives in so many ways: missed soccer games, missed school functions and award ceremonies, and missed vacations. You've allowed me to take on the characteristics of a manic-depressive. You have selflessly borne it all. I acknowledge you. I thank you. I love you.
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CHAPTER I
INTRODUCTION
Overview of Scientific Literacy

Scientific developments, especially recently, have blurred the line between an exclusive academic community and society at large (Mejlgaard, 2009). Science permeates personal, social, and political spheres of many people’s lives, creating stakeholders in the determination of its value and risk (Felt & Fochler, 2008; Holbrook & Rannikmae, 2007; Mejlgaard, 2009). It is almost impossible to think of anything good or bad that does not have a scientific or technological component (Gil-Perez & Vilches, 2005). The dominance of science in people’s lives has created an increased accountability demanded of science and has initiated the need for an educated public equipped with enough understanding to maneuver in the scientific world (Mejlgaard, 2009). Although informal educational outlets such as museums, print and audio-visual media play a part in creating an educated public, it is the formal educational system that plays the fundamental role in creating a techno-scientifically literate public (Gil-Perez & Vilches, 2005). As a result, this increased understanding will in turn lead to an increased appreciation and participation in societal science (Mejlgaard, 2009).

The relationship between science and technology and society cannot be disputed. Roth and Desautels (2004) deem science and technology social practices in and of themselves and go further to postulate that science and technology literally produce our social fabric. Technology drives scientific discoveries and scientific needs drive the development of new technologies, both of which in turn have an impact on societal issues. In addition to this, within its own sphere, science is a socially-oriented entity.
Scientific theories, knowledge, and practices are the collective intellectual and physical work of many. "No sociologist or anthropologist of science has noticed at work a disincarnated mind that, in solitary confinement, thinks of a theory or realizes an experiment," (Roth & Desautels, 2004, p. 153). Indeed the universal quality of scientific knowledge is produced by a worldwide network of human productivity (DeHaan, 2005; Roth & Desautels, 2004).

In order to empower citizens to manage the influx of science in their lives, a basic knowledge of scientific concepts is called for in order for them to analyze the effects, risk, value, and stakes of science (Mejlgaard, 2009). Yet, not only is scientific content knowledge important, but so are the process skills that science education can cultivate and perfect (Holbrook & Rannikmae, 2007). This knowledge construct, composed of both content and process knowledge, is termed scientific literacy. The study of science has a liberating effect on the mind and is crucial to the development of critical awareness within a culture (Gil-Perez & Vilches, 2005). Scientific literacy is not an acquired individual quality but a feature, like citizenship, of a population as a whole (Roth & Desautels, 2004). Figure 1 outlines the three major components of scientific literacy.
Notably, in the educational setting, content emphasis often has primacy over process skills, thus perpetuating a skewed concept of scientific literacy, indicating it involves strictly content knowledge. Yet, skills such as problem solving, rationalizing, and decision making contribute to scientific literacy (Holbrook & Rannikmae, 2007), mirror larger educational goals (Mercer, 2008), and can be extrapolated to a larger life-skill set considered useful in many areas of a person’s life by transference. In the overall scheme of things, learning is the acquisition of different capabilities that can be applied to situations that, while different, share common solution approaches (Vygotsky, 1978).

Despite the increased focus on a scientifically literate populace, research shows that most people are ill-equipped to participate in discussions and decisions regarding science and technology. Intertwined with this lack of scientific literacy is the educational approach to teaching science. A typical view of higher education has traditionally been a didactic environment where the teacher’s role is that of a transmitter of information to a passive audience (Postholm, 2007). Johnson, Johnson, and Smith (2007) concur, stating...
that lecturing has been the dominant mode of methodology, along with competitive assessment practices which tend to pit students against each other. Instead, the compelling force in science education should be for students to gain social and personal skills that will enable them to act responsibly and successfully within society (Holbrook & Rannikmae, 2007). Johnson et al. (2007) note the importance of three apprenticeships of education: an apprenticeship of the head that focuses on cognition and intelligence; an apprenticeship of the hand that focuses on skills; and an apprenticeship of the heart that focuses on attitudes and values. These three apprenticeships are at the heart of scientific literacy and are common in social learning methods.

Regarding instruction and cognitive development, bridges should be made between what is known about ways people learn and what teachers do in the classroom. If lecturing has been shown to lead to little more than memorization with minimal integration of new information into existing mental frameworks, then different strategies should be implemented to "achieve meaningful learning and transferable knowledge," (DeHaan, 2005, p. 261). For several decades many theorists, including Piaget and Vygotsky, have recognized the significance of the teacher’s role as a mentor rather than as an authoritarian source of knowledge. This vision of the teacher denotes the social component of development, learning, and intellectual growth (Rojas-Drummond, 2009) that is oft ignored, especially in higher education. Many current learning models recognize the importance of the social setting and social interactions that comprise a learner’s educational environment and the learning opportunities that are afforded through interaction (Dangwal & Kapur, 2009; Postholm, 2007). Instead of learning being
strictly regarded from the isolationist standpoint (Dangwal & Kapur, 2009), it is viewed as a constructivist process.

Community College Demographics

The social interaction called for by constructivism can have a special and significant impact for students at community colleges. Community colleges enroll a diverse and unique population of students compared to four-year institutions. Community colleges enroll higher percentages of minority students who are more likely to enroll part-time and come from low-income families, higher percentages of under-prepared students, greater concentrations of first-generation college students, and students from lower socio-economic backgrounds (Fike & Fike, 2008). Other demographic factors play a role in community college students' chances of success. High percentages of students at community colleges are employed, are single parents or have dependents, and are financially self-supportive (Schmid & Abell, 2003). Any institution’s success in making a difference in people’s lives depends on the retention of students and is a special problem for community colleges as attrition is high. Student attrition has an impact not only on the individual, but on families and society as well, since attrition results in overall lower education levels. It is essential that colleges and universities focus on student success (Fike & Fike, 2008). One area that can secure student loyalty and perseverance is the academic environment (Nitecki, 2011). The work of Fike & Fike (2008) in student development theory shows that academia and social interactions play an influential role in the transition stages of first-time-in-college students as they progress from first year to mature students nearing graduation. Nitecki (2011) also notes that classroom relations, including students’ social interactions, have a
profound effect on the college experience. In fact, the support felt through interactions with faculty and fellow students is crucial to retention (Nitecki, 2011). Constructivist practices can contribute to the development of this crucial socially-academic environment that aids in student success.

Statement of the Problem

Scientific literacy has been heralded as a significant aspiration of the 21st century and has several components, one of which is subject knowledge. Scientific literacy as a national aspiration has naturally trickled down to the classroom level as the foundation for its accomplishment, yet traditional didactic methods do not seem to promote and accomplish content mastery in effective ways. One proposed method of conveying subject knowledge is the use of social learning activities, especially those using talk, or verbalized, shared cognition. This project was designed to determine if social learning opportunities affect the mastery of content in gateway biology courses. Namely, this project was designed to determine if biological knowledge is improved through talk and to identify types of talk students engage in during cognitive collaboration.

Research Questions

Research Question: What differences exist in content knowledge acquisition when students participate in social learning activities and when they do not?

1. Specific Research Question: What is the impact of social learning activities on scientific content knowledge acquisition?

2. Specific Research Question: What types of talk exist in student conversations during social learning activities?
Research Sub-problems and Hypotheses

1. What differences exist in pretest and posttest scores when students participate in social learning activities and when they do not in gateway undergraduate biology courses?

   \( H_1 \): There will be a significant difference in the pretest and posttest knowledge scores when students participate in social learning activities and when they do not.

2. What differences exist in gain scores when students participate in social learning activities and when they do not in gateway undergraduate biology courses?

   \( H_1 \): There will be a significant difference in gain scores when students participate in social learning activities and when they do not.

3. What specific types of talk exist in peer-group conversations during social learning activities: Disputational Talk, Cumulative Talk, or Exploratory Talk?

Definitions of Terms

The following terms were used in this study and should be understood in full context.

- Accommodation - the modification or change of a child's internal patterns of understanding to fit reality. In this process existing internal insights are reconstructed so as to accommodate new data or information.

- Cumulative talk - initiations or contributions are typically accepted either without discussion or with only superficial amendments

- Dialogic discourse - a true interaction among a variety of voices

- Dialogism - interchange in which no single participant has dominance in a conversation
• Disputational talk - occurs when there is competitive or individualized activity and a noted absence of explicit reasoning

• Exploratory talk - occurs when knowledge is made public and reasoning is visible in the talk

• Intermental - a term used to describe cognitive engagement between two or more people

• Transfer of learning - the relationship between the person's learning process and his ability to use what he learns in future learning and life situations

Delimitations

Participants in this study consisted of two sections of gateway biology classes at a small southern community college during the fall semester of 2012. Only data provided by informed consent were used in the study.

Limitations and Discussion

A potential limitation of this study is the population sample. Subjects were drawn from two sections of gateway biology courses at a small southern community college. The results of this study may not be able to be generalized beyond the same community college population. Only topics in the subject of cell biology were used in this study, and that, too, may limit generalizations to college courses as a whole. Some students may have also shied away from having their comments recorded and may not have participated as fully as they were capable in the peer group discussion of the social learning activities.
The instructor acted as both teacher and researcher. As teacher, a conscious effort was made to deliver equitable lectures in both time and depth to both class sections regardless of whether or not they were acting under the treatment condition. The syllabus was organized such that no beginning or ending of units was noted by date in order to decrease the likelihood of participants preparing for the upcoming unit. A conscious organizational effort was made to keep both sections progressing through the material at the same pace. In short, effort was made to keep both conditions, control and experimental, alike except for participation in social learning opportunities. As researcher, the above provisions were made in order to maintain equivalency between the control and experimental conditions. The researcher administered all instruments (pretests, posttests, and social learning opportunities) and analyzed both the quantitative and qualitative data, which consisted of recorded talk during social learning activities.

Assumptions

- It was assumed that the instructor delivered lectures of equal depth to all groups of students.
- It was assumed that students who participated in the social learning activities did not share them or discuss them with students who were not participating in social learning activities.
- It was assumed that students who did not participate in social learning activities did not form study groups outside of class.
- It was assumed that students did not seek tutorial help.
- It was assumed that each student participated fully in the social learning activity.
It was assumed that all students understood the English language and social context.

Justification for the Study

Knowledge and understanding of scientific concepts, processes, and contributions to our world are important in order to evaluate the value and risk of science’s influx in our lives. Common, everyday events are inextricably tied to scientific advancements. Increasingly, individuals and society must make personal, moral, or political decisions regarding scientific advancements; yet, sadly, many Americans have poor scientific literacy and skill sets that enable them to knowledgeably and confidently engage in discourse regarding such matters. However, scientific literacy can be increased if methods or tools are used to increase learning and provide for the development of crucial critically-assessive skill sets.

One such method is the employment of social constructivism, specifically through the use of dialogue where language is the tool of communication between learners. Learning is a social process whereby a person’s mental construct of an unfamiliar entity can approach reality due to the experience a learner can have within a sharing of constructs among individuals (Vygotsky, 2004). This is important in science as many concepts are not directly observable. In addition to the increased likelihood of an accurate mental construct of unobservable reality, social interaction also allows for the progressive internalization of psychological tools that enhance and promote cognitive development (Reznitskaya et al., 2009). Such interaction involves the use of dialogue as the social context through which mental and cognitive constructs are transmitted from one learner to another. As such, it is important to recognize the value of discourse in the
learning process and the value of socially shared cognition (Dangwal & Kapur, 2009; Skidmore, 2006). Furthermore, the rational and reasoned discussion that social dialogue can produce can be extrapolated to the larger life skill of informed judgment development regarding complex issues. Students whose classroom experience is primarily discussion-based are equipped with knowledge and internalized skills that allow them to perform individually and successfully in future literacy tasks (Applebee, Langer, Nystrand, & Gamoran, 2003). As Reznitskaya et al. (2009) suggest, "...the commonly advocated benefits of dialogic teaching are of much greater magnitude and lie not in the students' ability to learn the right answers, but in their acquired disposition to reflect upon and question these answers," (p. 42).

Dialogue represents a form of communication firmly and historically fixed in our democratic society. Educators have long recognized the tendency of dialogue to create independent and critical thinkers that become active and engaged citizens (Reznitskaya et al., 2009). Reflecting upon the call for a scientifically-literate, engaged citizenry and the role of dialogue in creating such critical and active citizens, the importance of social dialogue in developing cognitive constructs of the learner regarding phenomena that is not directly observable and in the formation of reasoning skills cannot be ignored. Reznitskaya et al. (2009) regards dialogue as a platform where students can attempt to undertake and practice a variety of conversational and dialogic tools such as taking a position, challenging the positions of others, and developing reasoned argumentation skills that can lead to mindful participation in society. Still, dialogical approaches to education have received little research attention (Reznitskaya et al., 2009).
There is a relative dearth of research empirically linking dialogue and student learning (Reznitskaya et al., 2009; Rojas-Drummond, 2009), and most has been done in the elementary context. There is a pressing need to conduct such research and to provide empirical evidence linking participation in classroom talk with educational outcomes (Mercer, 2010). Skidmore (2006) calls this a "neglected line of enquiry, which future research could profitably pursue," (p. 503). There is also a need to explore the types of dialogue that occur within the classroom (Dorian, 2009). Solid connections need to be made between quasi-experimental research on cognitive development and research of qualitative accounts of peer interactions (Rojas-Drummond, 2009). The fact that past research has tended to be scarce regarding dialogue and learning and that what does exist is mostly based on the elementary school level is problematic. This lack of research serves to perpetuate the lack of dialogue as an instructional method as pedagogical knowledge must come chiefly from theoretical sources leaving instructors very little real-world application models (Reznitskaya et al., 2009). Adler, Rougle, Kaiser, & Caughlan (2004) agree, stating that teachers seem to be unaware of methodologies that support the development of social knowledge and higher-order thinking skills and tend to focus on recitation methods of instruction. This is especially critical at the college level where habitual teaching methods tend to be didactic. If educational policy and teacher training is to articulate more clearly how talk can promote successful educational outcomes, there need to be more research studies which combine quantitative and qualitative data consolidation supporting the connection between language and learning (Mercer, 2010).

Although research results are relatively scarce regarding social knowledge construction, forms of social knowledge construction are being used in primary and
secondary schools so that students arrive at college with expectations of activity tasks and project work (Postholm, 2007). Social construction of knowledge using language as a tool during dialogical exchange has promise in accomplishing complex educational outcomes (Reznitskaya et al., 2009) such as informed judgment, critical analysis skills, and reasoned argumentation (all components of scientific literacy), and can narrow educational outcome gaps seen among different types of learners (Skidmore, 2006), many of which populate community college campuses. Research indicates that children from low socio-economic status, foreign language students, and low achievers are more effective in classrooms using this type of instructional method as it capitalizes on existing knowledge and ideas as opposed to more traditional methods which tend to emphasize weaknesses in these types of students (Applebee, Langer, Nystrand, & Gamoran, 2003). When provided with opportunities of mindful engagement, learning is more meaningful and permanent (Hadjioannou, 2007). Exploring ways to incorporate these types of instructional methods at the college level and encouraging connections to existing knowledge processes may be the only way some students can continue their education (Postholm, 2007), thus contributing to the overall educational attainment of a population and, particular to this study, improving competency in scientific content and process knowledge which tends to foster the development of a more scientifically-literate citizenry.
CHAPTER II

REVIEW OF RELATED LITERATURE

Scientific Literacy

Knowledge and understanding of scientific concepts, or scientific literacy, is essential in today's global society and has become a major objective of educators. Included in the concept of scientific literacy is an awareness of the role science plays in one's personal life. The world is becoming increasingly complex due to advanced scientific discoveries and technological developments (Roth & Desautels, 2004). Accompanying this increased complexity is an increased public attentiveness in practical, ethical, and political realms that are influenced by these socio-scientific issues (Roth & Desautels, 2004). Such issues include a technologically-driven economy, the appreciation that technology can provide great benefits to some and great risk to others, the risks of health-related advancements, and the sustainability of the environment. Decisions will need to be made as to which technology or scientific advancements are actually worth it (Holbrook & Rannikmae, 2007). Gil-Perez and Vilches (2005) note that citizens, more so than scientists, are more likely to exercise caution in the application of techno-scientific advancements for hasty economical and commercial gain. Called the "precautionary principle" (Gil-Perez & Vilches, 2005, p. 257), this prudence "reflects growing social sensitivity to the risks of insufficiently tested innovations and the pursuit of short-term private interests at the expense of the wider public good," (Gil-Perez & Vilches, 2005, p. 257). In order to be able to participate in responsible civic action, the general populace must possess a certain level of scientific literacy (Gil-Perez & Vilches, 2005).
In order to fully participate in and understand the debate and policy-making procedures regarding certain socio-scientific issues, individuals must be scientifically competent in content and process skills. Desmastes and Wandersee (1992) describe the fundamental nature of this literacy as an understanding of essential biological principles and appropriate application of them when performing common, everyday activities such as reading the newspaper or discussing recent developments or events (Roth & Desautels, 2004). A well-rounded (not an in-depth) knowledge base is necessary. Historically, it has been made clear that detailed, specific, in-depth knowledge does not guarantee good decisions. Instead, a wider perspective is called for that can evaluate the effects of techno-scientific advancement applications within a particular field and among others, and this can be done by a scientifically literate citizenship (Gil-Perez & Vilches, 2005). Roth and Desautels (2004) also dispute the concept of a core group of essential biological principles by stating that not all individuals need to have the same stockpile of scientific knowledge, but agree with Demastes and Wandersee (1992) by noting that individuals must exhibit a similar aptitude in applying what knowledge they do have. Society must employ critical thinking skills in choosing substantiating data, such as can be found in published tables, graphs, or text, to support personal and societal decisions and judgments (Demastes & Wandersee, 1992). Holbrook and Rannikmae (2007) echo this idea stating that the goals of decision making and problem solving espoused by scientific literacy are crucially important. Science as an educational component of the curriculum can provide experience with critical skills such as working cooperatively, creative problem solving, critical thinking, and using technology effectively (Gil-Perez & Vilches, 2005).
Increasingly, individuals and society as a whole must make choices and engage in discourse involving issues and products of scientific inquiry that affect their lives (Gil-Perez & Vilches, 2005). Roth and Desautels (2004) observe that the globalization of society has only served to further embed science in the societal and personal issues of our times, providing as examples environmental degradation, climate change, and the potential of advancements in biotechnology to genetically modify organisms, including humans. To emphasize how the understanding of scientific concepts and possession of scientific knowledge will affect the opinions and decisions of citizens and continuing the thread of biotechnology as an important source of scientific advancement, Saka, Cerrah, Akdeniz, and Ayas (2006) state that an understanding of genetic inheritance is important, as society will increasingly be called upon to make educational, social, and ethical decisions based upon the principles of genetic makeup and transmission. Halverson, Siegel, and Freyermuth (2008) note, "As more responsibilities for making decisions regarding the application of science and technology advancements are being passed on to the general public, it has become essential for individuals to be scientifically literate," (p. 2). Understanding scientific concepts will enable individuals, and thus society as a whole, to make informed decisions regarding issues that affect their lives.

In fact, science and technology do not just affect society, they literally produce the social fabric. As time goes on, science and technology become increasingly mutually dependent and mutually supportive. Improved technology has provided enhanced means for studying the world around us, and the needs and demands of science have driven technological developments. These advancements in science and technology and the knowledge inherent in them frequently have an influence on society (Rutherford, 2005).
Through advancements, developments, and discoveries, scientists generate products that become common threads in the societal fabric and influence, and in fact can radically change, the relations of individuals in and components of an increasingly globalized world (Roth & Desautels, 2004). Roth and Desautels (2004) note that many agencies and international governments have developed policy and produced public statements specifying science as "a necessary ingredient in the development of an informed and engaged citizenship." (p. 151).

The call for this citizenry development implies that students need opportunities to increase their understanding of science and to engage critically with educational materials in order to practice the application of thinking skills that allow them to evaluate evidence, conclusions, and the logic of constructed arguments and assumptions (Demastes & Wandersee, 1992). These are the skills that will empower individuals to make social decisions as they participate in a globalized societal structure. Teaching strategies should be employed and educational activities should be designed to allow practice in approaching problematic situations (Gil-Perez & Vilches, 2005). Demastes & Wandersee (1992) point out the benefits and limitations of a literacy-driven approach to science education. In their investigation of a literacy-driven approach to teaching thermoregulation, they noted that participation and interest increased and made the experience more meaningful to students and that despite the decrease in memorized material, understanding actually increased. More broadly noted in her study of authentic discussion in English classes, Hadjioannou (2007) noted that teachers who treated students as active and capable meaning makers fostered the development of a population
of individuals who take initiative, express opinions, refocus lines of thought, and negotiate their rights.

Accurate working knowledge (conceptual frameworks) and the skills and confidence necessary to implement such knowledge will give individuals a sound basis upon which to make informed, educated decisions about personal or social policy. Our society has the need for citizens to be able to evaluate and participate in decisions related to science and technology. As Lewis & Wood-Robinson (2000) reported, students’ conceptual learning and understanding is not at a level that would facilitate an educated or informed participation. Some surveys indicate that large segments of the population cannot answer basic natural science questions (Mejlgaard, 2009). Demastes & Wandersee (1992) agree noting that the general public's understanding of science is insufficient to meet the demands of 21st century life.

Theoretical Foundation

Humans posses distinctly unique characteristics, including the ability to talk; to be time-binding, meaning that both the past and the future influence present perceptions; and to be highly imaginative. These characteristics give humans a unique social aptitude that is unlike other social organisms whereby they have the ability to transcend the physical and exist in an imaginative sphere. Additionally, these unique characteristics and the social nature they produce make learning more critical for humans than for other animals. *Homo sapiens* are biologically recognized as a species with superior intellectual capabilities and capacity. Indeed culture itself is the accumulation of multigenerational, cumulative learning (Bigge, 1982) and language and cognition are inextricably intertwined (Applebee et al., 2003) in its transmission.
Learning, unlike maturation, is a change in an individual that is not determined by a genetic and inheritable control. Learning is considered a change in a behavioral disposition that occurs due to experiences which have resulted in some alteration of perception, behavior, motivation, or cognition. Humans are imaginative and creative and via continuous learning have developed a self-perpetuating tendency to explore and increase contact with their surrounding world in concrete and abstract ways using their superior intelligence and capacity for communicative speech. Creativity and exploration inform learning and learning informs creativity and exploration. This exploratory tendency has not only driven humans to acquire more knowledge (learn), but has also compelled them to try to understand how they do so (Bigge, 1982).

From this desire to understand how humans learn several theories have emerged. Proponents of the notion of mental discipline consider disciplines to have value beyond their content, meaning that the principal value of any subject is the training it can have on the human mind. In the notion of mental discipline, the mind is a non-physical entity with capacities for such things as memory, reason, imagination, and thought (called mind substance) that can be strengthened through use, can be brought into automatic operation through a frequency of use, and leads to the production of intelligent behavior. This training of the mind endures after content material is forgotten and is considered to be the most significant product of education. In this way, education leads to a development of skills that enables one to bear the responsibilities of citizenship (Bigge, 1982).

These non-physical capabilities of the mind (reason, thought, memory, etc.) can be seen as processes involved in Gestalt psychology, formally introduced by Max Wertheimer in 1912. Gestalt-field psychologists regard learning and perception to be
closely related. This viewpoint implies that a learner will group items so that they form a meaningful pattern that he/she will retain, called a law of good continuation, and represents the manner in which the learner perceives his/her environment and the premises upon which the learner will base his/her actions. This perpetual formation of meaningful patterns from environmental or experiential cues and the use of this knowledge to act in his/her own environment is a self-perpetuating cycle called simultaneous mutual interaction, or the SMI concept (Bigge, 1982). Learning according to Gestalt-field psychologists is the formation of insightful and meaningful relationships and involves changes in thought and viewpoints.

The continual development and formation of insight and relationships among pieces of information as learning occurs is foundational to constructivism. Constructivism is a psychological theory of how children learn that has been extended to the classroom setting. Although constructivism as a theory is generally attributed to Jean Piaget, whose theory has been termed cognitive constructivism, constructivist application is also heavily influenced by the work of Lev Vygotsky, whose theory has been termed socio-cultural constructivist theory. Constructivist frameworks from either theorist acknowledged that learners approach learning situations with personal mental constructs of existing knowledge, or schema, based on his/her past experiences. It is within this personal construct that learners interpret new information (termed assimilation by Piaget) and adjust their mental schemata (termed accommodation by Piaget), thus resolving the tension between existing knowledge and new data, and in the process forming a new mental construct based on the learning experience (Curtis & O’Hagan, 2003; Pass, 2004; Zelinsky-Wibbelt, 2000). Intermental activity leads to intramental development (Mercer,
This tension-resolution process is termed equilibration by Piaget and internalization by Vygotsky (Curtis & O’Hagan, 2003; Pass, 2004; Zelinsky-Wibbelt, 2000). Internalization/equilibration is the method in which learners progress from a low (prior)-level of functioning to one of higher (new)-level of functioning (Zelinsky-Wibbelt, 2000). The resolution of cognitive tension and imbalance leads to learning or intellectual growth (Rojas-Drummond, 2009).

A central aspect of constructivist theory is the use of dialogue, although the structure of the dialogue exchange is interpreted differently by the two theorists. Piaget’s theory of cognitive constructivism focused on the internal dialogue that a learner would have with himself/herself to make sense (the equilibration process) of data presented in a learning situation, whereas Vygotsky’s theory of socio-cultural constructivism emphasized dialogue between the learner and a social other (a teacher or fellow student) as the learner internalizes information (Jaramillo, 1996; Lehmann & Chamberlin, 2009; Pass, 2004). Vygotsky’s theory noted three threads that come together to describe cognitive development: understanding the mind involves investigating how it changes; social interaction is fundamental to higher mental activity; and social interaction and mental activity are driven by signs and tools, such as language (Hausfather, 1996).

Language use plays an important role in constructivist theory and provides the basis for interaction. Learning is a social process whereby learners resolve tension between environmental data and their personal schemata using social interaction with expression in the form of language or dialogue. In this way deep learning, understanding, and cognitive development occur (Jaramillo, 1996; Lehmann & Chamberlin, 2009; Pass, 2004). Vygotsky (1978) advanced the idea of the primacy of social interaction’s effect
on learning and development using language as the tool for this interaction in his socio-cultural constructivist theory, noting that learners can lead a more abundant intellectual life through collaborative activity than they can alone.

Conceptual Framework

Any activity that is socially oriented derives its educational value from the dialogue associated with it, including activities within the classroom (Reznitskaya et al., 2009). Mercer, Dawes, Wegerif, and Sams (2004) agree, stating, "...it is recognized that the quality of teaching and learning is dependent on the quality of classroom dialogues." (Mercer et al., 2004, p. 375). As stated previously as a reflection of Vygotsky's sociocultural theory, cognitive development depends on intermental interactions that support intramental activities (Mercer et al., 1999). Continuous negotiation of meaning through verbal speech allows knowledge and understanding to be reciprocally, mutually, and jointly created. The joint creation of knowledge and understanding occurs because talk allows ongoing negotiation of meaning (Mercer, 2010), since spoken language provides a way for learners to mutually share their mental processes and knowledge. Researchers in socio-cultural educational studies have noted that science education involves discourse since becoming familiar with the language of science itself inherently requires the use of language and social interaction to make meaning, transmit knowledge, and share conceptual understandings (Mercer et al., 2004). The cumulative research of Mercer and his associates supports the idea that socio-cultural use of language as a pedagogic tool provides the best theoretical foundation in the improvement of educational practice due to its considerable impact on the development of student reasoning (Mercer et al., 1999).
Verbal language use is especially important in science because of the specialized vocabulary associated with the subject that is used to illustrate concepts or explain processes. Spoken language provides a common way for learners to share conceptualizations of the content, describe observations, and develop reasoned arguments in the context of peer group interaction (Mercer et al., 2004). Previous studies in which Mercer and colleagues were involved included the use of Raven's Progressive Matrices test of non-verbal reasoning and showed marked improvement in post-test scores when compared to pre-test scores after the use of specific types of talk by students, even without practice with such tests and the types of problems associated with them (Mercer et al., 1999). The improved scores on the Raven's test validates the theoretical socio-cultural relationship between language and learning by illustrating that by engaging in verbal meaning making with peers as a matter of course, learners acquire ways of thinking that allows them to reason better as individuals and supports the idea that collective reasoning can influence individual thinking and learning (Mercer et al., 2004).

In order to study the language-learning connection, socio-cultural discourse analysis methods have been employed. These methods differ from linguistic discourse analysis in that they focus more on the content of spoken language and ways shared knowledge construction develops as opposed to organizational structures typical of common discourse analysis methods (Mercer, 2010). Mercer's research in classroom joint dialogue analysis has revealed three types of talk that occur. These are characterized by Mercer and his colleagues as Disputational, Cumulative, and Exploratory Talk. Disputational Talk is described as "...unproductive disagreement, characterized by an initiation (e.g. proposition, hypothesis, instruction) followed by a
challenge (be this a direct rejection or a counter-proposition/hypothesis). Such challenges typically lack clear resolution or else result in resolution that is not supported by agreement," (Littleton et al., 2005, p. 168). Disputational Talk usually involves competitive and individualized activity. Utterances tend to be short and there is a noted absence of explicit reasoning (Mercer et al., 1999). In noting what type of dialogue would comprise Cumulative Talk, Mercer and colleagues state, "...Cumulative Talk adds uncritically to what has gone before. Initiations are typically accepted either without discussion or with only superficial amendments," (Littleton et al., 2005, p. 168). And finally, in explaining the characteristics of Exploratory Talk, Littleton et al. (2005) state, "...[Exploratory Talk] demonstrates the active joint engagement of the children with one another's ideas. Whilst initiations may be challenged and counter-challenged, appropriate justifications are articulated and alternative hypotheses offered. ...in Exploratory Talk knowledge is made more publicly accountable and reasoning is more visible in the talk," (Littleton et al., 2005, p. 169).

Social Interaction and Learning

Classroom organization and structure, including the social environment, have a notable impact on student learning (Postholm, 2007), yet only fairly recently has the pivotal influence of the learner's social environment in intellectual growth been recognized (Moreno, 2009; Rojas-Drummond, 2009). Several principles have emerged based on psychological and educational research. First, individuals construct their knowledge by integrating new information and forming new association patterns with existing knowledge. Second, learners use well-established patterns of association in their mental functions that are difficult but possible to change. Third, learning is most
effectively accomplished in social situations (DeHaan, 2005). Governments and educational institutions have instituted programs to raise standards of learning and achievement. One way to accomplish these goals is to nurture interactions among students (Harrison, 2006). Evidence shows that active involvement in learning activities produces increased understanding, retention, and transfer as compared with lecture classes. In studies of peer instruction whereby learners must struggle with a problem and use dialogical techniques to defend their position or convince others of it, there is evidence that transforming what would be a passive lecture session into a more student-centered approach elicits deeper learning (DeHaan, 2005). When students invest intellectual effort in social tasks whose design is to produce an alteration of an individual's mental schema, students experience a type of learning that promotes further learning because of the additional processing involved in entertaining alternative perspectives and justifying, elaborating on, or clarifying one's own perspective. Learning is a social activity resulting from both a restructuring of a learner's mental constructs and from the interaction the learner has with others so that through shared effort meaning is made from new information (Moreno, 2009). Traditionally, however, classrooms encourage competition among learners which motivates some high achievers but is also a sure way to guarantee failure for others. In order to offset this effect, some teachers allow students to work alone or at their own pace, but these methods along with traditional didactic methods limit students' ability to learn from group interaction, which allows for the development of skills in areas such as introspection, teamwork, and critical thinking in addition to cognitive development that can benefit learners educationally and
in the global marketplace in which they will live, work, and participate (Strom & Strom, 1999).

The beauty of social interaction is that individuals bring with them different and various viewpoints, understandings, perspectives, and interpretations. Research that specifically studies relationship aspects of classroom environments shows that interpersonal relationships do exist within a classroom and can profoundly affect learning (Hadjioannou, 2007). Social learning involves participant engagement in a shared activity whereby joint attention is given to the problem at hand in order to develop a solution during which process there is a cognitive and social exchange (Hausfather, 1996). Providentially, beyond the cognitive development that occurs during socially constructed learning opportunities, Dangwal and Kapur (2009) note other effects of peer group interactions that create a synergistic learning environment. First, social learning provides enthusiasm and motivation that spurs each child to continue to desire to learn. Secondly, during the process of knowledge sharing there is a decrease of negative behavior and encouragement of positive behavior such as sharing and cooperation. Thirdly, some societal social skills were internalized such as respect, organizational skills, and a willingness to voluntarily assist others.

Socially-oriented learning tasks as compared to individualist tasks can have far-reaching effects including higher achievement, greater retention, better reasoning, accurate and creative problem-solving, willingness to persist toward goals despite difficulties, increased intrinsic motivation, and the ability to apply skills learned to various situations (Johnson et al., 2007; Strom & Strom, 2002). Group learning can combine diverse students so that new schema or knowledge structures are constructed
based on the interactions students have with each other and can even elevate students to greater achievement than they could have accomplished on their own (Moreno, 2009). Social interaction precedes learning (Vygotsky, 1978). Through cooperation and social knowledge sharing students can make connections between previous learning and new information, clarify their own knowledge and identify misconceptions, and fill in knowledge gaps that exist in their own minds (Moreno, 2009). Learners, including college students, will bring with them skill sets, beliefs, knowledge, and ways of approaching new learning situations. Learners will connect new information or problem-solving tasks that are presented to them to what their existing mental constructs. In order to truly progress in learning, students need to employ certain metacognitive strategies including evaluating the connections between new and existing knowledge and utilizing thinking strategies in a specific and deliberate manner. There should be a marriage in cognitive thought within a learner’s mind between factual knowledge and strategic procedural knowledge that allows one to solve new and unfamiliar problems. Metacognitive strategies can be developed in learners through social interaction with others (DeHaan, 2005).

In studies of minimally invasive education by Dangwal & Kapur (2009) whereby a computer is mounted in a public place and left for children to use, learning to use the computer is accomplished by groups of children that teach, model for, and imitate each other and throughout the learning process carry on a continuous dialogue with each other. This social group interaction not only provides the stimulus for learning but provides the tools necessary for continued learning leading to the development of what is called "social networking," (Dangwal & Kapur, 2009, p.7). "Social networking is the process of
linking, that is, the way a child connects with another to create, construct a network or social group that she or he can then comes to depend upon in order to obtain or acquire information, as and when she or he needs it," (Dangwal & Kapur, 2009, p.7).

Sociocognitive instruction has as its basis classroom discussion and the exchange of ideas among learners. Sociocognitive instruction allows students, especially non-mainstream students, to constantly refine their understanding while at the same time cultivating strategies that will allow them to participate effectively in future discussions (Applebee, Langer, Nystrand, & Gamoran, 2003). Indeed, Mercer (2008) notes that learners internalize the dialogical strategies they have experienced in the classroom and use them as models in the future. Contemporary educational learning paradigms reflect a shift toward shared meaning making, calling for constructivist models of instruction and collaboration as opposed to teacher-centered methods (Dangwal & Kapur, 2009).

In studies of effective instructional methods, some researchers have looked at a process of envisionment which examines the ever-changing, constantly evolving understanding of students as they study literary texts. These studies have found that, at any time, a student's understanding is a mixture of hypotheses, questions, and connections to previous mental constructs. Classrooms that promote discussion exhibit the greatest envisionment which is correlated with greater and deeper understanding. In fact, classrooms can promote social processes that cultivate cognitive and linguistic aptitudes in students that will serve as tools for continued literacy by developing in them skills needed for comprehension and understanding, thinking and doing. There are documented relationships between social relations, learning, and development (Applebee et al., 2003; Mercer, 2008).
In a qualitative study of student experiences in a Norwegian teaching program organized around a Vygotskian framework, Postholm (2007) found that group activities were beneficial for learning and that the role of the teacher was expanded beyond what is considered traditional. Other studies support the social benefit to learning. In a study involving physics classes across the country there was a strong correlation between interaction with peers and learning gains in classes that involved social activity in solving physics problems and those that were more traditionally oriented toward lecture and workbook labs with limited or no interaction with peers (DeHaan, 2005). Relationships among students are important at the college level and can affect such things as academic and personal development, self-efficacy, skills for developing and maintaining interpersonal relationships (including communication skills), and achievement (Johnson et al., 2007; Moreno, 2009; Strom & Strom, 1999). Positive effects in these areas were seen in non-competitive academic environments. Increased achievement itself was shown to affect areas that would improve a student's chances of attaining a college education such as a lower risk of academic probation or dismissal, positive feelings regarding the relevance of a college education, continued intellectual investment in academics, and commitment to complete a degree (Johnson et al., 2007).

Higher Order Thinking Skills

For many years educational research has focused on how teachers teach and what students learn in different disciplines, including college science courses (DeHaan, 2005). Many educational institutions express the desire to create independence in their students within their stated mission statements or platforms expressing aims, objectives, and goals. Two characteristics of independence are an individual's desire and ability to maintain an
identity and the possession of higher mental processing skills that allow a person to individually perform tasks and in the process maintain their identity within the environment and culture in which the individual acts (Lockhorst, Wubbels, & Van Oers, 2010). Many sources point out that science education in particular should focus on application of knowledge, integration of specific concepts within an overall framework of the subject, and transference of knowledge and skills to situations outside the classroom instead of memorization, disjointed vocabulary, and rote recall (DeHaan, 2005).

Michael, Dickson, Ryan, and Koefer (2010) in a study of a tutoring program, found that underprepared students, when placed in situations whereby they are given occasion to generate responses, do so readily and also have the chance to practice interaction and verbal skills which are useful for developing analytical reasoning, something in which students in this study were deficient and which, if improved, would contribute to success in coursework.

However, the ways in which the aforementioned noble goals can be achieved are not so clear. One way to cultivate and develop higher-order thinking skills which can advance higher mental functioning is the use of socio-culturally designed activities that involve dialogue. "Higher mental functions are basic cultural competencies that draw upon natural dispositions but have gradually been extended across generations of people to include sophisticated forms of thinking and acting with the help of signs and symbolic tools," (Lockhorst et al., 2010, p. 100) and include such skills as cooperation, decision making, and problem solving using such processes as analyzing, synthesizing, decoding, etc. As students engage in meaningful activities they are called upon to develop and use these advanced skills. Activities should be designed to call upon advanced forms of
thought and students should be free to formulate decisions and act upon them. From a socio-cultural viewpoint language provides one of the aforementioned tools whereby learners engaged in collaborative activies are exposed to language models that can then be imitated and internalized and dialogue between students and teachers is also important in developing understanding (Lockhorst et al., 2010). Although widely accepted as a tool for gaining, sharing, and constructing knowledge, observational studies show that systematic language use as a means of social meaning making are rare (Mercer et al., 1999).

Dialogue

Dialogue is a crucial and indispensable conduit through which learning and understanding is achieved (Postholm, 2007). Harrison (2006) expounds on this idea by proposing that language more so than text fosters learning, that the power to formulate ideas is greater in oral communication than in written, and that a majority of people form thoughts through interaction with others. "We now understand from studies in fields such as linguistics and discourse analysis that language is not simply a medium to communicate thoughts. Rather, it is an active determinant of understanding. Learners do not build internal mental models of the world independent of the language necessary to express those models," (DeHaan, 2005, p. 257). Learning is enhanced by social interaction that is mediated by language use among learners. Allowing students to voice their ideas and listen to and discuss others' ideas is especially effective in cognitive development (DeHaan, 2005). Classroom dialogue makes crucial contributions to the development of thinking skills and academic achievement (Mercer, 2008) and promotes a
transferable competence that is commonly considered a desirable educational outcome (Mercer et al., 2004).

In studies relating dialogue frequency within the home to cognitive and social development, it was noted that children of professional, working class, and social assistance parents have different frequencies of talk in which the children are involved with the frequencies being highest in professional families, less in working class families, and markedly less in welfare families. As frequencies of talk within the home decreases, there is a notable correlation with cognitive and social disadvantages in the children (Harrison, 2006). Mercer (2008) also notes the relationship link of language to learning and the lack of opportunity for verbal exchange outside of school which can affect a student's level of achievement. Dialogue within the classroom may be a way to close the learning differentials among learners from different backgrounds, and conversely, without dialogical emphasis, the gap in achievement of different students can only continue to widen (Harrison, 2006). Considering the importance of dialogue to learning, its scarcity is perplexing (Adler et al., 2004).

In socio-cultural learning theories (constructivism), language is considered to be the integral link between external and internal processes (Postholm, 2007). Language as a cultural artifact is both material and conceptual, and a primary way that individuals interact with the world and with each other (Hausfather, 1996). Language is uniquely enabling in its ability to foster the development of relationships, reasoning, and understanding among people (Mercer, 2010). It is through verbal exchange (both internally and among peers) that cognitive conflicts are expressed and resolved leading to a reorganization of a learner’s personal schemata (Rojas-Drummond, 2009; Harrison,
Vygotsky proposes that social interaction precedes internal cognitive development, and that language is the bridge between external socially influential factors and internal mental constructs (Postholm, 2007), and Mercer (2008) also states that his work has revealed the vital link between language and cognition. According to sociocultural theorists, "the social experience of language use shapes individual cognition," (Mercer et al., 1999, p. 96), via three crucial but integrated functions of language itself in promoting cognitive development. First, language is a cognitive tool whose use allows individuals to process knowledge. It is a tool for thinking. Language allows individuals to characterize and make clear their knowledge, experiences, and cognition (Mercer, 2008; Mercer et al., 1999). Secondly, it is a social tool which allows individuals to share knowledge. Third, language is a pedagogic tool that can be used by one individual to instruct or guide another (Mercer et al., 1999).

Current research is trending toward a focus on understanding how social interaction with peers and adults shapes an individual's thinking (Mercer et al., 1999). Within this social relationship, the mind is constantly changing as the individual participates and influences the environment and in turn the environment influences the individual (Hausfather, 1996). A key feature noted by Dangwal and Kapur (2009) in their studies of minimally invasive education and peer group learning is that children maintain an ongoing dialogue with each other to support their mastery of a given task and by doing so eventually develop the skills to perform the task independently. Dialogue is a vital and necessary component of meaning making from a constructivist viewpoint, and as Harrison (2006) notes is essential in forming socially-constructed knowledge. As
Harrison (2006) states, "Classroom talk should not be used simply for the teacher to instruct but for the learner to develop," (p. 69).

In studies of United Kingdom classrooms, it was noted that teachers control what is said and generally ask one-word-answer questions thereby slanting dominance of classroom dialogue in their favor which has two effects: it limits the amount of expression and shared cognition among learners, and secondly it prohibits teachers from gaining adequate assessment of learners' existing knowledge base (Harrison, 2006).

**Dialogical Instruction**

Dialogism is considered to be an interchange in which no single participant has dominance in a conversation. In the classroom, dialogism supports a rejection of static knowledge and instead highlights an instructor's involvement in classroom activities such as overseeing student conversations, emphasizing metacognition, and the creation of a non-authoritarian learning environment where students collaborate and construct meaning with each other based on a designated activity or learning prompt (Dorion, 2009; Reznitskaya et al., 2009). Participants listen to multiple perspectives and use these to construct and direct their own input (Hadjioannou, 2007). Dialogical talk provides a platform for students to explore ideas using higher order thinking skills such as comparing and contrasting, taking a position, challenging other's positions, developing an argument, providing supporting evidence, and responding to counterarguments (Dorion, 2009; Reznitskaya et al., 2009). "...potentially it [dialogue] can create classroom experiences that are authentic, inclusive, and rational," (Reznitskaya et al., 2009, p. 30). However, the educational and cognitive development potential of dialogical interaction,
especially among students, is not being used to full advantage in the classroom (Mercer et al., 1999).

Although still uncommon, some researchers have begun designing and employing analytical frameworks for the investigation of the dialogic qualities of classroom discourse between students and students and teachers while other researchers specifically investigated learning gains of students involved in dialogic classroom discussions (Reznitskaya et al., 2009). A study by Applebee et al. (2003) found that students, regardless of track level, showed higher literacy skills when the instruction within their English course was based on discussion. One particular advantageous feature of dialogic teaching is the free exchange between participants regardless of their status within the classroom. This allows students and teachers alike to create meaning amongst themselves but in no way reduces the authority or negates the expertise of the teacher (Reznitskaya et al., 2009).

Dialogically-oriented instruction provides opportunities for students to practice skills involved in conversation, debate, and argumentation that will be of enduring value (Reznitskaya et al., 2009). Language is complex. It is intricate in structure and function and is governed by social conventions and culturally applied understandings, yet it is the instrument of negotiation of meaning and transmission of knowledge and is closely bound to cognition (Hadjioannou, 2007). An appropriately applied quote from N. Burbules is used by Reznitskaya (2009) saying, "answers, solutions, and agreements are fleeting things in human history - while the fabric of dialogical interchange sustains the very human capacity to generate and revise those provisional outcomes," (p. 43). Dialogic instruction and curriculum conversations are components of effective
discussion-based instructional methods that aid understanding (Applebee et al., 2003). Dialogical instruction provides cooperative social opportunities whereby learners can practice self-regulation of their existing mental models of reality with new insights gained through interaction in a joint meaning-making effort (DeHaan, 2005; Harrison, 2006; Kasworm, 2003). This regulation of learning not only reveals a learner's sense-making perspective to others in a group, but also to the learner himself/herself (Harrison, 2006). In the absence of dialogical interchange, a learner is left with only his/her own thoughts and interpretations, is denied exposure to multiple possibilities and interpretations, and is thus denied the chance to evaluate the validity of different perspectives and their own mental schema in light of different perspectives (Hadjioannou, 2007).

Summary and Rationale for Study

Science invades personal, social, and political spheres of many people’s lives. In order to empower citizens to manage the influx of science in their lives, a basic knowledge of scientific concepts is called for in order for them to analyze the benefits and risks of science. In addition, science education should also enable students to gain social and personal skills that will enable them to act responsibly and successfully within society. It is the formal educational system that plays the fundamental role in creating a knowledgeable public.

In order to combat the lack of scientific literacy, the educational approach to teaching science must be examined. Bridges should be made between what is known about ways people learn and what teachers do in the classroom. Learning is most effectively accomplished in social situations, yet typically science education occurs in a
primarily didactic environment. A correlation between interaction with peers and learning gains in classes involving social problem solving has been shown. Such interaction involves the use of dialogue as the context through which knowledge and thinking are transmitted from one learner to another. Socially-oriented learning tasks as compared to individualistic tasks can have far-reaching effects including higher achievement, greater retention, better reasoning, accurate and creative problem-solving, willingness to persist toward goals despite difficulties, increased intrinsic motivation, and the ability to apply skills learned to various situations, thus supporting the idea that social interaction is fundamental to higher mental activity.

Learning is enhanced by social interaction that is mediated by language use among learners. Allowing students to voice their ideas and listen to and discuss others' ideas is especially effective in cognitive development. Spoken language provides a way for learners to mutually share their mental processes and knowledge and thus has a considerable impact on the development of student reasoning. By engaging in verbal meaning making with peers, learners acquire ways of thinking that allows them to reason better as individuals. However, the educational and cognitive development potential of dialogical interaction is not being used to its full advantage in the classroom.

Social construction of knowledge using language as a tool can narrow educational outcome gaps seen among different types of learners, many of whom populate community college campuses. Community colleges enroll a diverse and unique population of students. Academia and social interactions play an influential role in the lives of community college students as most are entering college for the first time regardless of age. Many are first-in-the-family college students, and many are from
lower socio-economic backgrounds with minimal support systems. Sociocognitive instruction allows students, especially non-mainstream students, to constantly refine their understanding while at the same time cultivating strategies that will allow them to gain essential life skills. Contemporary learning paradigms reflect the importance of shared meaning making, and call for constructivist models of instruction and collaboration as opposed to teacher-centered methods, as the more student-centered approach elicits increased understanding, retention and transfer. This research supports the development of social learning activities in order to promote constructivist teaching and social knowledge construction in undergraduate biology.
CHAPTER III

METHODOLGY

Introduction

Scientific literacy is a global aspiration. In order to be considered scientifically literate, an individual must possess and effectively use process skills, social skills, critical thinking skills, content knowledge, evaluation skills, interest in, and confidence when confronted with science in everyday life. Best-practice methods are continuously devised to promote the attainment of scientific literacy. One proposed best method is the use of social learning activities, especially those using talk, or verbalized, shared cognition. The purpose of this project was to focus on content mastery and quantitatively determine if social learning opportunities affected such mastery in a gateway biology course and to qualitatively identify the types of talk students engage in during cognitive collaboration.

Research Design

A mixed-method approach consisting of both quantitative and qualitative components was used to examine student dialogue and its influence on biology content knowledge acquisition (learning) in students enrolled in a gateway biology course at a southern community college. Social dialogue was the proposed vector for knowledge construction among group members, as spoken language has been shown to be a critical component of learning.

Two sections of a gateway introductory biology class were included in this study. The instructor acted as both teacher and researcher. Equitable lectures in both time and depth were delivered to both class sections regardless of whether or not they were acting under the treatment condition (participation in social learning activities). The syllabus was organized such that no beginning or ending of units was noted by date. A conscious
organizational effort was made to keep both sections progressing through the material at the same pace. In short, effort was made to keep both conditions, control and experimental, alike except for participation in social learning opportunities. Acting as researcher, the instructor also made the above provisions in order to maintain equivalency between the control and experimental conditions; administered all instruments (pretests, posttests, and social learning opportunities); and analyzed both the quantitative and qualitative data.

This study examined content knowledge acquisition in nine units of introductory biology. Each unit comprised the state-required community college core curriculum for the gateway biology course in which this study was conducted. Table 1 summarizes the topics covered in each unit for the purposes of this study.

Table 1

*Description of Topics Covered by Unit*

<table>
<thead>
<tr>
<th>Unit Number</th>
<th>Topic(s) Covered</th>
<th>Table Reference Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General biological knowledge review: taxonomy, energy flow, characteristics of living things, evolution</td>
<td>Intro to Bio</td>
</tr>
<tr>
<td>2</td>
<td>Physical chemistry: atomic structure, bonding, properties of water</td>
<td>PChem</td>
</tr>
<tr>
<td>3</td>
<td>Organic molecules: carbohydrates, lipids, proteins, nucleic acids</td>
<td>Org Chem</td>
</tr>
<tr>
<td>4</td>
<td>Cell organelles, cell structure</td>
<td>Cell Struc</td>
</tr>
<tr>
<td>5</td>
<td>Cell membrane structure and function</td>
<td>Cell Mem</td>
</tr>
</tbody>
</table>

Each class section was randomly assigned to a treatment condition for each of the nine units prior to the first day of instruction so that one section was randomly assigned to receive social learning activities for four units and the other section was randomly assigned to receive social learning activities for the five remaining units. A pretest prior to instruction on each of nine units and a posttest at the completion of each of nine units were administered to both sections. After administration of the pretest, lecture on the unit topic was given to both classes. After the lecture, sections received or did not receive a social learning activity for that particular unit's content based on the random assignment into treatment conditions that occurred prior to the first day of instruction. Thus, one class participated in social learning activities, the treatment condition, and the other class did not participate in social learning activities and was released from class for each of nine topics. Each of the nine units proceeded sequentially this way, so that for approximately half the content, each student was subjected to the treatment, and for approximately half the content each student was not. The assignment into treatment conditions was random. Upon collection of data, pretest and posttest scores for all

<table>
<thead>
<tr>
<th>Unit Number</th>
<th>Topic(s) Covered</th>
<th>Table Reference</th>
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</thead>
<tbody>
<tr>
<td>6</td>
<td>Enzyme function, photosynthesis, cell respiration</td>
<td>Metab</td>
</tr>
<tr>
<td>7</td>
<td>Mitosis, meiosis</td>
<td>Mit/Meiosis</td>
</tr>
<tr>
<td>8</td>
<td>Genetics</td>
<td>Heredity</td>
</tr>
<tr>
<td>9</td>
<td>DNA structure, replication, transcription, translation</td>
<td>DNA to Prot</td>
</tr>
</tbody>
</table>
students were evaluated, mean pretest and posttest scores were determined for control and experimental conditions, and mean gain scores were calculated.

Qualitative analysis of peer group conversations recorded with student consent during social learning activities was performed and the data analyzed for the presence of Disputational, Cumulative, and Exploratory talk based on a model developed through research involving Neil Mercer and colleagues (Appendix D). Figure 2 outlines the differences in the three types of talk.

*Figure 2*. Description of Types of Talk.

Participants

Participants consisted of 57 undergraduate students enrolled in two class sections of a gateway introductory biology course at a southern community college. All participants were 18 years of age or older. A majority of the participants were female (61.4%). Caucasians comprised a majority of the ethnic groups (57.9%). Table 2 (p. 49) shows a representation of the demographic characteristics of the participants based on gender and ethnicity. After successful submission and approval by the Institutional
Review Board of the University of Southern Mississippi to conduct research (Appendix A), data collection began.

Instrumentation

A pretest and posttest (Appendix H) was administered in all units of the biology curriculum as the unit was approached within the context of the course. These tests were modified versions of the recommended test questions that accompany the text used exclusively for the gateway biology course by the community college where the research occurred. Under the college's contract with the publisher, use of the test bank material was permitted (Appendix F). Social learning activities (Appendix G) were completed immediately following lecture under experimental conditions for each of the nine units. These activities were modified versions of the recommended activities that accompany the text used exclusively for the gateway biology course by the community college where the research occurred. Under the college's contract with the publisher, use of the activity material was permitted (Appendix E). Dialogue generated among group members as they participated in the social learning activity was recorded, analyzed, transcribed, and coded using a model developed through research by Neil Mercer and colleagues (Appendix D). Social learning activities occurred immediately following lecture for the experimental condition and were not bound by time restrictions. The controlled condition was released from class following the posttest.

Procedures

Permission to conduct this research was requested and obtained from the University of Southern Mississippi’s Institutional Review Board. During the first class meeting, students were informed orally by the researcher and with a participant research letter and informed consent form of the inclusion of the research project within the
parameters of the course. As part of the research overview, students were informed that all units would have a pretest and a posttest that every student would take regardless of willingness to participate in the research. Students were also informed that only the posttest results would count as part of the grade for each student, regardless of willingness to participate in the research. Students were informed that there would be times during the course that the researcher would record group conversations occurring within the classroom among group members. The researcher read the research participant letter (Appendix C) to the students and questions were answered. Students were assured of confidentiality and anonymity through all phases of the research and in future publication of such research. Students were assured that they could withdraw from the study at any time with no penalty or retribution from the researcher. Students were assured, and it was noted in the documents given to them, that this study met IRB approval and thus carried no risk to humans beyond that associated with everyday life.

Students were asked to read the informed consent form (Appendix C) and indicate their willingness to participate in the research or not. The researcher was not in the room when consent forms were signed and collected. Students signed up for a code name by placing their signature next to a code on a form listing all codes the first day of class. Students used this code when taking pretests and posttests. Informed consent forms were collected, sorted into participant/non-participant categories, and stored by an independent party who was in no way associated with this research. The researcher graded the pretests and posttests, entered the grades by code, and passed these results to the independent party who noted the grades for those participating. The independent party created a list indicating the grade for each student by name, both those participating and
those not participating, and gave to the researcher to input as grades that applied to the final course grade. For purposes of analysis, the independent party reported correlated results of the pretests and posttests to the researcher using only code names of those who agreed to participate in the research. For the purposes of qualitative analysis, the independent party informed the researcher of those not willing to participate in the research so that the participants could be randomly grouped together and the non-participants could be randomly grouped together during the social learning activities.

Students were given the first unit's pretest on the first day of instruction prior to lecture. Those students who were absent on the first day were individually informed of the research project, given the opportunity to participate, and given the pretest. After administration of the pretest to each class section for each of the nine units as they occurred within the context of the course, lecture on the unit topic was given to both groups. Once the lecture was complete, the class section randomly assigned prior to the first day of instruction to receive a social learning activity for that particular unit's content participated in such social learning activity and peer discussion among small group members was recorded. Social learning activities occurred immediately following lecture for the experimental condition and were not bound by time restrictions. The controlled condition was released from class following the posttest. Thus, one class section received the social treatment (experimental condition), and the other section did not receive the treatment (controlled condition) for each particular unit. Social learning activities distributed to those not willing to participate in the research were printed on certain colors of paper, and social learning activities distributed to those willing to participate in the research were printed on certain colors of paper. This helped the
students define themselves as color groups rather than participants/non-participants, when in reality the colors were associated by the researcher as participant/non-participant and denoted the accessibility of the data by informed consent. Recorded transcripts were coded for types of talk and transcribed according to a model developed by Mercer and colleagues which includes Disputational, Cumulative, and Exploratory talk. Each of the nine units proceeded sequentially this way, so that for approximately half the content, the students were subjected to the treatment and for approximately half the content they were not. The assignment into treatment groups was random and done prior to the first day of instruction.

**Delimitations**

Participants in this study were limited to students in gateway biology classes at a small southern community college. Only data from those students who provided informed consent was used in the study, although all posttests counted as grades for each student regardless of whether or not the student gave consent for participation in the research.

**Limitations and Discussion**

A potential limitation of this study is the population sample. Subjects were drawn from two sections of gateway biology at a small southern community college. The results of this study may not be able to be generalized beyond the same community college population. Also, only topics in the subject of cell biology were used in this study, and that, too, may limit generalizations to college courses as a whole. Some students may have also shied away from having their comments recorded and may not
have participated as fully as they were capable of in the peer group discussion of the social learning activities.

Justification

Increasingly, individuals and society must make personal, moral, or political decisions regarding scientific advancements, yet sadly, many Americans have poor scientific literacy and skill sets that enable them to knowledgeably and confidently engage in discourse regarding such matters. However, the content knowledge component of scientific literacy can be improved if methods or tools are used to increase learning. One such method is the employment of social constructivism, specifically through the use of dialogue where language is the tool of communication between learners. The rational and reasoned discussion that social dialogue can produce can be extrapolated to the larger life skill of informed judgment development regarding complex issues. Students whose classroom experience is primarily discussion-based are equipped with knowledge and internalized skills that allow them to perform individually and successfully in future literacy tasks (Applebee, Langer, Nystrand, & Gamoran, 2003). Reflecting upon the call for a scientifically-literate, engaged citizenry and the role of dialogue in creating such critical and active citizens, the importance of social dialogue in developing cognitive constructs of the learner regarding phenomena that is not directly observable and in the formation of reasoning skills cannot be ignored.

There is a relative dearth of research empirically linking dialogue and student learning. There is a pressing need to conduct such research and provide empirical evidence linking participation in classroom talk with educational outcomes (Mercer, 2010). This lack of research serves to perpetuate the lack of dialogue as an instructional
method as pedagogical knowledge must come chiefly from theoretical sources leaving instructors very little real-world application models so that teachers seem to be unaware of methodologies that support the development of social knowledge and higher-order thinking skills and tend to focus on recitation methods of instruction. This is especially critical at the college level where habitual teaching methods tend to be didactic. Social construction of knowledge using language as a tool during dialogical exchange has promise in accomplishing complex educational outcomes such as informed judgment, critical analysis skills, and reasoned argumentation (all components of scientific literacy), and can narrow educational outcome gaps seen among different types of learners many of which populate community college campuses. Research indicates that children from low socio-economic status, foreign language students, and low achievers are more effective in classrooms using this type of instructional method as it capitalizes on existing knowledge and ideas as opposed to more traditional methods which tend to emphasize weaknesses in these types of students.

Data Analysis

Descriptive analysis was used to address the following research question:

- What specific types of talk exist in peer-group conversations during social learning activities: Disputational Talk, Cumulative Talk, or Exploratory Talk?

At the end of the course, analysis of voice-recorded dialogue that occurred during the social learning activities was performed. Five recorded dialogues for each unit were listened to and analyzed for the presence of the three types of talk. In order to determine the talk type, the voice recordings were played, listened to, and verbal interchanges
among group members were considered. Transcription of the talk was performed by the researcher. If a segment of the talk seemed argumentative, it would have been coded as disputational. Argumentative talk is considered to be verbal interchange involving commands on how to do something within the bounds of the activity or who should do it. The verbal exchange is not so much about the content as to how to accomplish the task. Reasoning about the subject content is not evident in the talk. The tone of the exchange denotes competition for job roles, not conflict in intellectually reasoning through material to arrive at a best answer. If initiations or contributions by group members were accepted by the other group members with no discussion, the type was coded as cumulative. This acceptance was noted by either a repeat of the proposed answer or a verbal affirmation of acceptance, such as "OK" or "Sounds good." If no reasoned support for the answer as correct was forthcoming or if no other possible answers were offered and supported with verbal reasoning and if the group moved on to the next item in the social learning guide, the talk was coded as cumulative. If the talk sequence consisted of verbal contributions where students were reasoning through a topic (as evidenced by discussion of the content material), questioning each other, and/or justifying answers, the talk was coded as exploratory.

To test the research hypotheses, several statistical approaches were used. Descriptive statistics defined means of pretests, posttests, and gain scores. A repeated measures ANOVA was used to analyze differences in the pretest and posttest scores for each condition. Mean gain scores between the control and experimental conditions were analyzed using a one-way ANOVA. All quantitative analyses were done using SPSS (Version 20.0, Sept, 2012).
Statistical analyses were used to address the following research questions:

- What differences exist in pretest and posttest scores when students participate social learning activities and when they do not in gateway undergraduate biology courses?
- What differences exist in gain scores when students participate in social learning activities and when they do not in gateway undergraduate biology courses?

At the end of the course, all pretest and posttest data were statistically analyzed. Pretest and posttest scores were analyzed using frequency and descriptive statistics and a repeated measures ANOVA. Gain scores were calculated for both treatment conditions and analyzed using ANOVA.

Summary

In summary, this study sought to determine if participation in social learning activities using verbal language as a tool for joint meaning making with peers made a difference in the mastery of content among community college students enrolled in gateway biology courses. In order to assess the effect of social learning activities on content mastery, differences in pretest and posttest scores and differences in gain scores of the treatment conditions were statistically analyzed. In addition to statistical analysis, qualitative analysis of peer group discussion determined the talk types which occurred during social learning activities.
CHAPTER IV
RESULTS

This study investigated the use of social learning opportunities within the classroom and their impact on content mastery in gateway biology courses. This study also sought to identify types of talk that students engage in during cognitive collaboration. Data collection occurred at a small southern community college within two class sections of introductory biology during the fall semester of 2012. Analysis of data examined differences between in pretest and posttest scores of students in each treatment condition, control and experimental, in gateway undergraduate biology courses. Analysis of data also examined differences in the gain scores of students involved in social learning activities (experimental condition) and those who were not (controlled condition). Additionally, this study sought to determine what specific types of talk exist in peer-group conversations during social learning activities based on research done by Neil Mercer and colleagues.

The study included a total of 57 participants (N = 57). Table 2 shows a representation of the demographic characteristics of the participants based on gender and ethnicity. Of the participants, a majority were female (61.4%) and Caucasian (57.9%).

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>35</td>
<td>61.4</td>
</tr>
</tbody>
</table>

Frequency Statistics of Gender and Ethnicity
Table 2 (continued).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>22</td>
<td>38.6</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>33</td>
<td>57.9</td>
</tr>
<tr>
<td>African American</td>
<td>16</td>
<td>28.1</td>
</tr>
<tr>
<td>Other</td>
<td>8</td>
<td>14</td>
</tr>
</tbody>
</table>

Findings

This study examined content knowledge acquisition in nine units of introductory biology. Each unit comprised the state-required community college core curriculum for the gateway biology course in which this study was conducted. Table 1 (p. 50) outlines the topics covered in each unit.

Several statistical approaches were used in the analysis of data, including frequency and descriptive statistics, *t*-tests, and ANOVA. In order to determine if the two class sections were equivalent prior to the study, a *t*-test was conducted to determine whether significant differences existed between the control and experimental conditions' pretest for each unit. Eight of the nine *t*-tests were non-significant indicating no pre-existing differences between control and experimental conditions, except for Unit 6, in which those in experimental condition scored significantly lower than those in the controlled condition. Table 3 shows the pretest means used to determine equivalency between the conditions in each unit and the significance values computed in the ANOVA.
Table 3

*Levene's Test for Homogeneity of Variance*

<table>
<thead>
<tr>
<th>Condition Unit</th>
<th>N</th>
<th>Pretest Mean</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Gen Bio</td>
<td>28</td>
<td>56.4</td>
<td></td>
</tr>
<tr>
<td>Exp Gen Bio</td>
<td>27</td>
<td>63.7</td>
<td></td>
</tr>
<tr>
<td>Control PChem</td>
<td>28</td>
<td>17.3</td>
<td></td>
</tr>
<tr>
<td>Exp PChem</td>
<td>27</td>
<td>11.8</td>
<td></td>
</tr>
<tr>
<td>Control Org Chem</td>
<td>28</td>
<td>33.0</td>
<td></td>
</tr>
<tr>
<td>Exp Org Chem</td>
<td>26</td>
<td>38.8</td>
<td></td>
</tr>
<tr>
<td>Control Cell Struc</td>
<td>26</td>
<td>38.5</td>
<td></td>
</tr>
<tr>
<td>Exp Cell Struc</td>
<td>24</td>
<td>42.6</td>
<td></td>
</tr>
<tr>
<td>Control Cell Mem</td>
<td>24</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Exp Cell Mem</td>
<td>23</td>
<td>55.7</td>
<td></td>
</tr>
<tr>
<td>Control Metab</td>
<td>26</td>
<td>82.3</td>
<td></td>
</tr>
<tr>
<td>Exp Metab</td>
<td>23</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Control Mit/Meiosis</td>
<td>24</td>
<td>38.5</td>
<td></td>
</tr>
<tr>
<td>Exp Mit/Meiosis</td>
<td>22</td>
<td>44.1</td>
<td></td>
</tr>
<tr>
<td>Control Heredity</td>
<td>22</td>
<td>60.6</td>
<td></td>
</tr>
<tr>
<td>Exp Heredity</td>
<td>25</td>
<td>59.4</td>
<td></td>
</tr>
<tr>
<td>Control DNA to Prot</td>
<td>27</td>
<td>39.6</td>
<td></td>
</tr>
<tr>
<td>Exp DNA to Prot</td>
<td>27</td>
<td>44.4</td>
<td></td>
</tr>
</tbody>
</table>

* indicates a significant difference

Next, pretest and posttest mean scores were compared between conditions for each unit. Gain scores were then calculated by subtracting the pretest score from the posttest score for each subject and the mean gain score for each condition was determined by unit. Table 4 shows the mean pretest, mean posttest, and mean gain score per condition for each unit.
Table 4

*Mean Pretest, Mean Posttest, and Mean Gain Score per Condition by Unit*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Unit</th>
<th>N</th>
<th>Pretest Mean</th>
<th>SD</th>
<th>Posttest Mean</th>
<th>SD</th>
<th>Gain Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>ConGenBio</td>
<td>ExpGenBio</td>
<td>282</td>
<td>56.4</td>
<td>18.7</td>
<td>67.5</td>
<td>14.0</td>
<td>11.1</td>
</tr>
<tr>
<td>ConPChem</td>
<td>ExpPChem</td>
<td>28</td>
<td>17.3</td>
<td>20.0</td>
<td>56.6</td>
<td>23.9</td>
<td>39.3</td>
</tr>
<tr>
<td>ConOrgChem</td>
<td>ExpOrgChem</td>
<td>28</td>
<td>33.0</td>
<td>15.4</td>
<td>42.3</td>
<td>17.6</td>
<td>9.3</td>
</tr>
<tr>
<td>ConCellStruc</td>
<td>ExpCellStruc</td>
<td>26</td>
<td>38.8</td>
<td>22.2</td>
<td>56.7</td>
<td>18.4</td>
<td>17.9</td>
</tr>
<tr>
<td>ConCellMem</td>
<td>ExpCellMem</td>
<td>24</td>
<td>42.6</td>
<td>19.9</td>
<td>63.8</td>
<td>21.7</td>
<td>21.2</td>
</tr>
<tr>
<td>ConMetab</td>
<td>ExpMetab</td>
<td>26</td>
<td>82.3</td>
<td>17.3</td>
<td>84.6</td>
<td>18.2</td>
<td>2.3</td>
</tr>
<tr>
<td>ConMit/Meio</td>
<td>ExpMit/Meio</td>
<td>24</td>
<td>38.5</td>
<td>17.0</td>
<td>60.3</td>
<td>21.1</td>
<td>21.8</td>
</tr>
<tr>
<td>ConHeredity</td>
<td>ExpHeredity</td>
<td>22</td>
<td>44.1</td>
<td>21.6</td>
<td>82.0</td>
<td>13.0</td>
<td>37.9</td>
</tr>
<tr>
<td>ConDNAProt</td>
<td>ExpDNAProt</td>
<td>27</td>
<td>60.5</td>
<td>27.2</td>
<td>71.7</td>
<td>25.0</td>
<td>11.1</td>
</tr>
<tr>
<td>ConDNAProt</td>
<td>ExpDNAProt</td>
<td>27</td>
<td>59.4</td>
<td>27.1</td>
<td>92.8</td>
<td>11.6</td>
<td>33.4</td>
</tr>
<tr>
<td>ConDNAProt</td>
<td>ExpDNAProt</td>
<td>27</td>
<td>39.6</td>
<td>18.7</td>
<td>63.0</td>
<td>19.4</td>
<td>23.3</td>
</tr>
<tr>
<td>ConDNAProt</td>
<td>ExpDNAProt</td>
<td>27</td>
<td>44.4</td>
<td>21.9</td>
<td>85.6</td>
<td>12.2</td>
<td>41.1</td>
</tr>
</tbody>
</table>

Descriptive analysis shows that for each unit, the posttest score means were higher than the pretest score means for both conditions in each unit. Importantly, for each unit, students in the experimental condition had a higher posttest mean than students in the control condition. Both conditions showed positive gain scores between the pretest
and posttest. Notably, for each unit, students in the experimental condition had a larger mean gain than students in the controlled condition.

**Results of Research Question One**

What is the impact of social learning activities on scientific content knowledge acquisition?

My analysis of descriptive statistics illustrates a difference in mean posttest scores and mean gain scores between the controlled and experimental conditions. For each unit, mean posttest and mean gain scores were higher when students participated in social learning activities than when they did not. These results indicate that participation in social learning activities improved content knowledge beyond that of solely exposure to lecture on content material.

**Research Sub-problems and Hypotheses**

Research sub-problem one stated: What differences exist in pretest and posttest scores when students participate in social learning activities and when they do not in a gateway undergraduate biology course?

**Results of Research Hypothesis One**

Research hypothesis one stated: There will be a significant difference in the pretest and posttest knowledge scores when students participate in social learning activities and when they do not.

A repeated-measures ANOVA (Appendix I) was conducted for pretest/posttest comparisons across all units for all students when they were in the experimental condition compared to when they were in the controlled condition. This repeated-measures ANOVA determined if the treatment (participation in social learning activities)
impacted content knowledge acquisition across all units (in an overall way). For each student a pretest and posttest mean was calculated for all units when the student acted in the controlled condition and a pretest and posttest mean was calculated for all units when the student acted in the experimental condition. A significant difference existed between pretest and posttest knowledge scores when students participated in social learning activities compared to when students did not, $F(3,168) = 148.83, p = .000$. Appendix I shows the ANOVA table for this analysis. This result supports the use of talk to improve biological content knowledge. Figure 3 shows the mean pretest and posttest scores of students when they were acting in the controlled condition and when they were acting in the experimental condition.

![Pretest & Posttest Mean Score Per Condition](image)

*Figure 3. Pretest & Posttest Mean Score by Condition.*
Research sub-problem two stated, what differences exist in gain scores when students participate in social learning activities and when they do not in gateway undergraduate biology courses?

*Results of Research Hypothesis Two*

Research hypothesis two stated, there will be a significant difference in gain scores when students participate in social learning activities and when they do not.

A one-way ANOVA (Appendix J) was conducted for each of the nine units to compare differences in gain scores of students who participated in social learning activities and those that did not. Four of the nine units provided statistically higher results in the gain scores of students in the experimental condition when compared to students in the controlled condition. Table 5 shows the units with statistical differences in the gain scores, the mean gain scores for control and experimental conditions, and the significance values.

Table 5

*Mean Gain Scores and Significance Values of Units with Significant Differences in Gain Scores Between Control and Experimental Conditions*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Unit</th>
<th>N</th>
<th>Gain Score</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Physical Chemistry</td>
<td>28</td>
<td>11.1</td>
<td>F(1,53) = 20.7, p = .000</td>
</tr>
<tr>
<td>Experimental</td>
<td>27</td>
<td>18.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Mitosis/Meiosis</td>
<td>24</td>
<td>21.8</td>
<td>F(1,44) = 6.50, p = .014</td>
</tr>
<tr>
<td>Experimental</td>
<td>22</td>
<td>37.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Heredity</td>
<td>22</td>
<td>11.1</td>
<td></td>
</tr>
</tbody>
</table>
Table 5 (continued).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Unit</th>
<th>N</th>
<th>Gain Score</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>25</td>
<td>33.4</td>
<td>F(1,45) = 9.56, p = .003</td>
<td></td>
</tr>
<tr>
<td>DNA to Protein</td>
<td>Control</td>
<td>27</td>
<td>23.3</td>
<td>F(1,52) = 9.46, p = .003</td>
</tr>
<tr>
<td>DNA to Protein</td>
<td>Experimental</td>
<td>27</td>
<td>41.1</td>
<td></td>
</tr>
</tbody>
</table>

Research question two stated, what specific types of talk exist in peer-group conversations during social learning activities: Disputational Talk, Cumulative Talk, or Exploratory Talk?

In evaluating the types of talk used in the experimental condition's peer discussion during social learning activities in each unit, it was found that the types of talk that existed in the introductory biology course in which this study took place consisted of two types: cumulative and exploratory. No instances of disputational talk (argumentative with little application to content knowledge) were found. Table 6 summarizes the types of talk found by unit.

Table 6

*Types of Talk by Unit*

<table>
<thead>
<tr>
<th>Unit</th>
<th>Types of Talk Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Introduction to Biology</td>
<td>Cumulative and Exploratory</td>
</tr>
<tr>
<td>2: PChem</td>
<td>Cumulative and Exploratory</td>
</tr>
<tr>
<td>3: Organic Chemistry</td>
<td>Cumulative</td>
</tr>
</tbody>
</table>
Table 6 (continued).

<table>
<thead>
<tr>
<th>Unit</th>
<th>Types of Talk Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>4: Cell Structures</td>
<td>Cumulative and Exploratory</td>
</tr>
<tr>
<td>5: Cell Membranes</td>
<td>Exploratory</td>
</tr>
<tr>
<td>6: Metabolism</td>
<td>Cumulative</td>
</tr>
<tr>
<td>7: Mitosis/Meiosis</td>
<td>Cumulative</td>
</tr>
<tr>
<td>8: Heredity</td>
<td>Cumulative and Exploratory</td>
</tr>
<tr>
<td>9: DNA to Proteins</td>
<td>Exploratory</td>
</tr>
</tbody>
</table>

The following is an example of Cumulative talk which occurred during the unit on heredity. There is a noted absence of justification of answers by the persons proposing an answer and a noted absence of discussion or questioning of the proposed answers by other group members. There is a general progression of acceptance with no rebuttal through the content material. This type of exchange is defined by Mercer and colleagues as Cumulative Talk (Mercer et al., 1999).

Sarah (Reading from the social learning guide) A parental first generation and second generation offspring is a...

Morgan I guess it's nine.

Sarah Nine, yeah, that does sound right. Ok.

Morgan Molecular forms of the same gene...that is alleles.

Sarah Alleles. Particular location of a gene on a chromosome...

Morgan That's gene locus.
Sarah: Gene locus? Ok. Unit of information about specific traits passed from parents to offspring...

Morgan: That is genes.

Sarah: That is genes. Ok.

In the overall analysis of the cumulative talk, I noticed that cumulative talk tended to occur under two different conditions. First, it occurred when students were truly on the right track and the answers proposed were essentially correct, so the group felt there was no need for discussion and the proposer felt there was no need for justification and was not asked for any. The previous example is indicative of this situation. At other times, Cumulative talk occurred when students generally had very little knowledge of the topic (even after lecture) so that they were willing to accept any proposed answer. Their lack of knowledge of the topic did not give them the ability to generate other better alternatives or perhaps the students did not know that they even should.

The following is an example of Exploratory talk which occurred during the unit on DNA to proteins. There is a noted justification of answers by the persons proposing an answer and/or a noted discussion or questioning of the proposed answers by other group members. Reasoning is visible in the talk. This type of exchange is defined by Mercer and colleagues as Exploratory Talk (Mercer et al., 1999).

Emily: Explain what semi-conservative replication means.

Maria: It means it conserves half. Wait. Is this about when it goes from DNA to RNA? It conserves half the letters?

Emily: Not the letters necessarily.

Maria: Yes, remember it swaps from C to U.
Kevin: You mean A to U or T to U. Take out T and it's U now. I don't know. It could be introns and exons. Introns get taken out. I don't know.

Emily: It means the helix has one original strand and one new strand.

Trish: Strands of what?

Emily: Strands of DNA. Each double helix contains one original strand and one new strand.

Trish: I remember that now.

The previous example is indicative of exploratory talk. There is a noted discussion of the proposed answers by group members and even by the proposer himself/herself. Reasoning is visible in the verbal exchange among group members.

Summary

This study examined content knowledge acquisition in nine units of introductory biology to determine if biological content knowledge is improved through talk. Students acted in either the control or experimental condition for each unit. Several statistical approaches were used in this study including, descriptive statistics, t-tests, repeated measures ANOVA and one-way ANOVA in order to answer the research questions and address the research hypotheses. In order to determine if the two class sections were equivalent prior to the study, a t-test was conducted to determine whether significant differences existed between the control and experimental conditions' pretest for each unit. All tests were non-significant indicating no pre-existing differences between control and experimental conditions for eight of the nine units.
Descriptive statistics and repeated measure ANOVA were used for pretest/posttest analysis across all units for all students when they were in the experimental condition compared to when they were in the controlled condition. This repeated measures ANOVA determined if the treatment (participation in social learning activities) impacted content knowledge acquisition. A significant difference existed between pretest and posttest knowledge scores when students participated in social learning activities compared to when students did not. This result supports the use of talk to improve biological content knowledge. Because the test reached statistical significance, research hypothesis one was supported.

The second research question addressed the gain scores of students involved in social learning activities and compared to those that were not. A one-way ANOVA was conducted for each of the nine units to examine differences in gain scores between students who participated in social learning activities and those that did not. Four of the nine units reached statistically significant results: PChem, Mitosis/Meiosis, Heredity, and DNA to Proteins. In these units, students who participated in social learning activities had significantly higher gain scores than students who did not. This result supports the use of talk to improve biological content knowledge.

The third research question addressed the types of talk found in introductory biology peer group discussion during social learning activities. Voice-recordings of social learning activities were qualitatively analyzed based on a model developed by the research of Neil Mercer and colleagues. Analysis revealed that cumulative and exploratory talk existed in peer discussions during social learning opportunities.
CHAPTER V
DISCUSSION

The world is becoming increasingly complex due to advanced scientific discoveries and technological developments (Roth & Desautels, 2004). In order to empower citizens to manage the influx of science in their lives, a basic knowledge of scientific concepts is desirable. Roth and Desautels (2004) note that many agencies have publicly specified science as "a necessary ingredient in the development of an informed and engaged citizenship," (p. 151).

Knowledge and understanding of scientific concepts, a major component of scientific literacy (Figure 1, p. 2) are essential in today's global society (Desmastes & Wandersee, 1992). Yet the general public's understanding of science is insufficient to meet the demands of 21st century life (Demastes & Wandersee, 1992; Lewis & Wood-Robinson, 2000; Mejlgaard, 2009). The call for a scientifically literate citizenry indicates the need for students to have opportunities to increase their understanding of science. One way to accomplish these goals is to nurture interactions among students (Harrison, 2006). Vygotsky (1978) advanced the idea that social interaction is fundamental to higher mental activity and that social interaction and mental activity are driven by signs and tools, such as language. Humans have a unique social aptitude (Bigge, 1982), and learning is most effectively accomplished in social situations (DeHaan, 2005).

Summary of the Study

This study focused on the content knowledge component of scientific literacy and sought to determine whether social learning opportunities involving verbal exchange between students impacted the mastery of content in gateway biology courses. The study
investigated whether biology knowledge was improved through talk. In addition, this study sought to identify the types of talk students engage in during cognitive collaboration. Random assortment into control and experimental conditions occurred before the study began. Both quantitative and qualitative analysis methods were used. The study was quantitatively based on a pretest/posttest design to determine differences in pretest and posttest scores and differences in gain scores for control and experimental conditions. The study was qualitatively based on an analysis framework developed by Mercer et al. (1999).

Several statistical analyses were conducted during this study, as well as qualitative analysis. In order to determine if the two class sections were equivalent, a t-test was conducted to determine whether significant differences existed between the control and experimental conditions' pretest for each unit. A repeated-measures ANOVA was conducted for pretest/posttest comparisons across all units for all students when they were in the experimental condition compared to when they were in the controlled condition to determine if participation in social learning activities impacted content knowledge acquisition. A one-way ANOVA (Appendix J) was conducted for each of the nine units to compare differences in gain scores of students who participated in social learning activities and those that did not.

Audio recordings of dialogic exchange during social learning activities among students in the experimental condition were qualitatively analyzed for Disputational, Cumulative, and Exploratory talk based on a model developed by Mercer et al. (1999).
Description of Study Variables

The variables in this study consisted of pretests and posttests (Appendix H) per unit that were modified versions of the recommended test questions that accompany the text used exclusively for the gateway biology course by the community college where the research occurred. Another variable associated with this study were the social learning activities (Appendix G) that were completed in experimental groups for each of the nine units. These activities were modified versions of the recommended activities that accompany the text used exclusively for the gateway biology course by the community college where the research will occur.

Analysis of Research Questions and Hypotheses

Research Question One

Specific research question one asked, what differences exist in pretest and posttest scores when students participate social learning activities and when they do not in gateway undergraduate biology courses?

The social nature of learning has long been recognized. Rojas-Drummond (2009) recognized the social component of learning and intellectual growth and Postholm (2007) and Dangwal & Kapur (2009) noted that social interactions provide learning opportunities. DeHaan (2005) noted the deficiencies of lecture alone as an instructional strategy and called for different strategies to be implemented in order to achieve meaningful learning.

Data revealed that both posttest scores and gain scores were higher for the experimental condition as compared to the controlled condition. There was no unit in which posttest scores of students in the experimental condition (those who participated in
social learning activities) did not exceed the posttest scores of the control condition. The results reached statistical significance and support the use of language as a pedagogic tool due to its considerable impact on the development of student reasoning and cognition (Mercer et al., 1999; Hadjioannou, 2007).

*Research Hypothesis One*

Research hypothesis one stated, There will be a significant difference in the pretest and posttest knowledge scores when students participate in social learning activities and when they do not.

This hypothesis is supported by the results of this study. Participation in social learning activities impacted content knowledge acquisition in a significant way. A significant difference existed between pretest and posttest knowledge scores when students participated in social learning activities compared to when students did not. This result supports the use of talk to improve biological content knowledge and the validity of dialogue as a tool for meaning making within the classroom.

This study compared content knowledge acquisition when involved in social learning activities compared to involvement in lecture alone. These findings support the work of DeHaan (2005) who noted that active involvement in learning activities produced increased understanding, retention, and transfer as compared with lecture classes. In a study involving physics classes across the country, DeHaan (2005) noted a strong correlation between interaction with peers and learning gains in classes that involved social activity compared to those that were more traditionally oriented toward lecture and workbook labs with limited or no interaction with peers. These results also
increase the body of evidence that dialogue is a crucial and indispensable conduit through which learning and understanding is achieved (Vygotsky, 1978; Postholm, 2007).

**Research Question Two**

Research question two asked, what differences exist in gain scores when students participate in social learning activities and when they do not in gateway undergraduate biology courses?

Postholm (2007) found that group activities were beneficial for learning. This portion of the study sought to identify which units reached statistical significance for differences in gain scores when controlled and experimental conditions were compared.

**Research Hypothesis Two**

Research hypothesis two stated, there will be a significant difference in gain scores when students participate in social learning activities compared to when they do not.

The results of the study support this research hypothesis. Four of the nine units provided statistically higher gain scores when students participated in social learning activities when compared to students who did not. These findings contribute to the growing body of evidence that socially-oriented learning tasks as compared to individualist tasks can have far-reaching effects including higher achievement, (Johnson et al., 2007; Strom & Strom, 2002). Mercer et al. (2004) also advance the idea that talk-based activities can have a useful function in the development of scientific understanding. The results of this study support the claims that the development of human mental abilities can be mediated by language use among learners (Mercer et al., 1999).
In analyzing the gain scores, it is worth noting that students in the experimental condition (those that received social learning activities) posted higher gain scores than the controlled condition in all units, even if some of the gain scores did not prove to be statistically significant. This trend lends major support to the idea that social learning can facilitate the construction of accurate mental schema regarding scientific concepts and improve students' content knowledge.

There may be several reasons why some of the gain score differences between control and experimental were insignificant. In some of the units the content is heavily based on application and in the other units it tends to be more memorization-based. One explanation for the statistically significant gain score in the chemistry unit, the mitosis/meiosis unit, the heredity unit, and the DNA unit is the ability to practice the application of the content during social learning activities. Reasons for non-significant results may be the fact that both groups knew a certain amount of information at the beginning of the unit or it was based on a skill many were familiar with so that the margin for gaining knowledge was much narrower, or perhaps the students just simply did not gain much knowledge from the lecture-based instruction.

Research Sub-problem Three

Research sub-problem three asked, what specific types of talk exist in peer-group conversations during social learning activities: Disputational Talk, Cumulative Talk, or Exploratory Talk?

This study developed with the idea in mind that any activity that is socially oriented derives its educational value from the dialogue associated with it, including activities within the classroom (Reznitskaya et al., 2009). As Harrison (2006) stated,
"Classroom talk should not be used simply for the teacher to instruct but for the learner to develop," (p. 69), indicating that interactions should be nurtured among students.

Mercer's research in classroom joint dialogue analysis has revealed three types of talk that occur. These are characterized by Mercer et al. (1999) as Disputational, Cumulative, and Exploratory Talk. Figure 2 (p. 42) outlines the differences in the three types of talk.

Earlier research by Mercer et al. (2004) revealed that teaching primary school children to reason collaboratively using Exploratory Talk lead to gains in scores on a non-verbal reasoning test. Mercer et al. (2004) also recognize that students' learning of science is a discursive process, with scientific concepts and ways of reasoning being learned through engagement in social interaction. Interaction among partners while carrying out scientific investigations is often claimed to be beneficial to students' learning. However, Mercer et al. (2004) have noted that discussions among young science students may not always be constructive. Instead they have noted that the talk which takes place in science when children are asked to work together is often uncooperative and ultimately unproductive (Mercer et al., 2004).

Based on the observations of Mercer et al. (2004), this study sought to determine what types of talk actually occur in introductory biology classrooms. Having an idea of the types of talk occurring in student conversations would give the researcher and teacher a starting point from which to further develop social learning activities and improve their effectiveness in using talk to improve biology content knowledge in the future.

Recorded conversations of verbal reasoning occurring among students during social learning activities revealed the existence of cumulative and exploratory talk, but did not reveal the presence of disputational talk. This finding is contrary to observations
in younger student science classes (Mercer et al., 2004) and may be due to the fact that at the college level, students have matured socially to the point where arguing is recognized as an inappropriate way of dealing with peers. It might also be due to the fact that observations of younger students may have occurred when they were engaged in different types of activities than the ones the students engaged in during this study, so that a different context of conversation was called for. However it may have happened, the absence of disputational (argumentative and unproductive talk) was seen as a positive aspect of the study.

Cumulative talk tended to be predominant in vocabulary sections of the social learning activities when the terms were dissimilar, as was the case with a majority of the vocabulary sections, and in sections of the social learning activities that tended to be based on memorization instead of application or problem solving. In these instances, answers were agreed or disagreed upon without the addition of supportive reasoning. Even if students could have added reasoning to the answer selections, they did not do so.

Exploratory talk tended to be predominant in sections that required reasoning skills or problem-solving effort. Examples include vocabulary sections (which in general consisted of dissimilar terms) that included related but distinguishable terms, such as simple diffusion and facilitated diffusion. In such cases, the vocabulary section of social learning activities generated exploratory talk. Exploratory talk was also noted among students during social learning activities that involved problem solving. Notably, this was during activities that required sequencing, distinguishing, applying, and problem-solving exercises. These types of activities occurred in the four units that exhibited significant gain scores, and in some units that did not. Perhaps the lack of a significant
gain score in some units despite the presence of exploratory talk (which contains verbalized supportive reasoning for answer choices) could have been the nature of the pretest and posttest, so that the tests did not lend themselves to the types of tasks that require reasoning. Or perhaps the type of exploratory talk that was verbalized in non-significant gain score units was itself based on content factual knowledge and students still had not acquired enough of such knowledge to put it to use.

Implications for Policy and Practice

The results of this study could impact instructional methods in science, especially in introductory courses which most likely contain a higher percentage of non-science majors and thus more likely represent a general population than a specifically science-minded population, by providing not just a method of increasing scientific knowledge, but also in providing a framework on which to structure the practice of scientific discussions (Mercer et al., 2004). It is noted in the literature that a scientifically-literate society is a major goal of the 21st century (Desmastes & Wandersee, 1992; Roth & Desautels, 2004), and that aspects such as knowledge, the ability to engage in reasoned discussion, personal attitudes toward science, and one's confidence in scientific matters are all components of scientific literacy (Gil-Perez & Vilches, 2005; Holbrook & Rannikmae, 2007; Mejlggaard, 2009).

In addition to a global perspective of improved knowledge, personal improvement is also at stake in the educational arena. This idea of personal improvement, accomplishment, and advancement is critical to retention at the community college level, as was noted earlier in this project, and is tied to academic perseverance. Students who are successful in the classroom tend to develop the confidence and the desire to remain in
the academic environment to complete an educational degree (Nitecki, 2011). This study has produced results supporting the idea that social learning opportunities improve academic performance, and therefore constitute methods of good practice. Also tied to the idea of academic perseverance is the idea that classroom relations can influence a person's desire and confidence in the academic arena (Fike & Fike, 2008; Nitecki, 2011). Social learning activities provide, again, a method of good practice towards the development of mutually-supportive classroom relationships.

The use of social learning activities could possibly not only improve scores or chances of progress within a science course, or any course, but could also improve chances of progress on a larger scale. By securing a higher grade in a science course, a student's overall GPA could possibly improve, especially if the difference is that of a letter grade or more. Many employers and higher education institutions view GPA as a good indicator of both intelligence and work ethic. Improving one's GPA through greater success in individual courses may have far and long-reaching effects on a person's chances of securing a decent means of living. Notably the results produced within this study support the idea that social learning activities increase test scores, which in turn will result in an improved final grade, which will in turn improve a GPA.

One interesting, surprising, and unexpected revelation of the research was the ability, when analyzing the types of talk, to note the areas of learning gaps. The ways in which students reasoned (or not) through certain portions of the material revealed areas that could use more instructional time, more individual activity time, and specific social activity time. Beyond the idea of social learning activities and the benefits they can bestow, recording student conversations as they engage in verbalized cognitive work and
listening to them on a regular basis can aid a teacher in his or her own endeavors in the scholarship of teaching and learning. This type of activity allows for the creation of knowledge about an instructor's own method of teaching which can be shared with other educators. This sharing of instructional experiences and self-evaluations could add to the pool of solutions aimed at solving what seem to be ever-increasing deficiencies in academics in our nation when compared to the rest of the world.

Limitations

Limitations are noted here to aid future research. A potential limitation of this study is the population sample. Subjects were drawn from two sections of gateway biology at a small southern community college. Educational background, belief systems, and social structures may have played a role in student performance during this study. The results of this study may not be able to be generalized beyond the same community college population, as the population may not represent the populations of community college students in other areas or of college student populations as a whole.

Another limitation is the fact that only topics in the subject of cell biology were used in this study, and that, too, may limit generalizations to college courses as a whole. Other subjects may invoke different mental schemes or analysis methods and may not lend themselves to social learning.

Some students may have also shied away from having their comments recorded due to the knowledge that the recordings would be listened to and the fear that they would be identified and judged. Thus they may not have participated as fully as they were truly capable of in the peer group discussion of the social learning activities. In
doing so, students may not have contributed data to the research that would have affected the results.

**Recommendations for Future Research**

This study sought to determine whether social learning opportunities involving verbal exchange between students impact the mastery of content in gateway biology courses and sought to identify the types of dialogue students engage in during cognitive collaboration. This study had a population size of 57 students. A replication of this study using a larger population size would be recommended to substantiate the findings and to possibly expand them. Also concerning the population, this study is limited in its applicability to small southern community college populations. It would be recommended that this study be extended to different student populations in order to better describe the impact of social learning on content mastery and the types of dialogue that occur in introductory biology courses.

Dialogue develops and allows the practice of knowledge generation and creation. Another recommendation for future research would be an extension of this project designed to associate content with dialogue whereby specific content or applications are identified beforehand and the dialogue that occurs in the classroom is analyzed to see which type best produces that particular knowledge or successful application. A closer linking of actual targeted content and the dialogue associated with it could be studied.

Another recommendation for future research would concern the area of teacher training. It would be interesting to note the ways in which student teachers are taught to encourage interaction among their pupils, notably the depth to which they are trained in
skills required to facilitate peer-to-peer learning in the form of encouraging a certain type of dialogue within student discussions.

And lastly, research could be done regarding the types of attitudes that students develop towards subject matter when they are involved in social learning activities compared to when they are not. Based on the research included here, it has been noted that students involved in social learning maintain their identity as a person capable of understanding and assessing the world in which they exist. They gain the skills that allow them to both derive knowledge and make judgments on, form opinions about, and analyze that knowledge.

What we know may change, but the ways to constantly question and further explore what we know are founded in dialogical exchange among societal participants. The ways to discover truth lie in dialogue. This study sought to determine whether social learning opportunities impact content knowledge acquisition in undergraduate biology courses. Statistically significant results obtained in this study indicated that they do. The statistically significant difference between students pretest and posttest scores when they were in the controlled condition as compared to when they were acting in the experimental condition across all units indicated that social learning opportunities can improve achievement regardless of content and support the idea that social interaction using language as a tool can indeed improve learning. Taking into consideration the results of this study and the growing body of evidence supporting social learning’s impact on achievement, opportunities for using dialogue as a tool for meaning making should be nurtured within the classroom as a way to enhance both teaching and learning.
APPENDIX A

IRB APPROVAL FORM

THE UNIVERSITY OF SOUTHERN MISSISSIPPI
INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.6820 | Fax: 601.266.4377 | www.usm.edu/irb

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

The risks to subjects are minimized.
The risks to subjects are reasonable in relation to the anticipated benefits.
The selection of subjects is equitable.
Informed consent is adequate and appropriately documented.
Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
Appropriate additional safeguards have been included to protect vulnerable subjects.

Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the “Adverse Effect Report Form”.

If approved, the maximum period of approval is limited to twelve months.

Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 12092503
PROJECT TITLE: Dialogue As a Tool For Meaning Making
PROJECT TYPE: Dissertation
RESEARCHER/S: Angela Suzanne Dudley Bruni
COLLEGE/DIVISION: College of Science & Technology
DEPARTMENT: Center for Science & Math Education
FUNDING AGENCY: N/A
IRB COMMITTEE ACTION: Exempt Approval
PERIOD OF PROJECT APPROVAL: 09/26/2012 to 09/25/2013

Lawrence A. Hosman, Ph.D.
Institutional Review Board Chair
APPENDIX B

PERMISSION FROM MISSISSIPPI GULF COAST COMMUNITY COLLEGE TO
CONDUCT RESEARCH

Angela,

The college executive council approved your request for research on 7/18/12. Two stipulations exist on the approval. First, IRB approval must be received prior to conducting the research. Please forward a copy of the IRB approval to my office when received. Second, the council requires employees to submit a copy of their research work upon completion of the work. You may also be asked to present on the work to your college colleagues if applicable.

You will receive a signed copy of the approved request via college courier.

Good luck with your research!

JP
Jason V. Pugh, Ph. D.
Vice President
Instruction, Student Services & Related Technologies
Mississippi Gulf Coast Community College
P.O. Box 609
Perkinston, MS 39573
ph: 601-928-6233
e-mail: jason.pugh@mgccc.edu

From: angela bruni <angela.bruni@mgccc.edu>
Date: Monday, July 16, 2012 9:46 PM
To: Jason Pugh <jason.pugh@mgccc.edu>
Cc: angela bruni <angela.bruni@mgccc.edu>
Subject: Request to conduct research

Hi, Dr. Pugh,
I am pursuing a Ph.D. in science education through the University of Southern Mississippi. This path has been approved through MGCCC. This specific research project has been approved by my committee chair, Dr. Sherry Herron. Please find attached my request to conduct research at the Jefferson Davis Campus of MGCCC.
Thank you for your time and consideration. I look forward to hearing from you.
Sincerely,
Angela Bruni
Dear Participant,

The purpose of this research is to gather information on the efficacy of certain teaching methods on student learning. Science educators like me have focused on what to teach and how to teach it. Professors can improve course instruction if they know how to help students prepare for a course, but I need your assistance in helping me determine what is most effective for students. I’m asking for volunteers to provide me with information about your existing knowledge of a topic and your knowledge at the end of instruction on topic, by allowing me to analyze pre-and post-test data from the course. The pre-test will not be a determinate of your final course grade, however, the post-test score will be included in the calculation of your final course grade.

You must be at least 18 years old to participate in this study and participation is completely voluntary. You may withdraw from the study at any time without consequence to you. Your confidentiality will be strictly protected. Your name will be replaced with a code. Only an independent source will have access to the master list that matches your name with the code. Participation should not require any extra time outside of class. All associated files will be securely stored in a locked file cabinet or password protected file. NO results will be reported in a manner that would allow a reader to associate any responses to you. You will not be purposely deceived, and this project does not pose physical danger. Participating in the study will subject you to no risks greater than those you normally encounter in everyday life.

This study is being conducted to provide a better understanding of how students respond to course instruction and how conceptual understanding changes due to instruction method. Students will benefit from analysis of their mental constructs at the beginning of a unit as compared with their mental constructs at the end of instruction. Results from this study will also influence teaching methods in other classes in an effort to improve instruction and student learning. Results from this study are for instructor informational purposes.

Please feel free to ask any questions during or after your participation in this study. If you have questions or concerns about this study, you may contact me at 228-897-3959 or angela.bruni@mgccc.edu.

This project and this consent form have been reviewed by the Human Subjects Protection Review Committee, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-6820.

Your signature on the attached consent form indicates that you have received a copy, read, and understand this letter that describes the study. The informed written consent is required by IRB for your participation.

Thank you for your consideration and help with this project.

Sincerely,

Angela Bruni
THE UNIVERSITY OF SOUTHERN MISSISSIPPI
AUTHORIZATION TO PARTICIPATE IN RESEARCH PROJECT

Participant’s Name ________________________________________

Consent is hereby given to participate in the research project entitled Dialogue as a Tool for Meaning Making. All procedures and/or investigations to be followed and their purpose, including any experimental procedures, were explained by Angela Bruni. Information was given about all benefits, risks, inconveniences, or discomforts that might be expected.

The opportunity to ask questions regarding the research and procedures was given. Participation in the project is completely voluntary, and participants may withdraw at any time without penalty, prejudice, or loss of benefits. All personal information is strictly confidential, and no names will be disclosed. Any new information that develops during the project will be provided if that information may affect the willingness to continue participation in the project.

Questions concerning the research, at any time during or after the project, should be directed to Angela Bruni at 228-897-3959. This project and this consent form have been reviewed by the Human Subjects Protection Review Committee, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-6820.

A copy of this form will be given to the participant.

__________________________________________  __________________
Signature of participant                         Date

__________________________________________  __________________
Signature of person explaining the study         Date
Dear Angela

Thanks for letting me know about your research - I am very happy for you to use the 3 types of talk model, and will be interested to hear what results you get.

It may be that you simply want to see what kinds of talk happen when you give students such activities, in which case your design would be fine. But our research suggests that unless students first undertake some awareness-raising activities about how they use talk to learn and solve problems together, and agree on some 'ground rules' for doing so, they are unlikely to use much exploratory talk. That is, simply giving them activities (even good ones) to stimulate dialogue is not enough to make productive dialogue happen.

You might also note the findings of Noreen Webb and others that the biggest influence on how students talk together in groups is how their teacher talks with them.

With very best wishes
Neil

On 4 Apr 2012, at 17:38, angela bruni wrote:

Hi, Dr. Mercer-
My name is Angela Bruni, and I am pursuing a Ph.D. in Science Education from the University of Southern Mississippi through the Center for Science and Mathematics Education. I am interested in using the sociocultural use of language as it relates to learning/cognition as described by Vygotsky as my theoretical framework, and am writing to ask your permission to use your work as a conceptual framework/model upon which to analyze my data. I am specifically interested in using your framework of Disputational, Cumulative, and Exploratory Talk.

I am interested in taking 3-4 concepts in General Biology I at the small southern community college at which I teach and providing activities that stimulate dialogue among students. These concepts would/will/could include: the structure of the atom as it relates to bonding; DNA replication, transcription, and translation; mitosis and meiosis; and basic genetics. I am interested in discovering what types of dialogue occur in these small groups.
Right now I plan to do a mixed-methods study whereby I qualitatively analyze the conversations according to your model, and I quantitatively analyze the groups via a pretest/posttest. I have two classes: One class receives the dialogue activities and the other class acts as “control” and does not receive the activities. By quantitatively analyzing with the pretest / posttest, I am trying to establish statistical data that supports the use of dialogue/peer conversations in the classroom as opposed to a strictly didactic method of teaching. I am hoping my research will lend itself to both analyses.

Please let me know if I have your permission to use your model in my research. If you have any other helpful hints those would be welcome, too! If you would like to see the work, I will send it as it progresses.

Thank you very much for your time. I hope to hear from you soon.

Angela Bruni

Biological Science Instructor
APPENDIX E

PERMISSION FROM CENGAGE LEARNING TO USE TEXTBOOK RESOURCES

Rights Administration and Content Reuse
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07/12/2012
Angela S. Bruni
Mississippi Gulf Coast Community College
Science
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Author(s): STARR/TAGGART ISBN: 9780495125846 (0495125849)
Publisher: Brooks/Cole Year: 2006
Specific material: pages 2-3; pages 6-6; pages 10-15; pages 20-21; pages 27-27; pages 32-32; pages 34-37; pages 43-47; pages 54-54; pages 56-57; pages 62-68; pages 72-72; pages 74-75; pages 84-86; pages 92-95; pages 97-97; pages 101-101; pages 103-103; pages 104-104; pages 111-111; pages 116-117; pages 124-128; pages 129-130; pages 132-135;
Total pages: 58
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Donna Phillips
Permissions Associate
Page 1 of 1 Request # 277641 Requestor email: angela.bruni@mgccc.edu
APPENDIX F

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07/12/2012
Angela S. Bruni
Mississippi Gulf Coast Community College
Science
4507 Courthouse Rd.
Gulfport, Mississippi 39507
Thank you for your interest in the following Cengage Learning/Nelson Education, or one of their respective subsidiaries, divisions or affiliates (collectively, "Cengage/Nelson") material.
Title: Test Bank for Starr/Taggart's Biology: The Unity and Diversity of Life, 11th 11E
Author(s): STARR/TAGGART ISBN: 9780495125884 (0495125881)
Publisher: Brooks/Cole Year: 2006
Specific material: Ch. 1-14 test items pages 1-113;
Total pages: 113
For use by:
Name: Bruni
School/University/Company: Mississippi Gulf Coast Community College
Course title/number: BIO 1134
Term of use: One Year 2012
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APPENDIX G

SOCIAL LEARNING ACTIVITIES

INVITATION TO BIOLOGY

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Sequence

Arrange the following steps of the scientific method in the correct chronological order. Write the letter of the first step next to 1, the letter of the second step next to 2, and so on.

1. _____ A. Develop a hypothesis.
2. _____ B. Repeat the tests or devise new ones.
3. _____ C. Devise ways to test the accuracy of predictions drawn from the hypothesis (use of observations, models, and experiments)
4. _____ D. Make a prediction, using the hypothesis as a guide; the “if-then” process.
5. _____ E. If the tests do not provide the expected results, check to see what might have gone wrong.
6. _____ F. Objectively analyze and report the results from tests and the conclusions drawn.
7. _____ G. Observe some aspect of nature and research what others have found out about it.

Matching

Choose the most appropriate answer for each of the following terms.

1. _____ molecule 2. _____ cell 3. _____ community 4. _____ ecosystem
5. _____ organ system 6. _____ organ 7. _____ population 8. _____ biosphere
9. _____ tissue 10. _____ atom 11. _____ multi-celled organism

A. the interaction of two or more tissues to perform a common task
B. all the regions of Earth that hold organisms
C. the smallest unit of life capable of surviving and reproducing on its own
D. the interaction of organs physically or chemically to perform a common task
E. two or more atoms bonded together
F. all populations of all species occupying a given area
G. the smallest unit that retains an element’s properties
H. the interaction of a community and the physical environment
I. a group of individuals of the same species occupying a specific area
J. organized arrays of cells that interact for a specific task
K. individual make of different types of cells
Sequence

Arrange the following levels of organization in nature in the correct hierarchical order. Write the letter of the least inclusive level next to 1. The letter of the most inclusive level is written next to 11.

1. _____ A. community
2. _____ B. tissue
3. _____ C. cell
4. _____ D. organ
5. _____ E. organ system
6. _____ F. atom
7. _____ G. ecosystem
8. _____ H. molecule
9. _____ I. population
10. _____ J. multi-celled organism
11. _____ K. biosphere

Matching

Choose the most appropriate answer for each term.

1. _____ reproduction
2. _____ energy
3. _____ development
4. _____ inheritance
5. _____ homeostasis
6. _____ DNA

A. the acquisition of traits from parents to offspring
B. the mechanism by which DNA is transmitted from parents to offspring
C. the capacity for doing work
D. the transformation of the first cell of an individual
E. the signature molecule of life
F. the maintenance of the internal environment
For the following diagram:

1. Name the white circular shape at the top of the diagram and discuss what it is providing to the system.

2. Label the appropriate levels for consumers, producers, and decomposers. Give some examples of each at the appropriate level.

3. Describe the directional flow of energy through the system and discuss what that means.

4. Discuss what the circular arrows mid-level in the diagram are indicating.
Matching

1. _____ atoms
2. _____ protons
3. _____ trace elements
4. _____ neutrons
5. _____ electrons
6. _____ atomic number
7. _____ mass number
8. _____ elements

A. subatomic particles with a negative charge
B. positively charged subatomic particles within the nucleus
C. the number of protons in an atom
D. chemical elements representing less than 0.01 percent of body weight
E. the number of protons and neutrons in the nucleus of one atom
F. fundamental forms of matter that occupy space, have mass, and cannot be broken down into something else
G. smallest units that retain the properties of a given element
H. subatomic particles within the nucleus carrying no charge

Draw electron shell models for the following atoms. Indicate the number of protons, neutrons, and electrons placing each subatomic particle in its appropriate location within the atom.

Helium  Oxygen  Nitrogen  Chlorine
Enter the missing information for each line in the following table.

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Atomic Mass</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Number of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>11</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Calcium</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Carbon</td>
<td>6</td>
<td></td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>1</td>
<td></td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5. Oxygen</td>
<td>16</td>
<td>8</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>10</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>17</td>
<td>35</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MOLECULES OF LIFE

Fill-in-the-Blanks

The molecules of life are _______________ compounds, which are defined as containing the element _______________ and at least one _______________ atom. The _______________ hydrogen atoms _______________ bond to _______________.

Like other organic compounds, each has a specific number of _______________ that are arranged in specific ways. Each organic compound has one or more _______________ groups, which are particular atoms or clusters of atoms covalently bonded to _______________.

Carbon’s importance to life starts with its versatile _______________ behavior. Each carbon atom can covalently bond with as many as _______________ other atoms. Such bonds, in which two atoms share one, two, or three pairs of electrons, are relatively _______________. They join together carbon atoms as a(n) _______________ to which hydrogen, oxygen, and other elements are attached. In those configurations we find clues to how the different molecules of life will function and what their _______________ -dimensional shape will be.

Choice

Choose the class of carbohydrates (a-c) associated with the terms in the items below.

a. oligosaccharides  b. polysaccharides  c. monosaccharides

1. _____ “complex” carbohydrates
2. _____ disaccharides
3. _____ ribose and deoxyribose
4. _____ glucose and fructose
5. _____ starch and glycogen
6. _____ cellulose
Choice
For the questions following, choose from the answers below. Some answers may used more than once.

a. triglycerides    b. phospholipids    c. waxes    d. sterols

1. _____ the sex hormones are formed from this class
2. _____ richest source of body energy
3. _____ cholesterol belongs to this class
4. _____ the primary component of cell membranes
5. _____ furnishes protection and lubrication for hair, skin, and feathers
6. _____ the neutral fats belong to this class

Matching
Choose the most appropriate answer for each term.

1. _____ enzymes
2. _____ condensation reaction
3. _____ monomers
4. _____ hydrolysis
5. _____ polymers
6. _____ functional-group transfer
7. _____ cleavage
8. _____ electron transfer

A. a class of proteins that make chemical reactions occur faster
B. a type of reaction that splits a molecule using water
C. the individual subunits of organic molecules
D. any reaction that splits a molecule into two smaller molecules
E. they type of chemical reaction that moves electrons between molecules
F. the movement of functional groups between molecules
G. the formation of a covalent bond by the removal of –OH and H+ functional groups, forming water
H. long chains of subunits, sometimes consisting of millions of individual subunits a change in the internal bond structure of a molecule
Matching
Choose the most appropriate answer for each term.

1. ______ amino acid
2. ______ peptide bond
3. ______ polypeptide chain
4. ______ primary structure
5. ______ secondary structure
6. ______ quaternary structure
7. ______ lipoproteins
8. ______ glycoprotein
9. ______ denaturation

A. coils or twists in amino acids caused by hydrogen bonds
B. three or more amino acids joined in a linear chain
C. proteins with linear or branched oligosaccharides covalently bonded to them.
D. the type of covalent bond linking one amino acid to another
E. globular proteins and hemoglobin are examples of this level of protein structure
F. the unwinding of protein structure causing a change in shape
G. the lowest level of protein structure consisting of a linear, unique sequence of amino acids
H. a small organic compound having an amino group, and acid group, a hydrogen atom, and an R group
I. these transport triglycerides and cholesterol in the body
J. a structurally stable unit of a polypeptide chain

In the following diagram, label the phosphate groups, nitrogenous base, and five-carbon sugar subunits.

Name the class of organic compounds to which this molecule belongs.

Provide the specific name of this molecule.
Short Answer
1. List the basic principles of the cell theory.

Matching
Choose the most appropriate answer for each term.
1. ______ prokaryotic cells
2. ______ plasma membrane
3. ______ cytoplasm
4. ______ ribosomes
5. ______ nucleus
6. ______ eukaryotic cells
7. ______ surface-to-volume
8. ______ lipid bilayer
9. ______ nucleoid
10. ______ cell
   A. an interior region of prokaryotic cells where DNA is found
   B. the structural basis of the plasma membrane
   C. the type of cell that lacks a nucleus
   D. a physical relationship that constrains increases in cell size
   E. the smallest unit of life that retains all the properties of life
   F. molecular structures that are involved in building proteins
   G. the thin outermost membrane of cells that separates metabolic activities from random outside events
   H. in eukaryotic cells, the membranous sac that contains the DNA
   I. the area between the plasma membranes and the region of DNA
   J. a type of cell possessing internal membranes that divide the cytoplasm into compartments
Labeling
First, identify each indicated part of the illustrations below. Then, using the letter of the proper function description in the parentheses, identify the cell organelle responsible.

1. ____________________ (A)
2. ____________________ (B)
3. ____________________ (C)
4. ____________________ (D)
5. ____________________ (E)
6. ____________________ (F)
7. ____________________ (G)
8. ____________________ (H)
9. ____________________ (I)
10. ____________________ (J)
11. ____________________ (K)
12. ____________________ (L)
13. ____________________ (M)

A. protects DNA from damaging reactions in cytoplasm
B. modifies new polypeptide chains; synthesizes lipids
C. protects and structurally supports plant cells
D. organelle of digestion, including the digestion of other organelles
E. produces ATP by aerobic respiration
F. produce and organize the microtubules
G. modifies, sorts, and ships proteins and lipids for export or for insertion into the cell membrane
H. site of protein synthesis
I. photosynthetic organelle
J. causes fluid pressure to build up inside living plant cells
K. store starch grains; abundant in potatoes and seeds
L. makes lipids; degrades toxins
M. selectively controls movement of substances into the cell
A CLOSER LOOK AT CELL MEMBRANES

Matching

Choose the most appropriate answer for each term.

1. _____ fluid mosaic model
2. _____ phospholipid
3. _____ transport proteins
4. _____ integral proteins
5. _____ recognition proteins
6. _____ peripheral proteins
7. _____ receptor proteins
8. _____ lipid bilayer
9. _____ passive transporters
10. _____ active transporters

A. proteins that allow molecules to move through the plasma membrane without expending energy
B. use the energy of adenosine triphosphate to transport molecules across the membrane
C. a composition of phospholipids, proteins, sterols, and glycolipids
D. the general name for proteins that are physically embedded within the cell membrane
E. the primary component of the cell membrane; consists of both hydrophobic and hydrophilic regions
F. bind extracellular substances that trigger changes in the cell’s activity
G. a general group of proteins positioned at the surface of the membrane
H. the double layer of phospholipids that forms the cell membrane
I. allow materials to pass through the cell membrane using the interior of the protein; may or may not require energy
J. act as molecular finger prints to identify tissues or individuals
Matching
Choose the most appropriate answer for each term.
1. _____ osmosis
2. _____ tonicity
3. _____ hypotonic solution
4. _____ hypertonic solution
5. _____ isotonic solution
6. _____ hydrostatic pressure
   A. refers to the relative solute concentrations of the fluids
   B. have the same solute concentrations
   C. the fluid on one side of a membrane that contains more solutes than the fluid
      on the other side of the membrane
   D. the diffusion of water in response to a water concentration gradient between
      two regions separated by a selectively permeable membrane
   E. the fluid on one side of a membrane that contains fewer solutes than the fluid
      on the other side of the membrane
   F. the general term for a fluid force exerted against a cell wall and/or membrane
      enclosing the fluid

Fill-in-the-Blanks
If the concentration of a substance in one region differs from that in an adjoining region,
it is called a(n) ____________. A(n) ____________ ____________ is a difference
between the number of molecules or ions of a given substance in adjoining regions.
__________ is the name for the net movement of like molecules or ions down a
concentration gradient; it is a factor in the movement of substances across cell
membranes and through cytoplasmic fluid. Diffusion is faster when a gradient is
___________. In addition, the rates of diffusion are faster at ___________ temperatures.
Molecular ____________ also affects diffusion rates. The rate and direction of diffusion
may also fall under the influence of a(n) ____________ gradient, a difference between
electric charges in adjoining regions. The presence of a(n) ____________ gradient may
likewise affect the rate and direction of diffusion.

If a membrane has selective ____________, it possesses a molecular structure that
permits some substances but not others to cross it in certain ways, at certain times. The
__________ transporters permit a substance that may not diffuse through the lipid
bilayer to follow its concentration gradient across a membrane. This process is also
sometimes called ____________ diffusion. The ATPase pumps engage in ____________
transport, with the net direction of movement being ____________ the concentration
gradient. Unlike passive transport, active transport requires an input of ____________ to
counter the concentration gradient.
**Short Answers**

The questions below refer to the following diagram, in which the left side has 25 milliliters of a 3% sucrose solution and the right side has 25 milliliters of a 6% sucrose solution. The membrane separating the sides is permeable to water but impermeable to sucrose.

1. In what direction will water move through the membrane?

2. In what direction is the net movement of water?

3. In what direction will sucrose move through the membrane?

4. What will happen to the sucrose concentration on the right side?

5. What will happen to the fluid level on the left side?

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GROUND RULES OF METABOLISM

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Fill-in-the-Blanks

The specific substance upon which a particular enzyme acts is called its ___________; this substance fits into the enzyme’s crevice, which is called its ___________. The ___________-__________ model describes how a substrate contacts the site without a perfect fit. Enzymes change the ___________, not the outcome, of a chemical reaction.

In the graph below, maximum enzyme activity occurs at _____________°C.

What happens to enzyme activity as the temperature rises or falls beyond the temperature indicated above? Why is this happening?
What do the peaks in the graph below indicate?

In the graph below, label the enzyme which functions best in basic solutions, the enzyme which works best in neutral solutions, and the enzyme which functions best in acidic solutions.


**PHOTOSYNTHESIS**

Plants and other organisms that can make their own food are called ____________, most of which trap the energy from light in the process of ______________. Organisms that cannot make their own food, like humans, are classified as _____________. A major change in Earth’s atmosphere occurred when photoautotrophic organisms began splitting ____________ to gain electrons and produced ____________ gas as a waste product.

Supply the summary equation for photosynthesis:

The two major sets of reactions of photosynthesis are the ____________ - ____________ reactions and the ____________ - ____________ reactions. The internal membranes and
channels of the chloroplast form the _____________ membrane and are organized into stacks. Spaces inside the thylakoid disks and channels form a continuous compartment where _____________ ions accumulate to be used to produce ATP. The semi-fluid interior area surrounding the thylakoid is known as the _____________ and is the area where the products of photosynthesis are produced.

Use the diagram of the Calvin-Benson cycle below to answer the following. The light-independent reactions can proceed without sunlight as long as _____________ and _____________ are available. The reactions begin when an enzyme links ______________ to ______________, a five-carbon compound. The resulting six-carbon compound is highly unstable and breaks apart at once into two molecules of a three-carbon compound, __________ attendee. This entire reaction sequence is called carbon ___________. It takes _____________ carbon dioxide molecules to produce twelve PGAL. _____________ _____________ formed in the cycle serves as a building block for the plant's main carbohydrates.
Fill-in-the-Blanks

With mitosis, a(n) _______________ parent cell can produce two diploid _______________ cells. This doesn’t mean each merely gets forty-six _______________. If only the total mattered, then one cell may get two pairs of chromosome 22 and no pairs whatsoever of chromosome 9. But neither cell could function like its parent without _______________ of each type of chromosome.

Mitosis has four stages- ________________, ________________, ________________, and ________________. Interphase has three stages- ________________, ________________, and ________________.

For the following diagram, label interphase and its stages, mitosis and its stages, and cytokinesis.
Meiosis is like ___________ in some ways, but the result is different. With meiosis, the chromosomes go through ___________ consecutive divisions that end with the formation of four ___________ nuclei. During meiosis I, ___________ ___________ are moved apart, and during meiosis II, ___________ ___________ are split apart.

For the following diagrams, label the series of images that represent mitosis by writing the word "MITOSIS" in large print in the left hand margin. Label the series of images that represent meiosis I by writing the word "MEIOSIS I" in large print in the left hand margin. Label the series of images that represent meiosis II by writing the word "MEIOSIS II" in large print in the left hand margin. Describe the features that helped you decide.
1. During which stage(s) do patches of new membrane fuse to form a new nuclear envelope around the decondensing chromosomes?
2. During which state(s) are daughter cells almost completely formed, each diploid with two of each type of chromosomes, just like the parent's nucleus?
3. During which stage(s) are ALL chromosomes are lined up at the cell's equator?
4. During which stage(s) do attachments between sister chromatids break and sister chromatids become chromosomes in their own right?
5. During which stage(s) are homologous chromosomes separated?
6. During which stage(s) do homologues pair and crossing over occurs?
7. During which stage(s) do two haploid cells form, each having one of each type of chromosome that was present in the parent cell and chromosomes are still duplicated?

Overall Summary

In the process of ____________, daughter cells have the SAME number of chromosomes as the parent cell that produced them.

In the process of ____________, daughter cells have HALF the number of chromosomes as the parent cell that produced them.

In *mitosis*, if a parent cell has 16 chromosomes, how many chromosomes will each daughter cell have?

At the end of *meiosis I* in corn (20 chromosomes), how many chromosomes will be present in the daughter cells?

If a parent cell has 16 chromosomes, how many *sister chromatids* will be present after duplication? How many molecules of DNA is this?
Matching
Choose the most appropriate definition for each term.

1. _____ genotype
2. _____ alleles
3. _____ heterozygous
4. _____ dominant
5. _____ phenotype
6. _____ genes
7. _____ homozygous recessive
8. _____ recessive
9. _____ P, F₁, F₂
10. _____ hybrids
11. _____ diploid organism
12. _____ gene locus
13. _____ homozygous dominant
14. _____ homologous chromosomes

A. parental, first-generation, and second-generation offspring
B. all the different molecular forms of the same gene
C. particular location of a gene on a chromosome
D. describes an individual having a pair of nonidentical alleles
E. an individual with a pair of recessive alleles, such as aa
F. allele whose effect is masked by the effect of the dominant allele
G. offspring of a genetic cross that inherit a pair of nonidentical alleles for a trait
H. refers to an individual’s observable traits
I. when the effect of an allele on a trait masks that of any recessive allele paired with it
J. an individual with a pair of dominant alleles, such as AA
K. units of information about specific traits; passed from parents to offspring
L. a pair of similar chromosomes, one obtained from the father and the other obtained from the mother
M. the particular alleles that an individual carries for a trait
N. having pairs of genes on homologous chromosomes
**Problems**

For the following genetics problems, please show your work.

1. In garden pea plants, tall \((T)\) is dominant over dwarf \((t)\). In the cross \(Tt \times tt\), the \(Tt\) parent would produce a gamete carrying \(T\) (tall) and a gamete carrying \(t\) (dwarf) through segregation; the \(tt\) parent could only produce gametes carrying the \(t\) (dwarf) gene. Use the Punnett-square method to determine the following results of a \(Tt \times tt\) cross.

a. The genotype probabilities of the offspring:

b. The phenotype probabilities of the offspring:

2. In fruit flies, the trait vestigial wings \((a)\) is recessive to normal wings \((A)\). You wish to determine whether a fly with a dominant phenotype is homozygous dominant or heterozygous. Using a testcross, you mate the fly with a homozygous recessive individual. Following are two possibilities for the \(F_1\) generation. For each, state if the results indicate that the genotype of the parent is \(homozygous\) dominant or \(heterozygous\).

a. 78 normal-winged offspring

b. 37 normal-winged offspring and 41 vestigial-winged offspring

3. Albinos cannot form the pigments that normally produce skin, hair, and eye color, so albinos exhibit white hair and pink eyes and skin (because the blood shows through). To be an albino, one must be homozygous recessive \((aa)\) for the pair of genes that code for the key enzyme in pigment production. Suppose a woman of normal pigmentation \((A_)\) with an albino mother marries an albino man. State the possible kinds of pigmentation for this couple's children, and specify the ratio of each kind of child the couple is likely to have. Show the genotype(s) and state the phenotype(s).
4. In four o’clock plants, red flower color is determined by gene $R$ and white flower color by $R^i$, while the heterozygous condition, $RR^i$, is pink. For each of the following crosses, give the phenotypic ratios of the offspring.

a. $RR \times RR^i$

b. $RR^i \times RR^i$

5. Indicate the possible blood types that may be present in the offspring of the following crosses.

a. $I^A_i \times I^A_i$

b. $I^B_i \times I^A_i$

c. $I^A_i \times ii$

d. $ii \times ii$

e. $I^A_i \times I^A_i$
DNA STRUCTURE AND FUNCTION

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Explain what "semiconservative replication" means.

The following sequences represent DNA in the midst of replication. Complete the replication by adding the required letters for the missing nucleotide bases.

T -- _____ _____ -- A
G -- _____ _____ -- C
A -- _____ _____ -- T
C -- _____ _____ -- G
G -- _____ _____ -- C
A -- _____ _____ -- T

What did the original strand look like? (Be sure you represent the double-stranded nature of DNA.)

How do the new strands compare to the parent/original strand?

The __________ of bases in DNA contains the coded information. The two steps from genes to proteins are called __________ and __________. In ____________, single-stranded molecules of RNA are assembled on DNA templates in the nucleus. In ____________, the RNA molecules are shipped from the nucleus into the cytoplasm, where they are used as templates for assembling ____________. This later step takes place at the ____________ (cellular organelle).
Complete the following table, which summarizes information about two important molecules involved in protein synthesis.

<table>
<thead>
<tr>
<th>RNA Molecule</th>
<th>Abbreviation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Messenger RNA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer RNA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Suppose the line below represents the DNA strand that will act as a template for the production of mRNA through the process of transcription. Fill in the bases below the DNA strand with the sequence of complementary bases that will represent the message carried by mRNA to the ribosome in the cytoplasm.

\[ T \ A \ C \ A \ A \ G \ A \ T \ A \ A \ C \ A \ T \ A \ G \ C \ T \ C \ C \ T \ A \ C \ G \ T \ C \ A \ T \ C \]

What is a codon? On which molecule is a codon found?

Given the following DNA sequence, deduce the composition of the mRNA transcript.

DNA: TAC AAG ATA ACA TTA TTT CCT ACC GTC ATC

mRNA:

From the mRNA transcript, deduce the composition of the amino acids of the polypeptide sequence.

_____ _____ _____ _____ _____ _____ _____ _____
The order of __________ __________ in a protein is specified by a sequence of nucleotide bases. The genetic code is read in units of __________ nucleotides. __________ carries the instructions for assembling a particular sequence of amino acids at the ribosomes. Codons are found in the molecule __________, NOT __________. __________RNA acts as a shuttle molecule bringing particular __________ __________ to the ribosome where it is incorporated into the growing polypeptide.
Unit: Invitation to Biology

1. Which of the following is not a component of a nonliving object?
   a. energetic interactions
   b. DNA
   c. Atoms
   d. Elements

2. Which of the following is the smallest unit of life that can exist as a separate entity?
   a. a cell
   b. a molecule
   c. an organ
   d. a population
   e. an ecosystem

3. Which of the following terms refers to the capacity to do work?
   a. metabolism
   b. electrolytes
   c. chemical reaction
   d. concentration
   e. energy

4. Which of the following do not depend directly on sunlight for energy?
   a. producers only
   b. decomposers only
   c. consumers only
   d. consumers and decomposers
   e. producers and decomposers

5. Which of the following best characterizes the flow of energy through our system?
   a. circular
   b. a ladder
   c. one way
   d. a funnel

6. Which of the following levels of organization includes factors such as sunlight, rainfall, and temperature?
   a. organ system
   b. ecosystem
   c. molecule
   d. population
7. In the scientific method, which of the following should be the first step taken?
   a. a prediction
   b. an observation of nature
   c. a hypothesis
   d. development of an experiment
   e. forming a theory

8. Which of the following makes energy from the sun available to all other forms of life?
   a. producers
   b. consumers
   c. decomposers

9. Which of the following places the indicated levels of organization in the correct hierarchical order?
   a. community, tissue, atom, cell, ecosystem
   b. atom, cell, tissue, ecosystem, community
   c. tissue, atom, cell, community ecosystem
   d. atom, cell, tissue, community, ecosystem

10. Which of the following is defined as the smallest unit that maintains an element's properties?
    a. molecule
    b. atom
    c. cell
    d. tissue

On the following diagram, label the terms indicated below by writing them into the correct place in the diagram and give one specific example of each. [1 point for the correct label. 1 point for a correct example.]

producers, consumers, decomposers

What do the circular arrows indicate is happening?
Unit: Chemistry

1. Which of the following choices correctly identifies the contents of an atom’s nucleus?
   a. neutrons and protons
   b. neutrons and electrons
   c. protons and electrons
   d. protons only
   e. neutrons only

2. Magnesium has 12 protons. How many electrons are in its third energy level?
   a. 2
   b. 4
   c. 6
   d. 8
   e. 10

3. Which of the following correctly defines trace elements?
   a. fundamental forms of matter that occupy space, have mass, and cannot be broken down into something else
   b. chemical elements representing less than 0.01 percent of body weight
   c. smallest units that retain the properties of a given element
   d. subatomic particles within the nucleus carrying no charge

Draw electron shell models for the following atoms. Indicate the number of protons, neutrons, and electrons and place each subatomic particle in its appropriate location within the atom.

<table>
<thead>
<tr>
<th>Nitrogen</th>
<th>Chlorine</th>
<th>Hydrogen</th>
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Enter the missing information for each line in the following table.

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<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Atomic Mass</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Number of Electrons</th>
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<tbody>
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<td></td>
<td>20</td>
<td>20</td>
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</tbody>
</table>

Enter the missing information for each line in the following table.


Unit: Molecules of Life

1. Which of the following atoms is diagnostically associated with organic compounds?
   a. carbon
   b. oxygen
   c. nitrogen
   d. sulfur
   e. hydrogen

2. Which of the following are lipids?
   a. sterols
   b. oils
   c. waxes
   d. all of these are lipids

3. Which of the following categories would contain triglycerides?
   a. carbohydrates
   b. nucleotides
   c. proteins
   d. fats

4. Which of the following does NOT accurately describe a role of lipids in the body?
   a. Lipids serve as food reserves in many organisms.
   b. Lipids are the molecules from which sex hormones are formed.
   c. Lipids are a major component of cell membranes.
   d. Lipids are a class of proteins that make chemical reactions occur faster.

5. Which of the following levels of structure occurs due to the sequence of amino acids in a protein?
   a. primary
   b. secondary
   c. tertiary
   d. quaternary

6. Amino acids are linked by what kind of bonds to form the primary structure of a protein?
   a. disulfide
   b. hydrogen
   c. ionic
   d. peptide
7. Which of the following molecules is considered the primary source of cellular energy?
   a. cyclic AMP.
   b. FAD
   c. NAD+
   d. ATP

In the following diagram, label the phosphate groups, nitrogenous base, and five-carbon sugar subunits.

8. Name the class of organic compounds to which this molecule belongs.

9. Provide the specific name of this molecule.
Unit: Cell Structure

1. Which of the following are the primary cellular assembly sites for the production of proteins?
   a. Golgi bodies
   b. ribosomes
   c. mitochondria
   d. lysosomes
   e. smooth endoplasmic recticula

2. Which of the following contain enzymes and are the main organelles of intracellular digestion?
   a. Golgi bodies
   b. ribosomes
   c. mitochondria
   d. lysosomes
   e. endoplasmic recticula

3. Which of the following contain enzymes used in the breakdown of glucose and generation of ATP?
   a. Golgi bodies
   b. ribosomes
   c. mitochondria
   d. lysosomes
   e. endoplasmic recticula

4. What type of cell would contain chloroplasts, mitochondria, and a central vacuole?
   a. a prokaryote
   b. an animal cell
   c. a plant cell
   d. a fungus

5. Which of the following structures assembles the subunits (protein and RNA) of ribosomes?
   a. mitochondria
   b. Golgi body
   c. nucleus
   d. nucleolus
On the diagram below, label the following organelles by writing their name next to the appropriate line.

central vacuole, chloroplast, mitochondria, nucleus, nucleolus, and rough endoplasmic reticulum
Unit: Cell Membranes

1. Which of the following molecules carries out most of the functions of plasma membranes? a. cholesterol.  
   b. proteins.  
   c. phospholipids  
   d. carbohydrates

2. Which of the following answer choices includes all factors that can affect the rate of diffusion through a semipermeable membrane? 
   a. steeper concentration gradients only  
   b. higher temperatures only  
   c. steeper concentration and higher temperatures  
   d. higher temperatures and molecular size  
   e. steeper concentration gradients, higher temperatures, and molecular size

3. Which of the following is defined as movement of a molecule against a concentration gradient? 
   a. diffusion  
   b. osmosis  
   c. active transport

4. Which of the following methods of movement requires the expenditure of ATP molecules? 
   a. diffusion  
   b. osmosis  
   c. active transport

MEMBRANE PROTEINS: MATCH THE PROTEIN WITH ITS CORRECT DESCRIPTION

A. adhesion protein  
B. receptor protein  
C. recognition protein  
D. transport protein

5. a hormone would most likely bind to which this membrane protein

6. proteins designed to hold cells to one another

7. proteins that allow molecules to pass from one side of the cell membrane to the other

8. this protein acts as a molecular fingerprint to identify tissues or individuals; it allows the body to determine if something is self or non-self
TONICITY: Answer the following questions in reference to the diagram included below.

9. Which side, right or left, has the highest solute concentration? Or are they equal?

10. Will the fluid level rise on one side? If so, which side will see an increase in the fluid level? If so, why?

11. If the red molecules are allowed to move, in which direction will they move?
Unit: Cellular Metabolic Activity

1. What term below is defined as the substance upon which an enzyme acts?
   a. intermediate
   b. energy carrier
   c. substrate
   d. activation energy

2. Which of the following can influence an enzyme's activity level?
   a. temperature
   b. regulatory chemicals in the allosteric site
   c. feedback inhibition
   d. pH

Answer the following questions regarding the diagram below.

3. At what temperature is the enzyme working at maximum activity?

4. According to the graph, describe what happens as the temperature increases from 50°-60° and decreases from 30°-10°.
**Answer the following questions regarding the graph below.**

5. Which enzyme, A, B, or C maximally operates at a pH of 7?

6. What has happened to enzyme A at a pH of 5.8?
Using the diagram of the Calvin-Benson Cycle below, answer the questions that follow.

7. Which of the following molecules does CO₂ combine with when it first enters the cycle?
   a. PGA
   b. RuBP
   c. PGAL
   d. glucose

8. Which of the following molecules has five carbons?
   a. PGA
   b. RuBP
   c. PGAL
   d. glucose

9. How many molecules of CO₂ enter the cycle to form one molecule of glucose?
   a. 1
   b. 2
   c. 3
   d. 6
Unit: Cell division

1. Which of the following is the proper sequence for mitosis?
   a. metaphase, prophase, anaphase, telophase
   b. metaphase, telophase, prophase, anaphase
   c. prophase, metaphase, anaphase, telophase
   d. anaphase, metaphase, prophase, telophase

2. The two attached DNA molecules of a duplicated chromosome which are attached at the centromere are called what kind of chromatids?
   a. mother
   b. daughter
   c. sister
   d. kinetochores

3. In mitosis, if a parent cell has 16 chromosomes, how many chromosomes will each daughter cell have?
   a. 64
   b. 32
   c. 16
   d. 8
   e. 4

4. Which of the stages listed below is not a stage of nuclear division?
   a. anaphase
   b. prophase
   c. interphase
   d. telophase
   e. metaphase

5. During which phase are chromosomes lined up on the equatorial plate?
   a. interphase
   b. prophase
   c. metaphase
   d. anaphase
   e. telophase

6. During which phase does condensation (thickening) and shortening of chromosomes occur?
   a. telophase
   b. prophase
   c. metaphase
   d. anaphase

7. During which phase do sister chromatids separate and begin to move to opposite poles?
   a. interphase
   b. prophase
   c. metaphase
   d. anaphase
   e. telophase
During which period of the cell cycle are daughter cytoplasmic masses formed?

a. G2  
b. mitosis  
c. S  
d. G1  
e. cytokinesis

9. If a parent cell has 16 chromosomes, how many sister chromatids will be present after duplication?

a. 8  
b. 16  
c. 32

10. How many DNA molecules are present in a duplicated chromosome?

a. 1  
b. 4  
c. 2

11. At the end of meiosis I in corn (20 chromosomes), how many chromosomes will be present in the daughter cells?

a. each cell has 20 chromosomes  
b. each cell has 10 chromosomes  
c. each cell has 40 chromosomes

12. Does the following diagram represent mitosis or meiosis? ____________

13. Describe one distinguishing feature that helped you decide if the above diagram represented mitosis or meiosis.
Unit: Chromosomes and Human Inheritance

Complete the following genetics problems. You may need to use a Punnett Square or a line diagram.

1. A couple is preparing for marriage. They both have blood type AB. They ask you what blood types their children will have. Specifically, they want to know:

   a. What percentage will have the same blood type as the parents?
   b. What percentage will have AA blood?
   c. What percentage will have BB blood?
   d. What percentage will have type O blood?

2. In peas, yellow is dominant to green. What will the results be of a cross-pollination of two heterozygotes? Specifically:

   a. What percentage of offspring are homozygous?
   b. What percentage of offspring are heterozygous?
   c. What percentage of offspring have the recessive phenotype?
   d. What percentage express the dominant phenotype?

3. In iris plants, purple flower color is determined by gene P and white flower color by P′, while the heterozygous condition, PP′, is lavender (pale purple). What would be the results of a cross if both parents were pale lavender? Specifically:

   a. What percentage of offspring are purple?
   b. What percentage of offspring are white?
   c. What percentage of offspring resemble the parents?
Unit: DNA Structure and Function

1. Which of the following terms describes the production of DNA molecules that are half old and half new?
   a. translation
   b. semi-conservative replication
   c. codon
   d. base pairing

2. Which of the following is a complementary base to uracil?
   a. guanine
   b. cytosine
   c. adenine
   d. thymine

3. Which of the following is a complementary base to cytosine?
   a. guanine
   b. cytosine
   c. adenine
   d. thymine

4. Which of the following cellular structures is the correct site for protein synthesis?
   a. ribosomes
   b. nucleus
   c. mitochondria
   d. nucleolus

5. On which of the following molecules are codons found?
   a. DNA
   b. tRNA
   c. mRNA

6. Which molecule carries protein assembly instructions from the nucleus to the cytoplasm?
   a. DNA
   b. tRNA
   c. mRNA

7. Which molecule carries amino acids to the ribosomes?
   a. DNA
   b. tRNA
   c. mRNA

8. How many nucleotides (bases) make up a codon?
   a. 1
   b. 2
   c. 3
   d. 4
9. If the DNA sequence is ACTGTA, which of the following correctly identifies the mRNA codons?
   a. AUG - CGU
   b. UAC - GCA
   c. UAG - CGU
   d. UGA - CAU
   e. ATG - CGT

10. Which of the following correctly identifies the sequence of amino acids specified by the mRNA transcript AUGCGACCC?
   a. methionine - arginine - proline
   b. valine - arginine - leucine
   c. methionine - alanine - serine
   d. tyrosine - alanine - leucine
   e. serine - histidine - methionine

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# APPENDIX I

## ANOVA TABLE FOR RESEARCH QUESTION 1

### Tests of Within-Subjects Effects

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<tr>
<th>Source</th>
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## Appendix J

### ANOVA Tables for Each Unit

#### Unit 1

**ANOVA**

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#### Unit 2

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### Unit 5

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