Examining the Effectiveness of Grand Round Scenarios Using BioWorld: Does Real-World Practice Improve Real-World Learning?

Maria Rowena Espinosa

Department of Educational and Counselling Psychology

McGill University

Montreal

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of

Masters of Arts

in Educational Psychology

August, 2000

0-612-70593-5

Short title:

Examining the Effectiveness of Grand Rounds Scenarios

Using BioWorld

ABSTRACT

The purpose of this study was to examine the effectiveness of cased-based learning, writing and peer discussions on learning about digestive diseases in a computer-based learning environment, BioWorld. This method was called the Grand Rounds method. Thirty-one, ninth grade biology students participated in the study. Two classes were randomly selected as the Rounds group and the No Rounds group. All students worked collaboratively in pairs to solve diagnostic problems on BioWorld. The Rounds group then engaged in the Grand Rounds activities while the No Rounds group conducted a web search and solved a final BioWorld problem. Both treatments demonstrated significant knowledge gains of digestive problems from pretest to posttest but the gains were greater in the Rounds group. There were no significant changes from pre to post questionnaire in students' attitudes towards biology or peer work/discussion. The verbal protocols revealed students used diagnostic heuristics while solving cases, and discourse communities emerged among the students. Overall, this study confirms the benefits of written and oral discourse, and authentic learning activities in classrooms.

RÉSUMÉ

Cette étude examine l'efficacité de l'apprentissage basé sur des cas ("cased-based learning"), des activités d'écriture et de discussion en groupe dans une tâche d'apprentissage sur les maladies du système digestif, à l'aide d'un logiciel nommé "Bioworld". Cette méthode se nomme "Grand Rounds". Trente et un étudiants d'une classe de biologie de neuvième année ont participé dans cette étude. Une classe a été sélectionnée de façon aléatoire pour fonctionner avec la méthode et une autre sans la méthode. Tous les étudiants travaillaient en groupes de deux pour résoudre des problèmes à l'aide de Bioworld. Ensuite, le groupe avec la méthode réalisait les activités "Grand Rounds", alors que l'autre groupe devait faire une recherche sur internet et un dernier problème avec Bioworld. Les deux groupes ont bénéficié de l'apprentissage sur les problèmes digestifs, tel que le révèle une comparaison entre pré-test et post-test, mais les acquis d'apprentissage étaient supérieurs dans le groupe qui a utilisé la méthode "Grand Rounds". Nous n'avons pas trouvé dans notre questionnaire avant et après la tâche de changement significatif dans les attitudes des étudiants envers la biologie et les groupes de travail et de discussion. Les protocoles verbaux révèlent que les étudiants ont utilisé des heuristiques diagnostiques pour résoudre les problèmes et que des communautés discursives émergeaient parmi les groupes. Cette étude confirme l'avantage des pratiques orales et écrites pour aider l'apprentissage, ainsi que les activités authentiques dans la classe.

ACKNOWLEDGEMENTS

I would like to extend my deepest gratitude to an outstanding scholar and mentor, my supervisor, Dr. Susanne P. Lajoie. Your constant guidance and confidence in me has seen me through some of my most challenging times. Thanks for always being there.

To my wonderful parents and family, your unconditional love, patience, and support have never let me down. Mom and Dad, thank you for allowing me to pursue my dreams and to find my true passions. You are definitely the two most remarkable human beings I will ever know. And of course, to the love of my life, Mike. You have held my hand through every point of this journey. I honestly do not think I could have accomplished this without your unfailing love and encouragement. You have been my tower of strength, and for that I will be eternally grateful.

I would like to thank Geoffrey Dowd, Principal at Trafalger School for Girls, for allowing me to conduct my research at Trafalger. A special thank you to Ms.Sue Brass, a truly gifted biology teacher, and Ms. Sue Broden.

My sincere gratitude to Andre Renaud, Deborah Ratcliffe-Branche, and Andrew Chiarella for their time and assistance in the data collection. A huge thanks to Marguerite Roy for sharing her statistical expertise with me.

This project was made possible through funding from the Social Sciences and Humanities Research Council of Canada.

CONTENTS

Page

ABSTRACT....i
RÉSUMÉ....ii
ACKNOWLEDGEMENTS....iii
LIST OF TABLES....viii

CHAPTER 1: INTRODUCTION AND REVIEW OF THE LITERATURE....1
- Rationale....1
  - Technology in Classrooms....3
  - Case-Based Learning....4
  - Written and Oral Discourse....5
- Summary of Study and Research Objectives....6
- Examining the Scaffolding and Impact of Reflection and Metacognition on Learning....9
  - Thinking About Thinking: Metacognition and Reflection....9
  - BioWorld....12
    - Argumentation....13
    - Scientific reasoning....13
    - Reflective thinking....14
  - Teaching (Grand) Rounds....15
  - Writing to Learn....16
  - Classroom Talk and Learning....20
  - Discourse Communities....25
  - The Use of Diagnostic Reasoning Strategies....25
    - Heuristics Reasoning....26
      - Accessibility....27
      - Anchoring and adjustment....27

Page

Conditions Affecting Heuristic Use.....28
Description of the Present Study.....29
Research Questions.....29

CHAPTER II: METHODOLOGY.....32
Subjects.....32
Procedure.....32
Part I.....33
Part II.....35
Rounds group.....35
No Rounds group.....37
Coding Schemes.....40
Coding Scheme for Pre/Post Knowledge Tests.....40
Coding Scheme for Verbal Protocols.....41
Heuristics Reasoning Coding Scheme.....42
Availability heuristic.....43
Anchoring and adjustment heuristic.....44
Discourse Community Coding Scheme.....45
Coding Scheme for Written Protocols.....46
Materials.....46
Audio-Visual Equipment.....46
Resources.....47
Pre/Post Attitude Questionnaire.....47
Pre/Post Knowledge Test.....48
Design.....48

Page

CHAPTER III: RESULTS....50
Synopsis of Results....50
Pre/Post Knowledge Test Data....51
Pre/Post Attitude Questionnaire Data....56
Additional Post Questionnaire Data....63
Verbal Protocol Data....64
Analysis of heuristics reasoning....64
Analysis of discourse communities....67
Written Protocol Data....72

CHAPTER IV: DISCUSSION....74
Interpretation of Results....74
The Cognitive Benefits of Collaborative Written and Oral Discourse....74
Learner differences between conditions....75
Emergence of discourse communities....77
The Cognitive Processes Used in Collaborative Problem Solving....80
Additional Findings....86
Written assignments....86
Pre and post questionnaires....88
Limitations....92
Future Directions for Research....93
Final Thoughts....97

References....99

Page

APPENDICES....................107

A. Parental Consent Form....................107

B. Pre and Post Knowledge Test....................110

C. Pre and Post Attitude Questionnaire....................111

D. Rounds Group Case Write-up Instructions....................114

E. Post Questionnaire of Students' Interest in BioWorld....................115

F. Post Summary Questionnaire....................116

G. List of Digestive System Diseases, Symptoms, and Diagnostic Tests on BioWorld....................117

H. Coding Scheme for Heuristics Reasoning....................120

I. Coding Scheme for Discourse Communities....................122

J. Example of Rounds Group Case Write-up Submission....................124

K. Sample No Rounds Group Web Search Submission....................125

LIST OF TABLES

Tables **Page**

Table 1. Subject{Class(Rounds, No Rounds)} X Test (Pre, Post) ANOVA on the Three Knowledge Types.....53

Table 2. Least Squares Means and Standard Errors of Pre/Post Knowledge by Class.....55

Table 3. Intercorrelations Between the Three Knowledge Types.....56

Table 4. List of the Five Questionnaire Items by Attitude Category.....58

Table 5. Subject{Class(Rounds, No Rounds)} X Questionnaire (Pre, Post) ANOVA on the Two Attitude Categories.....60

Table 6. Least Square Means and Standard Errors of Pre/Post Attitudes By Class.....62

Table 7. Frequency of Heuristics Use by Disease.....66

Table 8. Percentages of Information Inclusion in Web Search Assignment.....73

CHAPTER 1: INTRODUCTION AND REVIEW OF THE LITERATURE

Rationale

Instructional approaches in science have recently been criticized for lacking in authenticity. In line with this, the present research attempts to evaluate the effectiveness of authentic learning situations on student learning and cognition. Although it has been argued that the activity in which knowledge is embedded and developed is an integral part of what is learned, science instruction has predominantly focused on teaching factual knowledge without mechanisms for contextualizing such knowledge in situations that would make abstract principles more concrete (Resnick, 1987). Recent research on science and mathematics instruction has found that in many classrooms students have only little understanding of their work and the content (Hackling & Treagust, 1984; Helm & Novak, 1983; Tasker, 1981). Others have reported that classrooms engage students in a narrow range of routine activities allowing little opportunity to master challenging tasks or important concepts (Goodlad, 1983; Stake & Easley, 1978; Ward & Tikunoff, 1982).

In a study by Mitman, Mergendoller, Packer, and Marchman (1984) investigating 11 junior high science classrooms, it was noted that only a small proportion of observed tasks required higher level, creative, or expressive skills. These studies illustrate a lack in a conception that is commonly neglected in learning and instruction: for knowledge to be contextualized, activity, concept and culture must be seen as being interdependent (Brown, Collins, & Duguid, 1989). The learning process involves all three of these aspects. Instead, however, teaching methods often attempt to impart abstract concepts as rigid, well-defined, and independent entities that can be fully represented through prototypical examples and textbook assignments. However, such representations are incapable of providing students with necessary vital insights into the culture or the authentic activities engaged in by members of that culture. Consequently, students often use the tools of a discipline without being able to adopt its culture.

To learn to use tools as practitioners employ them, a student must enter that community and its culture somewhat like an apprentice (Brown et al., 1989). As a response to these views, new reforms have contended that science instruction should go beyond teaching basic skills and memory and begin engaging students in problems that reflect real-world practice and provide more meaningful, challenging, and richer learner experiences that foster the development of reasoning abilities (Johnson & Lawson, 1998; Metz, 1995, 1997). These new reforms have led to the incorporation of new and innovative instructional techniques in the classroom such as computer-based learning environments (CBLE), case-based learning, writing-across-the-curriculum class activities, and peer discussions. Indeed, results have already been observed in various science classrooms of all levels.

Technology in Classrooms. The incorporation of technology in classrooms and science classrooms, in general, has been one of the leading trailblazers in the redesigning of learning activities. With the help of technology, the gap between theories learned in schools and real-life has been progressively lessened. The Computer Supported Intentional Learning Environments (CSILE), a project aimed to use computer technology in supporting intentional learning by students, is one example (Scardamalia, Bereiter, & Lamon, 1994). CSILE has been used as an aid to teach numerous school subjects: history, social studies, science, literature, geography, and mathematics. This instructional aid has been employed to support anything from traditional schoolwork to student-initiated inquiry. Furthermore, CSILE has also been found to create significant channels for communication in the classroom that are not mediated by the instructor. Indeed, evaluations have shown advantages for CSILE students with regards to understanding, metacognition, and active construction of knowledge (Scardmalia et al., 1994). Another prime example of how technology helps bridge the gap between rote declarative knowledge and higher level processing is BioWorld. BioWorld is a technology based curriculum support tool that assists students' understanding of biological terminology by situating the concepts in a simulated hospital setting (Lajoie, 1993; Lajoie, Greer, Munsie, Wilkie, Guerrera, & Aleong, 1995; Lajoie, Lavigne, Guerrera, & Munsie, 2000). In traditional high school biology classrooms, students are taught declarative information about bacterial and viral infections, how infections are transmitted, how different infections affect different parts of the human body, and how bodies have different defense systems to guard against certain diseases. Opportunities to reason, understand complex concepts, and use higher-level skills are rarely afforded. However, by engaging students in scientific inquiry, argumentation, and reflection BioWorld helps render abstract knowledge more concrete.

Cased-Based Learning. Case-based learning is an instructional technique that has traditionally been employed in the domains of business, law, and particularly, medicine (Williams, 1992). It has been shown to be a valuable tool for engendering critical thinking skills and schema construction (Alvarez, 1990).

The premise behind this approach is that by engaging students in studying a number of domain-specific cases, they acquire knowledge of a given topic. A prime example of this method is medical teaching (grand) rounds. Teaching rounds is a case-oriented instructional session usually held in a hospital conference room with the ward team. It is the teacher's primary opportunity to teach medical concepts in the context of patient care. In this context, expert practitioners are given the opportunity to articulate their own knowledge of practice, and facilitate the development of experiential learning for medical students and residents. This technique has been found to motivate students to collaborate, to learn medical information, and to apply the acquired knowledge as a means of solving clinical problems (Regan-Smith, 1987).

Written and Oral Discourse. A principle feature of medical grand rounds is its promotion of knowledge articulation. In order to be successfully engaged during these rounds, preparedness via written case reports and the readiness to convey patient information succinctly and carefully are necessities. Research has shown that articulation of knowledge through both written and/or oral discourse promotes reflection and, in turn, enhanced understanding. Researchers conducting writing-across-the-curriculum research have found that writing in all content area classrooms help students learn better, retain material, think more critically and at higher levels, make connections to personal and previous learning experiences, and gives good writing practice (Langer, 1986; Langer & Applebee, 1987). Likewise, when students present their ideas to others they are engaged in creating their own narrative community and in synthesizing and applying their new understandings to a new context. However, even more importantly, they are given the opportunity to share and construct new meanings and modify old ones as a consequence of the oral discourse.

Summary of Study and Research Objectives

Although research has been conducted on all of the above techniques, each technique has been predominantly evaluated in isolation of the other. The benefits afforded by these innovative teaching methods, have the potential to be immensely expanded if these instructional styles are employed in conjunction with one another. Not only can combining these techniques help students achieve further empowerment of their knowledge, but it also provides students with multiple opportunities and channels through which they can display their understanding.

The present study aims to evaluate the effectiveness of combining computer-based learning, case-based learning, writing, and peer discussions on learning about infectious diseases. Specifically, the goal is to investigate how participating in Grand Rounds scenarios affects students' knowledge and understanding of diseases and the disease process after using a CBLE called BioWorld (Lajoie, 1993; Lajoie et al., 1995; Lajoie et al., 2000). By emulating the grand rounds structure in the present research project, we provide opportunities for peers to learn from each other and for instructors to assume more of a mentor role. Consequently, we hope to build a community of students reasoning scientifically, who share their reasoning, knowledge, and argumentation skills. In essence, we are setting up an environment which facilitates the enculturation of students into the community of medical practitioners. This instructional set-up deals directly with the problems of generalization and transfer highlighted by situated cognition tenets.

The Cognition and Technology Group at Vanderbilt (1996) nicely illustrate the appeal of situated cognition with the contention that if we want students to solve complex problems that arise in day-to-day life, they need opportunities to learn in these contexts. This approach is precisely what the Grand Rounds attempts to achieve. Presenting Grand Rounds requires students to present, in written and oral form, the case they solved using the BioWorld technology with an explanation of how they solved it. The written segment will provide a reflection of the why and how of the students' diagnoses as well as provide a knowledge product of the students' understanding of the given disease and the diagnostic process. The oral component will provide a forum for open discussion about how students reasoned with data to solve the case. Hence, using the Grand Rounds technique can help foster an interpretative community in the classroom, thus resulting in better and richer learning opportunities.

This investigation focuses on (a) the overall cognitive benefits of collaborative written and oral discourse, and (b) the cognitive processes engaged in while working collaboratively to solve, represent, and explain a problem scenario.

The remainder of the chapter will discuss the theoretical foundations which underly the aforementioned focal points of the present study. Since the investigation aims to implement a myriad of instructional strategies into a variegated whole, a number of pertinent topics will be discussed: the importance of reflection on learning; the cognitive benefits afforded by the CBLE implemented in the present study, BioWorld; the cognitive benefits introduced by the cased-based, teaching rounds technique; and the upshot of collaborative written and oral discourse on learning and instruction.

Examining the Scaffolding and Impact of Reflection and Metacognition on Learning

As stated previously, several important areas of concentration are discussed in this portion of the literature review. Firstly, an introduction to metacognition and reflection is provided. The role of metacognition in learning and cognition is also discussed. Secondly, a discussion of the BioWorld CBLE is given. This discussion will include highlights of how the technology promotes higher level reasoning. The teaching rounds instructional technique will then be introduced as well as its great potential to scaffold metacognitive processes. Next, a summary of the educational and developmental benefits of writing, both individually and collaboratively is provided. The contributions of classroom discourse on cognitive growth and development will also be discussed. Lastly, the formation of discourse communities as a result of classroom discussion will be introduced.

Thinking About Thinking: Metacognition and Reflection

An invaluable and vital characteristic of learning is the usage and development of metacognitive processes. Metacognition can be defined as an individual's cognitions about his or her own cognition (Nelson, 1999). In relation to the acquisition of critical thinking skills, metacognition refers to what the learner knows about his or her thinking process and the ability to control these processes by planning, choosing, and monitoring.

According to Butler and Winne (1995) when students recursively plan strategies about how to learn, they partake in serially interpretive decision making and reflective cognition which leads to self-regulatory learning. Specifically, once a task has been interpreted in terms of what students believe and know, they frame goals, select tactics they believe can attain those goals, implement those methods, and observe the results. By monitoring the match between the results and the standards of what they intended to produce, students internally spawn information that is looped back into the process. Furthermore, students may also monitor the process of monitoring itself (Winne, 1997).

A second model suggests that there are two basic components of the metacognitive process: awareness and action (Wilen & Phillips, 1995). Awareness pertains to awareness of the purpose of the assignment, of what is known about the task, of what needs to be known, and awareness of the strategies and skills that facilitate and hinder understanding. Action refers to the ability to employ self-regulatory mechanisms to ensure successful completion of the task such as: planning strategies, checking outcomes, evaluating, revising, and remediating any difficulties encountered. These two components of metacognition are intrinsically linked and naturally lead to reflection on one's own knowledge.

The ability to reflect on one's thought is a uniquely human capacity and it is one that figures prominently in several theories of cognition and its development (Piaget, 1950; Sternberg, 1985; Vygotsky, 1962). In general, reflection has been regarded as a key link between experience and learning. Furthermore, it is seen as an essential phase in the learning process. However, Zimmerman (1994) contends that the nature of the classroom context plays a crucial role in facilitating self-regulating learning through reflection. Classrooms that do not allow for much independence, control, or choice on which tasks to perform, or strategies used to perform tasks hinder opportunities for the development and usage of self-regulatory strategies. Research has suggested that activities in which students engage in can have substantial impact on students' motivation and on the level of self-regulated learning and reflection in the classroom (Cohen, 1994). Furthermore, it has been shown that differences in instructional methods can affect the motivational ends that students adopt for their learning as well as their self-regulated learning (Wolters & Pintrich, 1998). More specifically, traditional instructional strategies that are more delimited, sequential, and static may be inhibiting the development and use of reflective and self-regulated learning.

Computers and software programs such as BioWorld support reflective thinking when they allow users to develop new knowledge by adding new representations, modifying old ones, and comparing them. Yet another instructional method which promotes reflective learning is the teaching rounds method. By providing opportunities for learners to co-construct knowledge through collaborative writing and case discussions, teaching rounds may ease the process of reflection as well as the generation of emerging knowledge. The subsequent sections will provide a description of the BioWorld technology and the teaching rounds technique as well as a discussion of how they scaffold reflection and metacognitive processes.

BioWorld

BioWorld is a CBLE designed to scaffold the acquisition of scientific reasoning skills in high school students (Lajoie, 1993; Lajoie et al., 1995; Lajoie et al., 2000). It assists students' understanding of biological terminology by situating concepts in a simulated hospital setting. BioWorld provides the mechanism for putting declarative knowledge into practice by enabling students to use such knowledge in the context of realistic problem solving tasks, such as diagnosing a disease. The various tools available on BioWorld support different types of cognition: (a) argumentation, (b) scientific reasoning, and (c) reflective thinking.

Argumentation. Students solve these problems by engaging in an argumentation process whereby they form a diagnostic hypothesis and collect evidence to either confirm or disconfirm their current diagnosis. As students engage in argumentation, they can adjust a belief meter to indicate how comfortable they are with a stated diagnosis based on the collected evidence. Upon completion of the problem, students justify their final diagnosis by constructing a final argument supported by their observations and evidence.

Scientific reasoning. BioWorld engages students in the scientific reasoning process in two ways. Firstly, BioWorld promotes scientific inquiry and allows for the development of explanations and model-based reasoning by engaging students in actively hypothesizing about the patient's disease as opposed to simply tutoring students on the various disease types and how they are transmitted. The second way in which BioWorld engages students in scientific reasoning is by requiring them to collect data in order to evaluate hypotheses. The process of evaluating diagnostic hypotheses is facilitated by a variety of on-line resources within BioWorld.

Medical information can be obtained from an on-line library of biological terms, diagnostic tests, and symptoms. Experimental data is available by requesting to perform diagnostic tests provided in the patient chart resource tool. These resources (i.e., problem scenario, on-line library, and patient chart) provide students with information with which to construct arguments.

Reflective thinking. The evidence palette provides a mechanism for making the arguments constructed by students visible so that they can begin to monitor their own scientific thinking. Actions such as selecting evidence, and performing library searches or tests are displayed dynamically in the evidence palette. Formulating hypotheses and building justifications require students to engage in top-down reasoning, i.e., set goals and subgoals, justify goals with supporting facts, and monitor all this information (Anderson, 1983). As a result of making actions and results visible in the evidence palette, reasoning is facilitated by supporting memory. BioWorld also scaffolds metacognitive processes via the belief meter. In summary, the many aspects of BioWorld clearly illustrate its potential to authentically engage students in higher-order thinking and contextualized learning.

Teaching (Grand) Rounds

Similar to the BioWorld technology, teaching rounds aims to scaffold metacognitive processes by contextualizing knowledge through the activities in which it engages its learners. The teaching rounds technique has predominantly been employed in medical schools. Clinical teaching in medicine involves discourse surrounding particular cases. This traditional form of dialogue is the hallmark of teaching rounds. Teaching rounds is a case-oriented instructional technique performed with the ward team. It is the teacher's primary opportunity to teach medical concepts in the context of patient care. During these grand rounds attending physicians, residents, and other health care specialists (i.e., respirologist, dieticians, etc.) working in the ward discuss patient cases they are currently caring for. These discussions include presenting courses of action taken regarding a given patient, explaining why certain actions were taken, and constructive feedback from the ward members regarding these actions. As practitioners and medical students present their cases, they dynamically refer to their written notes and self-prepared patient reports. This method of instruction allows expert practitioners to articulate their own knowledge of practice, and facilitate the development of experiential learning for medical students and residents.

Grand rounds possess five principle characteristics that facilitate hands-on learning in clinical settings: anchoring instruction in cases, actively involving learners, modeling professional thinking and action, providing direction and feedback, and creating a collaborative learning environment (Irby, 1994). In sum, teaching rounds enable medical practitioners and students to enhance and modify their preexisting knowledge by engaging them in higher level cognitive operations. Furthermore, the degree of higher level processing is additionally enhanced by engaging participants in written and oral discourse which, in turn, strongly scaffolds reflection and molds deeper learning experiences. Hence, the teaching rounds method not only serves the best interest of the patients in the ward but it also provides continual learning for residents and physicians alike.

Writing to Learn

The connection between writing and thinking has long been recognized. Historians have cited the acquisition of writing within a culture as a fundamental factor in the development of modern thought - promoting most notably scientific discourse. They attribute this development to the fact that the act of writing facilitates a logical and linear presentation of ideas. Furthermore, the permanence of writing permits reflection upon review of what has been written. Written language does more than just make ideas more widely and easily accessible, it changes the evolution and shape of the ideas themselves (Langer & Applebee, 1987). More specifically, the explicitness required for effective written communication, the active nature of writing, and the richness of discursive tools for refining ideas all combine to make writing a remarkably powerful instrument for shaping thought. Hence, incorporating writing in classrooms has the potential to greatly expand students' knowledge and thought. However, most classroom writing is intended solely for the teacher in the role of the examiner where much of the written work involves simple mechanical tasks such as filling in blanks. Expressive or persuasive writing is a rarity in science classrooms, as is the use of writing that is directed to oneself or to a wider audience.

It is uncommon for students to employ writing as a means of performing meaningful authentic learning tasks or for clarifying their own ideas about scientific topics. Howard (1988) argued that too much emphasis has been placed on writing as communication and not enough on writing as articulation. Juxtaposing these viewpoints with the current emphasis on a thinking curriculum which believes in challenging students to use knowledge in solving meaningful problems, leads to the conception that writing can serve as a channel for eliciting responses to complex problems requiring higher order reasoning. Consequently, advocates of "writing across the curriculum" have stressed the importance of writing in learning, especially for higher order learning (Langer, 1986; Langer & Applebee, 1987). Although the movement has waxed and waned, a recent barage of reports and studies have influenced scientific thought internationally and across North America.

In general, incorporating the preparation of written reports into educational curriculum has been found to help students clarify their thinking, think more critically, make connections to personal and previous learning experiences, and gain knowledge. Langer (1986b) conducted case studies of 67 children from 8 to 14 years of age and concluded that children seem to be more aware of their use of strategies, rhetorical structures, and background knowledge while writing than while reading. She suggested that this metacognitive awareness may implicate writing as a particularly effective technique for writing to learn.

Using different modes of writing in science classrooms has been found to be especially beneficial for learning and retaining course content (Tierney, 1981; Wotring, 1981; Johnston, 1985; Reynolds, 1987). Testimonials from students in a tenth grade honors biology class engaged in a reading response journal assignment revealed that writing provides insight into their thought processes as well as a greater understanding of the studied topic (Reynolds & Pickett, 1989). Furthermore, Zeakes (1989) found that writing about case studies in a parisitology class attended by university health majors promoted student-centered learning and helped improve creative thinking and problem-solving skills. Yet, another type of writing activity that has received emerging interest is collaborative writing.

Collaborative writing is based on the social constructivist theory which emphasizes student discourse as playing a quintessential role in the learning and writing process (Bruffee, 1984). It refers to a group of students engaged in the preparation of a valid and meaningful document or assignment (Dale, 1992). Through collaborative writing activities students work together to collect and share information, discuss, debate, and negotiate on a particular topic, all of which results in a final written text. Hence, not only does collaborative writing allow students to become actively engaged in the writing process but it also gives students the opportunity to generate ideas, discuss and exchange ideas, and to effectively plan and evaluate their written work. In the present study, students were engaged in collaborative writing when preparing written reports of their problem scenarios and reasoning processes.

Classroom Talk and Learning

Peer discussion is another scaffold for higher order thinking. The effects of classroom discussion have been a fundamental area of interest for researchers and psychologists alike. Piaget argued that social interaction is important because it stimulates cognitive conflict. Talk is seen as a catalyst for internal change. However, rather than directly influencing the forms and functions of thought it brings about the disequilibriums which make cognitive elaboration necessary. Put simply, the role of talk in mental growth is analogous to the role of a catalyst in a chemical reaction: although it is not present in the final product, it is nonetheless indispensable for the reaction to take place. Vygotsky also asserted to the benefits of speech by claiming that social interaction went beyond leading to the development of problem-solving abilities, memory, etc. He contended the very means of speech and social interaction are taken over by the individual and internalized (Cazden, 1988). With these views of discussion in mind it is no surprise that for centuries, teachers have initiated classroom talk in the belief that discussion improves understanding. However, while most instructors agree that classroom discussion is an extremely valuable teaching technique (Alverman & Hayes, 1989; Alvermann, O'Brien, & Dillon, 1990), there is less consensus on the issue of what constitutes discussion.

In many instances research and practical experience reveal a pattern of classroom discourse that is teacher-centered, limiting students to brief responses to the teacher's low-level informational questions. In discussions such as these, the structure of the discussion is largely predetermined by the instructor and student responses do not significantly influence outcomes. In contrast, a true discussion is a forum where ideas and opinions about topics are openly exchanged. Students rather than teachers ask the questions and they respond directly to each other rather than to or through the instructor. Here, the role of discussions is to open an arena where students negotiate the meaning of text or learner material. As students discuss, they test their ideas and consider the ideas of others. What results from this active participation is a personal construction of meaning. It also helps enhance long-term concept memory and recall as well as aid students to review or master subject matter (Kletzien & Baloche, 1994). While such interactions do take place at home and in the community as well as at school, they are especially vital to the classroom because of the limitations and rigidities characteristic of most teacher-student interactions in educational settings. It is this student-centered conception of discussion that students in the present thesis engaged in while discussing their problem scenarios with peers.

Classroom discourse also leads to the development of new meanings out of combined understandings. Research has shown that students learn from knowing when they are right and when they are wrong, but most importantly, when they are wrong (Bloom & Bourden,1980). Furthermore, it has been found that varied opinions can be particularly important when critical choices must be made (Resnick, 1991). Liedtke (1988) also argues that in mathematics classes evidence suggests that increasing the time spent on developmental tasks and student participation, and thus decreasing the time students spend on practice can have positive effects on mathematics achievement. Allowing students to listen to each other's responses and compare alternative explanations given to one's own, can serve as an extremely valuable learning experience. Hence, the importance of social interaction in learning should not be undermined.

Social factors are no longer regarded as external independent variables impacting on cognition. Rather, they play an intrinsic part in the process of creating meaning. Doise and Mugney (1984) illustrated this very point by observing the impact of social interaction on an individual's cognitive development by using Piagetian tasks of conservation of quantities (liquid, number, and length) and representation of spatial relations. The basic paradigm of the study consisted of a pretest to evaluate participants' operatory level. The pretest was followed by an experimental session during which time subjects would either solve a task alone, observe an adult model, or be confronted with a contradictory judgment given by an adult or another child. A week later, a posttest assessed the progress made by the participants.

Findings generally confirmed that children who were initially nonconservers on a Piagetian conservation task are likely to improve in the structuralization of this notion when given the opportunity to interact with peers concerning the notion. Such improvement was not observed with control groups who did not engage in peer interaction. Furthermore, a detailed examination of the content of the peer-group discussions during the experimental session and of participants' argumentation in the posttest indicated that participants who progressed to the stage of conservation managed to defend newly acquired cognition with arguments different from those heard from their partners during the experimental session. Likewise, their consistent generalizations to other conservation tasks during the posttest evaluation can not be explained by mere imitation or compliance to their partners' points of view. Hence, the responses generated by these experimental subjects are cognitively superior to their initial ones. These subjects demonstrated a capability to integrate larger viewpoints and to produce new reasoning that they can defend with arguments.

In another investigation of a second grade writing class, a peer collaboration activity was held whereby children held peer conferences discussing their writing with each other. The children were given the opportunity to take turns performing the teacher's role for each other, asking questions about content as opposed to form. The benefits of this technique for each child were two-fold: they each benefited as an author through experiences with a responsive audience; and they benefited as a critic by internalizing the questions asked during the conference not only by answering them as the teacher, but also by asking them of peers (Cazden, 1988). In sum, it appears that cognition is not as autonomous a function as initially postulated. Instead, cognition is dependent on the communication constraints developed by the individual as well as on the patterns of intersubjectivity that the individual's discussion partners encourage him or her to establish.

Discourse Communities

Classroom discussions also help create an arena where students can share a discourse community; a community which shares preferred ways of speaking or writing and that judge the quality of ideas in part as a function of the extent that they are expressed according to community standards. Likewise, shared objects, displays, and/or a common history (i.e., having done something together, gone somewhere together, or having common acquaintances) facilitate the process of referential anchoring - making sure that speakers and listeners understand a word or phrase in the same way (Resnick, 1991). The presence of this shared cognition provides the possibility to conduct a class discussion differently then if there was no such shared past history. In line with these views of establishing a community of discourse, constructivist theories of learning contend that higher thought is an internalized dialogue and ideas are seeded in discussion (Brown, 1994).

The Use of Diagnostic Reasoning Strategies

If discourse communities are formed and can be emulated, then it is plausible that the members of a given community would use similar reasoning strategies as the community it is attempting to emulate. Specifically, it is reasonable to assume that if the shared history of diagnosing diseases leads members of a community (even if the community is an emulation of another) to communicate more cohesively, it may also lead them to use similar cognitive tools while diagnosing diseases. The remainder of this literature review will discuss common diagnostic strategies employed by diagnosticians, notably heuristics reasoning. First, the accessibility heuristic will be introduced. Next, the strategy of anchoring and adjustment will be discussed. This will be followed by a discussion of the conditions which may affect heuristic use, particularly the amount of knowledge base and the complexity of the diagnostic situation.

Heuristics Reasoning

Although diagnostic reasoning has been studied since the 1960s, no general descriptive model has been formulated. However, evidence does suggest that diagnoses are made based on specific client and contextual variables using processes involving both intuitive and analytic thinking (Bjorkman, 1984). Another common tool used in diagnostic reasoning is heuristics. Heuristics are short-cut mental strategies that streamline information. Three heuristics are particularly relevant to diagnostic reasoning: (a) accessibility, (b) similarity, and (c) anchoring and adjustment. However, since the similarity heuristic is predominantly contingent on extensive clinical knowledge it will not be discussed in this review.

Accessibility. Accessibility is particularly prominent in two genres of reasoning: (a) availability, or the retrieval of instances and examples; and (b) simulation, or the construction of scenarios and instances (Tversky & Kahneman, 1973). When availability is used, the frequency or probability of an event is determined by the ease with which it is brought to mind. Although this method is a satisfactory measure of frequency when the diagnostic situations accurately reflect the most likely diagnoses, these situations may be based on factors unrelated to actual frequency. Simulation, the second type of accessibility, refers to the ease with which examples or scenarios are mentally constructed. This strategy is highly dependent on the amount of knowledge possessed. However, since the participants examined in the present investigation have not had much previous exposure to diagnostic cases, the availability heuristic may be more relevant for its purposes.

Anchoring and adjustment. A large body of literature supports the view that clinicians quickly form an initial diagnostic hypothesis (an anchor) when faced with a patient, and adjust this tentative judgment until a final diagnosis is arrived upon (O'Neill, 1995). Once the anchor has been established and the search for information begins, reasoning takes place in a backward fashion from hypothesized diagnosis to supporting data. This strategy, however, often leads clinicians to focus their attention on information that confirms their initial diagnosis (Jones, 1988) and to disregard data inconsistent with the preliminary hypothesis. Similar to the availability heuristic, the anchoring and adjustment technique may be particularly relevant to the present study since it may be a useful strategy regardless of level of experience.

Conditions Affecting Heuristic Use

Certain conditions affect the use of heuristics, notably the amount of knowledge possessed by the diagnostician and the complexity of the diagnostic situation (O'Neill, 1995). Although heuristic use is contingent, in part, on the amount of knowledge available with regards to the particular clinical problem, not all heuristic strategies are knowledge-dependent. For example, similarity is a heuristic contingent on considerable knowledge of a given domain whereas accessibility and anchoring and adjustment are not (Sherman & Corty, 1984). Accessibility requires only one salient example in a specific diagnostic area. Anchoring and adjustment may also be useful regardless of experience since early hypothesis generation and conservatism are common reasoning strategies regardless of knowledge base. However, reasoning does vary with the complexity of the judgment task. Hughes and Young (1990) found that when nurses are confronted with complicated client problems, there is a higher tendency to use heuristic strategies as a means of facilitating their diagnostic process.

Description of the Present Study

The objective of this study was to investigate the effectiveness of combining computer-based learning, case-based learning, writing, and peer discussions as a teaching method for infectious diseases. This method will be referred to as the Grand Rounds method. The study aimed to examine performance differences reflected through pre and posttest scores between grade nine high school biology students who participated in the Grand Rounds activities and those who did not. The study also aimed to investigate the scientific and diagnostic reasoning of students as they solved problems pertaining to the digestive system using a CBLE called BioWorld.

Research Questions

This study involves students solving problems dealing with different diseases and collaboratively explaining how they solved these problems both in written form and orally. Focus will particularly be placed on the students' reasoning and diagnostic processes and on how explaining and reflecting on these processes affect their learning. Computer-based learning, writing, and peer discussions all promote reflection on one's knowledge which, in turn, leads to enhanced understanding. This investigation aims to further examine the cognitive processes engaged in while employing these learning tools through two main questions.

The first question pertains to the cognitive benefits of collaborative written and oral discourse. Specifically, it deals with whether there will be any differences between students who engage in collaborative written and oral discourse activities and those who do not. Any cognitive benefits that resulted from the collaborative work were assessed through a posttest evaluation of participants' knowledge of diseases and disease processes. It is hypothesized that preparing a write-up of a patient scenario and discussing this patient scenario in a Grand Rounds-style forum will improve students understanding of diseases and the disease process as compared to students who do not engage in the Grand Rounds activities. The formation of a discourse community among the students will also be assessed. Since all students will have the shared experience of using BioWorld, I hypothesize that using the system will allow both the Rounds group and the No Rounds group to create their own community of discourse. However, since the Rounds group will be given the opportunity to discuss their patient case with other peers, I hypothesize that the formation of a discourse community will be more evident among the Rounds group students as reflected through their class discussions.

The second question will examine the cognitive processes engaged in while working collaboratively to solve, represent, and explain a problem scenario. This will be examined through verbal protocols and written work prepared by the students. In light of O'Neill's (1995) finding that heuristics reasoning is frequently used while formulating diagnoses, it is hypothesized that the students will reveal the use of heuristics while performing and discussing their diagnoses. In particular, it is hypothesized that students will predominantly employ the availability and the anchoring and adjustment heuristics.

CHAPTER II: METHODOLOGY

Subjects

A total of 31, ninth grade biology students attending an all girls school in the Montreal area participated in the study. Participants were drawn from two classes both of which were taught by the same teacher and followed the same curriculum. One class (N=17) served as the intervention group which we will refer to as the Rounds group. The second class (N=14), the No Rounds group, was the control group. Participation in the study was voluntary. Both student and parental consent was obtained from all participants (see Appendix A).

Procedure

The study aimed to investigate the effectiveness of combining computer-based learning, case-based learning, writing, and peer discussions as a teaching method for infectious diseases. This technique will be collectively referred to as the Grand Rounds method.

Two classes were randomly assigned as either the Rounds group or the No Rounds group. The Rounds group was instructed via the Grand Rounds method while the No Rounds group was not. Students in both classes worked in pairs except for one group in each class who, due to absenteeism and uneven class numbers, worked in a group of three. Each group was randomly preselected by the class instructor. The investigation was conducted during the students' regularly scheduled biology classes. The study lasted a duration of approximately one week.

Students were first individually administered a pretest evaluating their preexisting knowledge of diseases and disease processes (see Appendix B). They were also given an attitude questionnaire (see Appendix C) dealing with student interest in biology. Throughout the study, particular emphasis was placed on students' reasoning and diagnostic processes while using the BioWorld system, as well as on the learner differences between students who participated in the Grand Rounds activities and those who did not. In order to achieve this, the study was conducted in two main parts: Part I and Part II. In general, Part I required students to solve diagnostic problems using the BioWorld CBLE and Part II engaged students in a variety of in-class activities.

Part I

Part I of the investigation involved exposure of all students to the BioWorld technology. During this segment, all students were exposed to a simulated hospital setting through the BioWorld system. The CBLE provided the students with various diseases to diagnose. There were four diseases featured on the system: Ciliacs

Disease, Cirrhosis, Shigellosis, and Hepatitis A. Each of the four diseases pertained to the digestive system. Each disease was presented in the form of a problem statement that provided information with which the students could use to diagnose the case. BioWorld also featured various on-line resources from which students could obtain additional information such as definitions of terms as well as obtain test results.

All students spent two days, Days 1 and 2, working with BioWorld. Students worked on the system in the school computer lab. Upon arrival at the lab, students were instructed to sit at preselected computer work stations. The work station seating arrangements were chosen such that no group sat directly adjacent to another group as a means of preventing any exchange of answers and discussion between groups.

During Day 1, students from both classes were shown a demonstration of how to use the CBLE and the various resources available on it. Throughout the course of the demo, students were asked for their input on what the next step should be and how they would solve the case. The demonstration featured the Cirrhosis problem scenario. In the second half of the class, each pair was given the opportunity to diagnose a disease, Hepatitis A, on their own. This latter activity served as a hands-on practice problem for the students.

On Day 2, students were asked to solve one of two problems featuring one of the following diseases: Ciliacs Disease or Shigellosis. The order of presentation of these two diseases was counterbalanced to control for any ordering effects. The instructions provided to the students on this second day differed with respect to class. Students in the Rounds group were asked to "pay close attention" to their reasoning processes. They were asked to monitor their thinking and reasoning processes by writing down notes of why they opted to take the steps they did. The students were informed that these self-made notes would be useful for the proceeding class during which time they would work in groups to prepare a write-up on their given problem scenario. The control group, the No Rounds group, was not asked to monitor their thought processes. The successive days required students to engage in Part II of the investigation.

Part II

Rounds group. For the Rounds group, Part II required participants to engage in the Grand Rounds activities. There were two basic activities the Rounds group was expected to complete: (a) work collaboratively to prepare a write-up on the last disease they diagnosed when working with the BioWorld system (i.e., during Day 2), and (b) present, explain, and discuss their disease and diagnostic process to the other students in the class who did not solve that particular case. Each activity lasted a duration of one biology class period. The first day of the Grand Rounds activities consisted of the write-up preparation. The write-up was to include patient information, relevant symptoms, the students' diagnostic processes, and explanations for why these processes were followed (see Appendix D). Students were told that their patient report should be sufficiently informative and comprehensive such that the other students could understand the disease and the process through which it was diagnosed. In order to complete the write-up, pairs worked collaboratively with each other; all the pairs who had solved the Ciliacs Disease problem scenario worked together and all the pairs who solved the Shigellosis problem scenario worked together. Hence, this activity resulted in the class separating into two groups. The aim of grouping the pairs was to allow students who had diagnosed the same disease to exchange ideas and develop a consensus regarding the best possible representation of the illness and potential diagnostic routes.

The second day of the Grand Rounds activities consisted of the Grand Rounds oral presentations whereby each of the two groups was required to explain their disease and their diagnostic process to the other. During this second day, the room was set up as a hospital conference room with all the students congregated around a large rectangular table. The aim of the Grand Rounds presentations was to create an arena for student-centered discussion. Therefore, students were informed that they should regard this activity as a discussion forum rather than a traditional oral presentation where interruptions are not generally accepted. They were told they could ask questions of the speakers whenever they needed clarification and that they could provide their own input at any point during the discussion.

No Rounds group. Part II for the No Rounds group did not require them to participate in the Grand Rounds activities. Instead, they engaged in two other activities: (a) perform an internet search on the last disease they diagnosed while working on the BioWorld technology (i.e., during Day 2), and (b) solve another problem scenario on BioWorld. Similar to the Rounds group, each of these two activities lasted a duration of one biology class period.

On the first day of the activities, each pair conducted a web search of the disease they diagnosed on Day 2. Students were told that they could approach the search in any way they deemed appropriate (i.e., through search engines, familiar websites, etc.). Students were expected to hand-in a piece of paper including the names of the websites they visited, any interesting information found on the website, and why they thought the particular bit of information was interesting. The researcher defined "interesting" as being a relative term for each student. For example, for any given pair or student "interesting" may refer to historical information about the disease, the way in which the disease is transmitted, reported current or past outbreaks of the disease, etc. They were told they could also include whether a given website was helpful and why they thought it was. Again, "helpful" was defined as a relative term. The students could view "helpful" as pertaining to a useful resource for doctors, potential or current disease victims, and/or simply for curious web surfers.

On the second day of activities, the pairs were given a final disease scenario to solve on the BioWorld system. Each pair received one of two problem statements: Ciliacs Disease or Shigellosis. The disease that each pair was given was contingent on the disease they had diagnosed during Day 2 of Part I. Specifically, the pairs who solved Ciliacs Disease on Day 2 were given the Shigellosis problem scenario and vice versa.

Finally, all students were individually administered a posttest evaluating their knowledge of diseases and disease processes (see Appendix B). This posttest was identical to the pretest administered at the beginning of the investigation. They were also given an attitude questionnaire (see Appendix C) dealing with student interest in biology which, again, was identical to the one provided at the beginning of the study. A questionnaire assessing students' interest in the BioWorld activities was administered at the conclusion of the study (see Appendix E) as well as a summary questionnaire asking students what they had learned from using BioWorld (see Appendix F).

Throughout the investigation various sources of data were obtained. As stated earlier, in addition to the learner differences between the two classes emphasis was placed on the diagnostic processes engaged in by the students. To examine this two groups, one group in each class, were randomly selected and were audio and videotaped while using the BioWorld system. In the Rounds group, additional protocols were obtained from each of the two Grand Rounds groups as they collaboratively prepared their write-up. Lastly, a verbal protocol of the Grand Rounds oral presentation was also obtained. Diagnostic and reasoning process indicators were also available from the Rounds groups' patient report write-ups.

Coding schemes were developed to analyze the pre- and posttests, the verbal protocols, and the write-ups prepared by the intervention group. The coding scheme for the pre- and posttest analyzed the degree of knowledge possessed by each student both before and after the study. The coding schemes for the verbal protocols and written work analyzed the cognitive processes engaged in by the students while solving diagnostic problems.

Coding Schemes

Coding Scheme for Pre/Posttests

Both the pre and posttests were administered to all students. These evaluations consisted of two questions: the first question targeted general knowledge about diseases, the second question tested knowledge regarding digestive diseases. For the purposes of the present investigation, only responses to the second question were examined. A coding scheme was developed to capture the degree of knowledge change and improvement that the students experienced after using the BioWorld technology and participating in the various in-class activities involved in the study.

The question aimed to tap into three different types of knowledge regarding digestive problems: (a) knowledge of diseases, (b) knowledge of symptoms, and (c) knowledge of medical tests used to diagnose digestive problems. The question was rated on an overall score of 15 and each of the three components were scored on a subscore of 5.

Each component of the question was coded according to the information provided in the BioWorld system (see Appendix G). Specifically, the component targeting students' knowledge of digestive diseases was coded according to the full list of digestive diseases available on the CBLE. Students were given a score of five on five if they provided at least five of the digestive diseases listed on the system. Students who listed less than five of the given diseases received one point for each correct disease provided. Similarly, the component targeting students' knowledge of digestive disease symptoms was coded according to the full list of digestive disease symptoms available on the CBLE. Again, listing any five of the possible symptoms led to a score of five on five. Students who listed less than five received one point for each correct response. The component targeting students' knowledge of medical tests used to diagnose digestive problems was coded in a comparable manner. Students were given a score of five on five if they listed at least five of the medical tests used to diagnose digestive diseases available on the system. Students who listed less than five received one point for each correct medical test provided.

Coding Scheme for Verbal Protocols

Audio and video recordings were obtained from two groups of students, one group in each class, while they worked to solve diagnostic problems on the BioWorld technology. In the Rounds group, additional recordings were obtained from each of the two groups engaging in the Grand Rounds write-up activity. The discourse that resulted from the Grand Rounds presentations was recorded as well. Two coding schemes were developed to capture the cognitive strategies employed by the students as they worked to solve the problem scenarios. These schemes was applied to all the verbal protocols. The first coding scheme attempted to examine the use of heuristics reasoning during the diagnostic process. The second coding scheme was designed to capture the emergence of a community of discourse among the students as they worked collaboratively with their groups.

Heuristics Reasoning Coding Scheme

This coding scheme was developed to examine students' use of two heuristics: (a) the availability heuristic, and (b) the anchoring and adjustment heuristic. The protocols were examined in segments. Each unit of analysis consisted of a segment in which the students selected a potential diagnosis, collected evidence to help confirm or reject it, and then finally maintained or altered their initial diagnosis. Specifically, each segment began with a hypothesized diagnosis and ended with a conclusive decision regarding this diagnosis.

Availability heuristic. The availability heuristic is a form of the accessibility heuristic. When this reasoning strategy is used, the frequency or probability of an event (i.e., a patient having a given disease or illness) is determined by the ease with which it is brought to mind. There was one principle guideline employed to detect the use of the availability heuristic - diagnosing a disease according to what is familiar to the diagnostician. Three specific instances were coded as being indicative of the availability heuristic: referencing familiar cases as a means for selecting a given diagnosis, diagnosing a disease as either salmonella or any of the hepatitis illnesses, and immediately concluding that the diseases encountered were digestive problems. See Appendix H for specific examples of coded instances of the availability heuristic.

There were two reasons for coding salmonella and the hepatitis diseases as evidence for the availability heuristic: they are familiar and relatively well-known to the majority of the mass public, and several girls noted that they were familiar with these diseases. With regards to immediately hypothesizing that the diseases were digestive problems, concluding that discomfort after eating is directly linked to problems with the digestive system is a rational, highly probable diagnosis. However, the strategy employed to arrive at such a conclusion depends on a generalized mental association most people posses about eating and digestion. Since this association is so common and familiar, it renders the information easily accessible which, in turn, is indicative of the availability heuristic.

Any given instance of the use of the availability heuristic was coded only once, except for situations where the hypothesis was abandoned and later resurfaced. In these cases, the resurfaced instance was coded as another occurrence of the heuristic.

Anchoring and adjustment heuristic. The anchoring and adjustment heuristic can be described as quickly forming an initial diagnostic hypothesis (an anchor) when faced with a patient, and then adjusting this tentative judgment until a final diagnosis is arrived upon. Coding for the presence of this strategy was quite simple. Once a participant selected a potential diagnosis, the disease was coded as the anchor. If the diagnostician discovers incongruencies between the description of the potential illness and the symptoms or test results of the patient in question, they may either elect to continue looking for evidence that is compatible with the initial anchor or they may abandon the current search and adjust their hypothesis by choosing a new anchor. Selecting a new anchor in response to conflicting findings was coded as the adjustment component of the anchoring and adjustment heuristic. See Appendix H for specific examples of coded instances of the anchoring and adjustment heuristic.

As with the availability heuristic, any given instance of the anchoring and adjustment strategy was coded only once, except for situations where the hypothesis was abandoned and was later retaken. In these cases, the resurfaced hypothesis was coded as another incident of the heuristic.

Discourse Community Coding Scheme

This scheme attempted to snapshot a global representation of the interactions and shared understandings among the students. The objective was to simply highlight whether discourse communities emerged from the shared experience of learning collaboratively about diseases that affect the digestive system. Since the aim was to achieve a comprehensive picture of the quality of the discourse among the participants, the unit of analysis was each verbal protocol. In a given protocol, all instances where two or more students engaged in a discussion which reflected issues pertaining to the investigation were coded as evidence of discourse communities. See Appendix I for detailed examples of coded instances of discourse communities.

Coding Scheme for Written Protocols

There were two sets of written protocol data. One set was obtained from the two groups working collaboratively in the Rounds class as they engaged in the Grand Rounds write-up activity. The second set consisted of the web search assignment submissions completed by students in the No Rounds class.

The heuristics reasoning coding scheme applied to the verbal protocol data was also used to analyze the Grand Rounds write-up submissions. There was no coding scheme applied to the internet search activity. Since the results of the web search activity was not a prime focus of the present study, only general information such as what students chose to include in their submissions was examined.

Materials

Audio-Visual Equipment

Two video cameras, one Sony Handy Cam CCD-TR101 and one Hitachi VM-E230A, as well as two realistic voice activated cassette recorders with microphones were used in the present investigation. This equipment was used to audio and video record student interactions of two groups, one group in each of the two classes, while they worked to solve the diagnostic problems on the BioWorld technology. Recordings were also obtained during the

Grand Round activities and from one pair of students in the No Rounds class during the internet search activity.

Resources

All students worked on the BioWorld CBLE which was installed on nine IMac computers in the school computer lab. Apart from using the BioWorld computer-based learning environment, students did not use many other resources throughout the course of the study. However, students in the No Rounds group did have access to the world wide web while they engaged in their internet search activity. Access to the web lasted a duration of one biology class session.

Pre/Post Attitude Questionnaire

A 14-item pre/post questionnaire was developed to note changes in student's perceived knowledge about biology, their interest in biology, and their interest in engaging in collaborative work with their peers. Most questionnaire items were based on a five point ordinal scale. However, some items were based on multiple choice format (see Appendix C). In conjunction with the post questionnaire, an additional one-item questionnaire (see Appendix F) as well as a three-item questionnaire (see Appendix E) were administered at the conclusion of the investigation. The one-item questionnaire addressed students' perceptions of what they had learned from participating in the study. The three-item questionnaire addressed students' perceived enjoyment in participating in the investigation as well as any suggestions the students may have had with regards to it.

Pre/Post Knowledge Test

A two-item pre/posttest was designed to note any knowledge change and improvement in the student's understanding of digestive diseases and infectious diseases, in general. The first test item targeted general knowledge about diseases and diagnostic tools. The second test item tapped into three different types of knowledge regarding digestive problems: knowledge of digestive diseases, knowledge of digestive disease symptoms, and knowledge of diagnostic tests employed to detect digestive problems.

Design

Various sources of data were obtained from the investigation: (a) knowledge-assessing pre- and posttests, (b) attitude-assessing pre and post questionnaires, and (c) verbal and written protocols.

A repeated measures multivariate analysis of variance (MANOVA) design was used to monitor any pre- and posttest knowledge differences between the two classes. The pre- and post questionnaires assessing students attitudes towards biology and peer work were also examined through a repeated measures MANOVA. Frequency counts were used to examine participants' responses to the additional three-item post questionnaire and the summary question. Students' use of diagnostic heuristics as reflected through the verbal and written protocols were also analyzed through frequency counts. Descriptive analyses were employed on the verbal protocols to examine the emergence of discourse communities among the students.

CHAPTER III: RESULTS

Synopsis of Results

A doubley multivariate repeated measures analysis of variance was conducted on the pre and post knowledge tests to assess learner differences between the two classes. The hypothesis that the Rounds group showed greater improvement in their understanding of digestive problems in comparison to the No Rounds group was confirmed. A doubley multivariate repeated measures analysis of variance was also conducted on the pre and post attitude questionnaires to assess differences in students' attitudes towards biology and towards peer work/discussion. The results indicated no significant differences between classes. Students' use of diagnostic heuristics was examined through conducting frequency counts on the verbal protocols and written protocols. It was found that students largely employed the availability and the anchoring and adjustment heuristics while engaging in their diagnostic processes. This finding confirmed the prediction that novices would use these knowledge-independent diagnostic heuristics during their problem-solving process. Descriptive analyses were performed on the verbal protocols to investigate the emergence of discourse communities among the students. The analysis revealed communities of discourse did emerge and that these communities became more evident as students were given opportunities to discuss with peers. These results confirmed the hypothesis that discourse communities would be evident amongst students in both classes but that these communities would be more apparent in the Rounds group.

The subsequent sections provide a more in-depth report of the statistical analyses and results obtained from the investigation.

Pre/Post Knowledge Test Data

The pre and posttests were analyzed to capture any learner differences and knowledge improvement that may have developed with regards to digestive problems among the students. This data was examined using the coding scheme described in Appendix G. It was hypothesized that the Rounds group would show greater improvement in their knowledge of digestive problems in comparison to the No Rounds group. As previously described, the tests consisted of two questions, the first was a general question about diseases while the second question was more specific to digestive problems. However, for the purposes of the present investigation only the question addressing digestive problems, question #2, was analyzed. This question aimed to explore three different types of knowledge regarding digestive problems: (a) knowledge of digestive diseases, (b) knowledge of symptoms, and (c) knowledge of medical tests. Therefore, it was analysed both as a whole and in terms of these three knowledge types.

A doubly multivariate repeated measures analysis of variance was performed on this data. The analysis consisted of one between factor (Class) and one within factor (Test) on multiple dependent/outcome variables (Knowledge type). Therefore, a Subject{Class(Rounds, No Rounds)} X Test(Pre, Post) MANOVA was conducted on multiple dependent variables (Disease knowledge, Symptom knowledge, and Medical Tests knowledge) measured simultaneously. A significant main effect of Test ($F(3,27) = 4.8$, $p < .05$) was found. There was also an overall significant Test X Class interaction effect ($F(3,27) = 4.9$, $p < .05$). See Table 1 for the Analysis of Variance of the pre/posttest scores by Class and Test on the three dependent variables.

Table 1

Subject(Class(Rounds, No Rounds)) X Test(Pre, Post) ANOVA on the Three Knowledge Types.

Source	df	F	p
Between			
Class	3,27	1.51	0.2337
Within			
Test	3,27	4.89	0.0076*
Disease	1,29	11.36	0.0021*
Symptoms	1,29	12.61	0.0013*
Medical Tests	1,29	0.83	0.3712
Test X Class	3,27	4.97	0.0071*
Disease	1,29	4.04	0.0539
Symptoms	1,29	3.93	0.0569
Medical Tests	1,29	4.75	0.0375*

Note. *$p < .05$.

There was no significant main effect of Class found on all the three dependent variables considered simultaneously. This indicates there were no initial differences in degree of prior knowledge of digestive problems between the Rounds and the No Rounds conditions.

A significant main effect of Test

($F(3,27) = 4.8$, $p < .05$) on all three knowledge types considered simultaneously was found. This result suggested that both conditions improved in their knowledge of digestive problems from pre to posttest. Subsequent univariate tests revealed significant differences in disease knowledge ($F(1,29) = 11.3$, $p < .05$) and in knowledge of symptoms ($F(1,29) = 12.6$, $p < .05$). However, no significant differences in medical test knowledge were found. These results demonstrate that both conditions significantly improved in their knowledge of digestive diseases and symptoms but did not significantly improve in their knowledge of medical tests.

There was a significant interaction effect between Test and Class found ($F(3,27) = 4.9$, $p < .05$) whereby the Rounds group demonstrated greater gains in scores on all three dependent measures considered simultaneously. This result confirms the hypothesis that the Rounds group would show greater improvement in their knowledge of digestive problems in comparison to the No Rounds group.

Analysis of the two classes' least squares means revealed their overall pre and post performance on each of the three knowledge types. The trend illustrated a larger improvement in the Rounds Class from pretest to posttest on their knowledge of digestive diseases and on their knowledge of symptoms in comparison to the No

Rounds Class. However, the No Rounds Class experienced a higher increase from pretest to posttest performance on their knowledge of medical tests when compared to the Rounds Class who actually decreased in performance on this measure. The overall pre and post least squares means of the three dependent measures for both classes are shown in Table 2.

Table 2

Least Squares Means and Standard Errors of Pre/Post Knowledge by Class

		Class			
		Rounds		No Rounds	
		M	SE	M	SE
Knowledge Type					
1. Disease					
	Pre	0.41	0.19	0.28	0.21
	Post	1.82	0.40	0.64	0.44
2. Symptoms					
	Pre	1.23	0.33	2.00	0.36
	Post	3.00	0.40	2.50	0.44
3. Medical Tests					
	Pre	0.64	0.18	0.50	0.20
	Post	0.41	0.28	1.07	0.31

The correlation values among the three knowledge types are shown in Table 3. The results indicated that test scores on symptom knowledge were significantly correlated with both disease knowledge and medical tests knowledge. There was no significant correlation between performance on disease knowledge and medical tests knowledge.

Table 3

Intercorrelations Between the Three Knowledge Types

Knowledge Type	1	2	3
1. Diseases	--	0.56*	0.31
2. Symptoms		--	0.36*
3. Medical Tests			--

Note. *$p < .05$.

Pre/Post Attitude Questionnaire Data

A pre and post questionnaire was administered to students as a means of assessing any changes in the student's perceived knowledge of biology, interest in biology, and in their interest in working collaboratively with peers. The questionnaire consisted of 14 questions. However, only five of the 14 questions were examined: question #2, question #5, question #6, question #8, and question #11. These five questions were further categorized into two categories, which addressed two separate issues of relevance for the present investigation.

The first category aimed to capture students' *attitudes towards biology*. This category included questions #2, #5, and #11. Scores on these three questions were collapsed to obtain the category score for each participant. The second category targeted students' *attitudes towards peer collaboration*. This category was comprised of questions #6 and #8. Scores on these two questions were collapsed to obtain the category score for each participant. Table 4 provides a listing of the five questions organized according to attitude category.

Table 4

List of the Five Questionnaire Items by Attitude Category

Category	Question
Attitudes Towards Biology	1) Compared to other subjects I like biology: A much less; B less; C about the same; D better; E much better
	2) I am ___________ motivated to do well in biology as in other subjects. A not at all; B not; C just as; D more; E much more
	3) My interest in biology is: A very low; B low; C average; D high; E very high
Attitudes Towards Peer Collaboration	4) Do you enjoy working in group projects? A not at all; B not; C somewhat; D yes; E a great deal
	5) Do you enjoy classroom discussions with your peers? A not at all; B not; C somewhat; D yes; E a great deal

A doubly multivariate repeated measures analysis of variance was conducted on the questionnaire data. The analysis consisted of one between factor (Class) and one within factor (Questionnaire) on multiple dependent/outcome variables (Attitude). Therefore, a Subject{Class(Rounds, No Rounds)} X Questionnaire (Pre, Post) MANOVA was conducted on multiple dependent variables (Attitudes towards Biology, Attitudes Towards Peer Collaboration) measured simultaneously. There was a significant main effect of Class found on the two dependent variables considered simultaneously, F (2,28) = 4.01, $p < .05$. No significant interaction effects were found. Table 5 provides the Analysis of Variance of the pre/post questionnaire scores by Class and Questionnaire on the two dependent variables.

Table 5

Subject(Class(Rounds, No Rounds)) X Questionnaire (Pre, Post) ANOVA on the Two Attitude Categories

Source	df	F	p
Between			
Class	2,28	4.01	0.0293*
Within			
Questionnaire	2,28	1.87	0.1716
Biology	1,29	0.17	0.6811
Peer Collab.	1,29	3.38	0.0761
Questionnaire X Class	2,28	0.55	0.5817
Biology	1,29	0.51	0.4808
Peer Collab.	1,29	0.46	0.5051

Note. *$p < .05$.

The significant main effect of Class found suggests that there were significant differences between the conditions on their prior attitudes towards biology and peer collaboration. The least square means of the pre questionnaire scores illustrated in Table 6 reveal that the No Rounds group indicated more positive initial attitudes towards both biology and peer collaboration in comparison to the Rounds group. The results revealed no significant main effect of Questionnaire on the two dependent variables considered concurrently. This indicates that neither condition experienced significant overall changes in attitude from pre to post questionnaire. Subsequent univariate analysis revealed there were no significant differences in attitudes towards biology from pre to post questionnaire. Likewise, there were no differences in students' attitudes towards peer collaboration.

It was determined that there was no significant interaction between Questionnaire and Class on both the dependent measures considered simultaneously. This finding suggests that there were no differences between conditions in their attitudes towards biology and peer collaboration from pre to post questionnaire.

Examination of the least squares means of the two Attitude categories for both conditions revealed overall changes in students' Attitudes Towards Biology and Attitudes Towards Peer Collaboration. The trend demonstrated that the Rounds Class experienced a slight increase from their pre questionnaire scores with regards to their Attitudes Towards Biology in comparison to the No Rounds Class. The No Rounds Class experienced a slight drop in this attitude. Both the Rounds and the No Rounds Class showed a decrease from their pre questionnaire scores on the Attitudes Towards Peer Collaboration measure. However, the drop for the No Rounds Class on this measure was greater in comparison to the decrease experienced by the Rounds Class. The overall pre and post least squares means of the two dependent measures for both classes are shown in Table 6.

Table 6

Least Square Means and Standard Errors of Pre/Post Attitudes By Class

	Class			
	Rounds		No Rounds	
	M	SE	M	SE
Attitude Category				
1. Biology				
Pre	3.78	0.17	4.04	0.19
Post	3.82	0.14	3.90	0.16
2. Peer Collab.				
Pre	3.69	0.12	4.17	0.13
Post	3.55	0.13	3.89	0.14

Note. Maximum score = 5; Minimum Score = 1.

The correlation analysis revealed that students' attitudes towards biology were not significantly correlated to their attitudes towards peer collaboration ($r = -0.15$, $p > .05$).

Additional Post Questionnaire Data

An additional three-item questionnaire was also administered to all students at the end of the investigation. The questionnaire addressed students' enjoyment in participating in the study and any suggestions for improvement that they may have had.

The results showed that in the Rounds group, 94.1% of the students stated they enjoyed participating in the investigation. A total of 58.8% of the students indicated they enjoyed engaging in group work because it gave them the opportunity to share ideas and get different opinions from others.

The two most frequent suggestions from students in the Rounds group were: to have more time working on the BioWorld technology at 29.4%, and that the Grand Rounds presentation activity was occasionally boring at 11.8%. In the No Rounds group, 85.7% indicated they enjoyed participating in the investigation and 78.6% of the students noted that they enjoyed the group work because it allowed them to share ideas and opinions with others. A total of 35.7% participants suggested providing more opportunities to solve problems on the BioWorld system, and 21.4% indicated that the web search activity was tedious at times.

Lastly, a one-item summary questionnaire was also given to all students at the end of the study. The question addressed students' perceived learning experience from participating in the present investigation. In the Rounds group, 82.4% of the participants revealed they achieved a better understanding of digestive system diseases. The data also indicated that 70.6% of students felt they had a larger degree of appreciation and understanding of the diagnostic process. Furthermore, 35.3% stated they learned that getting various opinions is crucial for medical practitioners. In the No Rounds group, 78.8% of participants stated they had learned more about digestive diseases. A total of 64.3% indicated they had achieved a better understanding of the diagnostic process.

Verbal Protocol Data

There were two objectives in analyzing the verbal protocol data: (a) examine students' use of diagnostic heuristics during their problem solving processes, and (b) assess the emergence of discourse communities among students. Qualitative descriptive analyses were conducted on the protocol data as a means of capturing the cognitive activities engaged in by the participants.

Analysis of heuristics reasoning. Descriptive analyses were performed on the verbal protocol data as a means of detecting the use of two heuristic strategies during the diagnostic process: (a) the availability heuristic, and (b) the anchoring and adjustment heuristic. Students' use of heuristics was evaluated using the coding scheme described in Appendix H.

As previously mentioned, it was hypothesized that these strategies are those most likely to arise in this investigation since they are not dependent on the diagnostician's degree of knowledge regarding digestive diseases and since the participants had not received any formal instruction on digestive diseases. All protocols except for the Grand Rounds presentations protocol were included in this analysis. The reason for this exclusion was due to redundancy; the diagnostic processes and hypotheses that were presented during the presentation activity were previously reflected in the Grand Rounds write-up activity which was also recorded and analyzed.

Inter-rater reliability was performed on 25% of the verbal protocols, since this number was considered adequate for the present investigation. Inter-rater reliability was assessed between two raters using the Pearson correlation. The Pearson correlation coefficient indicated a high overall correlation ($\underline{r}$ = 0.86) among raters.

Frequency counts were conducted on the protocols. The frequency of heuristics use for each disease solved by the students is presented in Table 7. The results revealed that the students generated a total of 27 diagnostic hypotheses. The frequency at which the availability heuristic was employed was 70.4%. In other words, 19 of the 27 hypotheses were generated using the availability strategy. The anchoring and adjustment heuristic was employed at a 96.3% frequency. Of the 27 diagnostic hypotheses generated by the students, 26 of the diagnoses were arrived upon using the anchoring and adjustment strategy. These results support the hypothesis that students would employ both the availability and the anchoring and adjustment heuristics throughout their diagnostic processes.

Table 7

Frequency of Heuristics Use by Disease

	Heuristics					
Disease	Availability		Anchor & Adjust		Hypotheses Generated	
	Raw	%	Raw	%	Raw	%
Hepatitis A	7	25.9	9	33.3	9	33.3
Shigellosis	4	14.8	7	25.9	7	25.9
Ciliacs Disease	8	29.6	10	37.0	11	40.7
Total	19	70.3	26	96.3	27	100

The analysis also indicated that there were no major changes in frequency of diagnostic heuristics use over time. The diseases listed in Table 7 are provided in the order in which they were solved by students on the BioWorld technology.

More in-depth analyses of the data revealed that there were three diseases most frequently selected by the students as their first diagnostic hypothesis: Salmonella, Hepatitis A, and Shigellosis. Salmonella was chosen as first diagnosis at a frequency of 50%. Hepatitis A was chosen first 25% of the time. Finally, Shigellosis was selected first 12.5% of the time. In addition to these diagnostic processes engaged in by the students, students also verbally attested to employing the process of elimination when selecting hypotheses.

Analysis of discourse communities. Descriptive analyses were also performed on the verbal protocols to capture whether a discourse community emerged among the students. The presence of communities of discourse was assessed using the coding scheme specified in Appendix I. It was hypothesized that communities of discourse would arise as a remnant of the students' shared experience of solving diagnostic diseases on the BioWorld CBLE and working collaboratively. However, since the Rounds group had more opportunities to discuss on a larger scale with their peers it was hypothesized that any emergence of such communities would be more evident in the Rounds class.

The analyses revealed that discourse communities were created among the students. While working on the BioWorld CBLE each pair in both the Rounds group and the No Rounds group engaged in a discourse community amongst themselves. Furthermore, evidence of the implicit knowledge and understanding among the team members regarding their task seemed to increase throughout the investigation. The students began to refer to past cases encountered while using the BioWorld system. They also referenced familiar medical tests and symptoms. More importantly and interestingly, these references were not done in an explicitly obvious manner; they could only be truly understood through shared experiences. The following excerpt of a dialogue between two students in the Rounds group aims to illustrate this phenomenon. The excerpt was taken on the second day of working on the technology.

> Student1: So, but I don't think it would be salmonella because that's getting sick from like chicken right? And this is kind of...
>
> Student2: Well we could just like research, oh we have to choose the one that we think.
>
> Student1: Well yeah and then ...
>
> Student2: we don't know what Shigellosis is
>
> Student1: Yeah we did, remember when we did it yesterday
>
> Student2: do we lose points or whatever, what's Shigellosis?

Student1: can't remember, which one's the drinking one?

Student2: cirrhosis, that's not here

Student1: so how is it not given to

Student2: cirrhosis is...

Student1: no it's here

Student2: Well Hepatitises are also from drinking

Another excerpt obtained from students in the No Rounds group also demonstrates the implicit understanding shared among the team members. The following excerpt was taken on Day 2 of working on the BioWorld system.

Student2: Okay. Alright, I think it's digestive because of diarrhea, vomiting. What do you want Ciliacs, hepatitis A? Let's try hepatitis. Oh! Remember the one we got yesterday? Oh, I think its salmonella, diarrhea.

Student1: Yeah, vomiting, sweating um. Oh, and when you eat cereal and bread.

Student2: Okay, we're pretty sure, that's good.

Further evidence of the formation of discourse communities emerged during the Grand Rounds write-up activity. Students in each of the two write-up preparation groups, the Ciliacs group and the Shigellosis group, created their own communities of discourse through their common experience of solving the same problem scenarios. An excerpt from the Ciliacs write-up group illustrates this point.

Student1: we ran um.. uh a gluten whatever protein test

Student7: there's another one too wasn't there?

Student1: I don't know

Student7: there was an iron one

Student1: we ran a gluten protein test

Student5: we also ran the folic acid

Student7: (referring to gluten protein test) which was high

Student5: ya, we ran the hepatitis b titer and that's how we knew it wasn't those ones

Student3: okay, the results were high?

Student1: and we knew it wasn't shig

Student3: see look we should talk about those, though

Student1: see you guys, we didn't know about the Hepatitises too much

Student3: and we thought it was one of the Hepatitises so we ran all the tests of the Hepatitises. Just as there's a Hepatitis titer, B Hepatitis titer. The results were high after we ran the total lubrication. Did anybody take an iron test?

Student4: ya, we did.

Student3: what was it?

Student4: it was low (emphasizing the low)

Student3: was it really?

Student4: ya

Analysis of the Grand Rounds presentations revealed the emergence of a variety of discussion topics reflecting the myriad of experiences encountered throughout the course of the study. These discussion topics led to the formation of a larger community of discourse. The topics discussed included: the pros and cons of collaborative work; the necessity of collaborative work in the workforce, especially among medical practitioners; the similarities among the various digestive diseases introduced via the BioWorld technology; and a discussion of students' personal experiences with similar digestive health problems. An excerpt from the discussion of similarities between the digestive diseases encountered during the investigation highlights evidence of this phenomenon.

> Student2: once you knew a little bit about the diseases it's better
>
> All: ya
>
> Student2: because you can narrow it down
>
> Student4: ya you could narrow it down
>
> Researcher: Did you find similarities between the symptoms that they said and the symptoms that you said
>
> All: ya
>
> Student2: ya, well I think like within, if it's within the digestive it's all similar. There's always like
>
> Student4: nausea
>
> Student2: vomiting, diarrhea, nausea like feeling sick after eating
>
> Student4: losing weight
>
> Student2: or like headaches or fever

Student6: especially after eating because

Student2: tiredness, jaundice was one of them

The results from the verbal protocol data confirmed the hypothesis that communities of discourse would arise among the students. In addition, as students were given more opportunities to discuss with other peers the emergence of discourse communities became more evident as seen through the write-up and case presentation activities. This phenomenon further supported the hypothesis.

Written Protocol Data

Descriptive analyses were performed on the written reports prepared by the students during the Grand Rounds write-up activity as well as on the web search assignments submitted by the students in the No Rounds group. The coding scheme developed to examine the use of heuristics reasoning in the verbal protocols was applied to the Grand Rounds write-up data. No coding scheme was applied to the web search assignment data since the majority of the students printed out the website information directly from the internet site itself or simply copied the information available on the site verbatim.

Analysis of the diagnostic write-ups revealed they were written representations of each group's Grand Rounds presentation. Since, the information provided on the reports were virtually identical to the information presented during the oral session no further analyses on this data was conducted. However, a sample disease write-up is shown in Appendix J.

A total of nine web search assignments were submitted. The submissions included a variety of information regarding each of the two diseases researched. The majority of the information submitted involved: symptom information, outbreak statistics and demographics, primary modes of disease transmission, and dietary information. The percent frequencies at which this information was included in the assignments is presented in Table 8. An example of a web search assignment submission is provided in Appendix K.

Table 8

Percentages of Information Inclusion in Web Search Assignment

Symptoms	Outbreaks	Transmission	Diet Info
44.4%	44.4%	33.3%	33.3%

CHAPTER IV: DISCUSSION

The present investigation attempted to address two principle research questions: the first question pertained to the cognitive benefits afforded by collaborative written and oral discourse, while the second question aimed to examine the cognitive processes employed while engaging in collaborative problem solving and representation. This chapter presents a general discussion of the results and interpretations of the present investigation, followed by a description of the study's limitations. A discussion of future directions for research in this area will also be given. Finally, the chapter will conclude with some final thoughts and insights regarding the implications of the study.

Interpretation of Results

The Cognitive Benefits of Collaborative Written and Oral Discourse

The first research question aimed to explore the cognitive benefits of collaborative written and oral discourse. This question was examined from two perspectives. One perspective assessed learner differences between students who engaged in the Grand Rounds method and those who did not. The second perspective examined the emergence of discourse communities among students.

Learner differences between conditions. It was hypothesized that students who actively engaged in the articulation of one's knowledge through both written and/or oral discourse would display a greater improvement in their understanding of digestive problems when compared to students who did not participate in these activities. This was assessed through the pre and post knowledge tests given to all participants.

The hypothesis was partially confirmed by the findings. Both the Rounds and the No Rounds conditions displayed significant gains in their knowledge over time, but the Rounds group experienced greater gains in their knowledge. Specifically, the Rounds group displayed a greater understanding of digestive diseases and digestive disease symptoms when compared to the No Rounds group. Although these results were just shy of meeting significance, the trend illustrating this phenomenon was quite strong as seen through the least squared means.

The findings are congruent with past research that has shown that writing in science classrooms is especially beneficial for learning and retaining course content (Tierney 1981; Wotring, 1981; Johnston, 1985; Reynolds, 1987). The findings also support the social constructivist view which emphasizes that student discourse plays a vital role in the learning process (Brufee, 1984).

Interestingly, however, the No Rounds group displayed greater gains in their knowledge of medical tests in comparison to the Rounds group. One explanation for the No Rounds group's better performance may be that much of the terminology regarding diagnostic tools (i.e., total bilirubin, SGOT) is more complex and unfamiliar to high school biology students when compared to the terminology pertaining to diseases (i.e., Hepatitis A) and symptoms (i.e., nausea, vomiting). In fact, some students attested to the fact that the medical test terms were quite complex. A statement from a student in one of the Grand Rounds write-up groups illustrates this point, "No, I want to do the symptoms ... because the tests are longer and harder." Retaining and acquiring such information may be difficult for a layperson with little experience of medical terms due to cognitive overload of new terminology.

Since the No Rounds group had more sessions working on the BioWorld technology, this led to more opportunities to run and read about medical tests. Therefore, it may have been easier for them to retain such knowledge given their increased exposure to it. In other words, because this terminology was relatively new to students, actual hands-on experience with the computer environment may have been more helpful to problem solving than simply reporting. This explanation may not be applicable to knowledge of diseases and symptoms because many of the terms pertaining to these topics are already known to the general public. For instance, some diseases such as salmonella and hepatitis and some symptoms such as vomiting and diarrhea are commonly known, thus making it easier for students to build on prior knowledge. Therefore, it is plausible that discussing knowledge which is already familiar to the discussants through personal and shared experiences can serve to further improve this prior knowledge above and beyond what hands-on practice can accomplish alone.

In summary, the findings from the pre and post knowledge tests demonstrate that collaborative written and oral discourse can contribute to enhanced learning outcomes in classrooms.

Emergence of discourse communities. Verbal protocols were obtained from various sources to examine the formation of communities of discourse among the students: from one group in each class, from the groups participating in the Grand Rounds write-up activity, and from the Grand Rounds presentations. It was hypothesized that communities of discourse would evolve among the students in both conditions as a result of their shared experiences with the BioWorld CBLE.

However, since the Rounds group had more opportunities to discuss these experiences on a larger scale with their classmates it was hypothesized that the emergence of discourse communities would be more evident in this group. This hypothesis was confirmed by the finding that communities of discourse did emerge between the students but these communities were more apparent throughout the discussions of the Rounds group.

Examination of the protocols demonstrated that communities of discourse were created in both classes. Discourse communities were established among the pairs in both classes as they worked to solve the problem scenarios. Here the discourse centered around previous cases encountered while using the BioWorld system and on some references to personal experiences as a means of facilitating the diagnostic process.

During the Grand Rounds write-up activity, each of the two write-up groups created their own discourse community. Their discussions illustrated each group's common understanding of the symptoms and medical tests associated with the respective disease. The students' newly acquired knowledge was also evident through their discourse. However, this knowledge was conveyed throughout the discussions so implicitly that only those who had diagnosed the same disease could truly see the full picture of what was being discussed. This phenomenon supports Resnick's (1991) view that sharing a common history through mutual experiences facilitates the process of referential anchoring. This shared, past experience renders it possible to conduct a class discussion differently then if there was no such joint history.

When the two write-up groups were given the opportunity to present their case and discuss amongst each other, a wide variety of discussion topics emerged. These topics were the foundations of a greater discourse community; a community that reflected the students' shared experiences of participating in the investigation. Their discussions revolved around working collaboratively to solve problems, what they learned from simulating activities engaged in by real-world physicians, their new understandings and schemas regarding digestive problems, how problems affecting the digestive system can also affect other body systems, and how their personal experiences related to what they had learned and discussed. These results are consistent with findings that classroom discourse leads to the development of new meanings out of combined understandings (Bloom & Bourden, 1980; Resnick, 1991; Liedtke, 1988).

In summary, the results from the discourse community analyses suggest that students can engage in meaningful discussion about their learning. Furthermore, the results illustrate that peer discussion can help students make their learning more concrete by providing an arena where they can relate classroom knowledge to real-world experiences which, in turn, leads to more authentic learning.

However, there was one problem that arose during the Grand Rounds discussion forum. There appeared to be moments where the students reached a stalemate in the discourse. At these points, the instructor or researcher had no other alternative but to intervene. This occurrence is not surprising, since many classrooms display an absence of student-centered discussion. Therefore, the students may not have fully understood the role they were assumed to take when given the opportunity to participate in such discussions. Hence, it seemed necessary for the class instructor and the researcher to occasionally act as catalysts in order to maintain the continuity of the discussion. Nonetheless, once the momentum was revived the students undertook remarkable control over the classroom discourse.

The Cognitive Processes Used in Collaborative Problem Solving

The second research question attempted to examine the cognitive processes engaged in by the students as they worked collaboratively to solve and represent the problem scenarios. Particular emphasis was placed on whether the students employed the use of heuristics reasoning while they solved the diagnostic cases. It was hypothesized that the students would engage in the use of diagnostic heuristics, similar to those used by real-life diagnosticians, during their problem solving process. Specifically, it was hypothesized that they would primarily employ the availability heuristic and the anchoring and adjustment heuristic. This hypothesis was supported by the finding that students in both conditions largely employed these two forms of heuristics throughout their diagnostic process. Since participants in the present study were merely high school students and had not received prior instruction regarding digestive diseases, their knowledge level on this topic was quite rudimentary. Therefore, these results support O'Neill's (1995) finding that using the availability and the anchoring and adjustment heuristics does not depend on the amount of knowledge possessed by the diagnostician.

It is important to note that the degree of sophistication used by the students to employ these heuristics does not match that of expert physicians. Understandably, the participants used the availability and the anchoring and adjustment heuristics at a very basic level. Hence it is plausible that, as with many forms of reasoning, the complexity at which heuristics reasoning is employed may be represented as a continuum. This continuum may range from a very primitive level of heuristic use to a highly sophisticated level. Nonetheless, the finding that students did employ strategies similar to expert diagnosticians is evidence of their emerging knowledge regarding digestive diseases and the diagnostic process.

As stated previously, both the availability and the anchoring and adjustment heuristics were employed. However, the results revealed that the anchoring and adjustment strategy was used more frequently than the availability heuristic. There are two possible reasons for this finding. One explanation may be that because students had only limited knowledge of digestive diseases, they often approached the problem-solving task using an exhaustive search strategy. In other words, due to their low level of knowledge regarding the subject matter it is possible that students transversed through numerous diagnostic paths before they achieved the correct diagnosis. If this were indeed the case, it would explain why students employed the anchoring and adjustment heuristic so frequently.

A second explanation pertains to the frequency with which students used the availability strategy. Although a large degree of knowledge regarding diseases is not necessary for using the availability heuristic (Sherman & Corty, 1984), the more knowledge the diagnostician possesses about diseases the more opportunities he has to employ the heuristic. Hence, since the students may only be familiar with a small number of diseases the extent to which they employ the availability strategy may be constrained. Hence, the frequency at which they employ the heuristic may be dependent on how many diseases the students are familiar with. In summary, the anchoring and adjustment heuristic may have been used more often than the availability heuristic because the former is less dependent on the degree of knowledge base possessed by the diagnostician. It is also possible that using the availability heuristic may require a higher level of sophistication with regards to diagnostic reasoning in comparison to that required by the anchoring and adjustment heuristic.

The results also suggested that the anchoring and adjustment heuristic was the predominant means with which students arrived at their hypotheses. Specifically, all but one of the hypotheses generated by the students were devised by quickly forming a hypothesis and then collecting evidence to help confirm or disconfirm it. Students rarely attempted to collect and check evidence first and then proceed to formulate a hypothesis. In fact, their diagnostic process followed a primarily backward reasoning strategy. Interestingly, this approach is characteristic of novice behavior in most scientific domains (Gick, 1986). Even more intriguing is that though the participants had only a few days of instruction on digestive problems while using the BioWorld technology, their cognitive activity resembled that of novices in the medical field.

Another noteworthy point is that the students were unaware that they were using heuristics reasoning to facilitate their diagnostic process. This phenomenon suggests that even complex cognitive strategies that require a large degree of mental planning and reflection, such as diagnosing diseases, can lead to engaging in a variety of unconscious mental processes.

Some students did attest to using the process of elimination while working on the problem scenarios. This diagnostic approach is to be expected due to the participants' lack of medical expertise. However, analyses of these occasions revealed that they were also illustrations of the availability and the anchoring and adjustment heuristics. For example, while students engaged in process of elimination strategies, evidence of the anchoring and adjustment heuristic as defined by O'Neill (1995) was also seen. This phenomenon is in line with the rationale discussed earlier for why the anchoring and adjustment heuristic was used so frequently. Since students did often engage in exhaustive search strategies to diagnose the cases, they may have interpreted this as using the process of elimination. However, throughout these searches students continued to maintain an anchor on which to gather evidence and adjusted this anchor when faced with contradictory information. Therefore, it is clear that participants did not merely engage in a haphazard process of elimination. Rather, their approach was more systematic.

Furthermore, students may have believed that they were solely using the process of elimination during many of the times they applied the availability heuristic. They often appeared to strategize by first selecting diseases that were familiar to them. Once this search was exhausted, they engaged in choosing less familiar diagnoses. To the layperson this approach can, justifiably, be seen as a process of elimination technique. However, when analyzed more thoroughly it is clear that there are number of other intrinsic cognitive activities at play during this process, notably the use of the availability heuristic embedded in an anchoring and adjustment strategy.

To sum up, the findings of the heuristics reasoning analyses revealed that the participants did engage in the use of diagnostic heuristics. Furthermore, it is possible that the complexity of heuristic use can be represented as a continuum where students in this study would fall at the lowest end of the spectrum. Unfortunately, little research has been done in the area of diagnostic heuristics, especially among high school populations where courses on the topic of pathology are not generally offered. Therefore, additional studies are needed to further explore this assumption. Although the strategies employed by the students are probably not at the level of sophistication used by expert diagnosticians, the findings demonstrate the students' emerging knowledge of the diagnostic process and diseases. As a whole, the results suggest that employing heuristics is an extremely instrumental strategy to the diagnostic process regardless of knowledge level. Despite the fact that using these "short-cuts" can occasionally lead to unfruitful diagnostic paths, they can aid the problem solving process even for high school biology students.

Additional Findings

Written assignments. A brief analysis of the written assignments provided by the students in both classes was also conducted. Similar to the findings from the pre and posttest data discussed earlier, learner differences and differences in information processing are found in these reports. It appeared that the write-up activity, engaged in by the Rounds group students, provided opportunities for reflection on their knowledge of digestive problems. Although the summaries were written representations of what the students presented to their peers during the Grand Rounds presentations, analyses of the reports revealed that preparing them involved students to actively think about their diagnostic processes. Specifically, students included why and how they arrived at their hypotheses as well as delineated which medical tests they deemed pertinent in helping them form their final decision. They extended this information further by providing reasons for why the diagnostic tests were important to their decision-making, and why they believed that certain symptoms were more critical than others.

These results support the Reynolds and Pickett (1989) finding that writing provides insight into students' thought processes. Furthermore, they also confirm results from past research that writing in classrooms helps students think more critically and at higher levels (Langer, 1986; Langer & Applebee, 1987). Perhaps even more interestingly, the findings illustrate that the metacognitive activities engaged in by the Rounds students represented a hybrid of the Wilen and Phillips (1995) and the Butler and Winne (1995) models of metacognition. The students used a combination of: (a) monitoring the match between their actual outcomes and their desired outcomes (Wilen & Phillips, 1995); and (b) engaging in a variety of self-regulatory mechanisms such as planning strategies, revising, and remediating difficulties encountered (Butler & Winne, 1995) throughout the collaborative writing process.

The web search activity engaged in by the No Rounds group, however, did not require students to actively reflect on their recent learning. In fact, many of the students simply copied the information straight from the websites they visited. Although these participants did seem to collect some interesting facts about their respective disease, much of the activity involved primarily passive as opposed to reflective learning.

In summary, these results are comparable to Zeakes (1989) finding that writing about case studies in a parisitology class promoted student-centered learning, and helped improve creative thinking and problem solving skills. The written reports revealed that students in the Rounds group participated in both knowledge recall and knowledge construction as a direct result of their problem representation task. Therefore, not only did writing make their ideas more widely and easily accessible but it also changed the evolution and shape of the ideas themselves (Langer & Applebee, 1987). In contrast, students in the No Rounds group did not engage in any kind of knowledge generation process. Instead, they merely collected information that complemented and supplemented what they had already learned.

Pre and post questionnaires. The pre and post attitude questionnaires assessing changes in students' interest in biology and in their interest in working collaboratively with peers were analyzed. The results indicated that there were no significant changes over

over time in the students' attitudes towards biology or towards peer work and discussion. However, the trend showed a slight increase in the Rounds group's interest in biology and a decrease for the No Rounds group on this measure. Furthermore, both groups indicated a decrease in their interest in peer work and discussion but the drop was much larger for the No Rounds group when compared to the Rounds group. This attitude drop in both conditions can be attributed to a number of factors.

One explanation for the decrease may be due to the fact that students are rarely given the opportunity to participate in classroom collaborative work. Working in groups requires various social, cooperative, and negotiating skills that can only be acquired over time. It is possible that given the students' inexperience with working in groups, they found it difficult to organize themselves around the required task. With regards to the Rounds group, another possibility is that the write-up groups may have been too large (n=9 and n=8) to promote ideal working conditions for the students. This explanation may also account for a finding indicated in the three-item post questionnaire assessing students' perceived enjoyment of participating in the study.

The results from the three-item questionnaire showed that a higher percentage of students in the No

Rounds group stated they enjoyed participating in group work because of opportunities to exchange ideas. Since students in the No Rounds class worked in smaller sized groups (n=2) throughout the entire course of the study, it may have been easier for them to communicate and negotiate their opinions with each other, thus potentially affecting their perceived level of enjoyment. Additional results from the three-item post questionnaire revealed that a high percentage of students in both classes enjoyed participating in the study. However, this percentage was higher for students in the Rounds group.

The one-item post questionnaire addressing students' perceived learning experiences from participating in the study, indicated that the majority of students felt they had achieved a greater understanding of digestive system diseases. All students also stated they had gained a better grasp of the diagnostic process. However, this perceived improvement in understanding was higher among the Rounds group students. These findings further support reports from tenth grade biology students that writing provides insight into their thought processes as well as a greater understanding of the studied topic (Reynolds & Pickett, 1989). Likewise, the notion that active participation in classroom discussion results in the personal construction of meaning is also maintained

(Kletzien & Baloche, 1994). Furthermore, several students in the Rounds class stated they had a greater appreciation of the difficulties that physicians face as well as of the importance of collaborative work in the medical setting.

The findings from this questionnaire suggest that providing students with opportunities to reflect on their own thinking processes through written and oral discourse may enhance their understanding of their cognitive processes and the products of these processes. In addition, embedding students in the culture of a discipline allows them to personally experience it and, thus achieve a more concrete and authentic learning experience.

In closing, a number of interesting conclusions can be formulated from the findings of the present investigation. Firstly, employing innovative instructional techniques that engage students in authentic and contextualized learning situations akin to the Grand Rounds methodology can yield beneficial learning outcomes in medical problem solving contexts. Secondly, not only are high school biology students capable of forming discourse communities centering around digestive diseases and diagnostic processes, but they also employ cognitive tools similar to those used by expert diagnosticians. Taken together, these findings may implicate a need for advocating more frequent collaborative work and authentic learning scenarios in classrooms. Likewise, the results indicate that the need for instructors to move towards more student-centered learning and discussion is ever-present and can only serve to enhance the classroom environment. However, perhaps even more importantly, the findings suggest that engaging students in authentic learning situations, even for a short period of time, can improve students' knowledge of learned material. Despite the promise of the study's results, there were a few limitations that deserve discussion. The subsequent section discusses these limits.

Limitations

One limitation of the present study pertains to the small sample size. Although the Rounds group did display a greater degree of improvement on their knowledge of digestive diseases and symptoms, the trend would have probably been more pronounced with a larger sample size.

The second limitation is related to time constraints imposed on the study. The investigation lasted a duration of only one week. It is encouraging and exciting that students' understanding of digestive problems improved as much as it did in such a short time period. However, this finding might have been enhanced further if the students were allotted more time to work on the system and to work collaboratively with peers.

Lastly, there were also limitations with regards to scheduling. Because the investigation was conducted near the end of the school year, accommodations for exam schedules and school activities had to made. As a consequence of the limited time alloted for the investigation, the groups formed during the Grand Rounds activities were relatively large (n=8 and n=9). Although these group sizes are generally representative of group numbers in real-world workplaces, the students might have been more comfortable working in smaller groups.

Future Directions for Research

The findings of the present study suggest a number of future extensions and implications for the field of educational psychology. Primarily, more research is needed to test the long-term effectiveness of the Grand Rounds technique in secondary school biology classrooms. A longitudinal study lasting a duration of one full school year where students learn about the six body systems through this technique should be conducted. Such an investigation would provide the researcher with a more comprehensive picture of the changes and the learner differences that develop among students. Furthermore, it would allow the researcher to monitor the students' understanding of diseases and the diagnostic process throughout the various body systems. This data can also be used to map generalizations that students may construct about the diseases encountered and about how these diseases affect the different body systems. In addition, it would be interesting to assess any changes that may evolve over time in the students' use of diagnostic heuristics. Notably, would experience with more cases lead students to employ more sophisticated heuristic strategies over time? Secondly, in the present study students in the Rounds group solved only one of the two possible final problem scenarios using the BioWorld system; either Shigellosis or Ciliacs Disease. Therefore, a further extension of the study should be conducted whereby the students in the Rounds group are given the opportunity to solve both diagnostic problems before they engage in the Grand Rounds write-up activity. If the students are given prior exposure to all the diseases, it may facilitate and provide more continuity to the classroom discussion during the Grand Rounds presentation session.

Thirdly, the effectiveness of different modifications to the Grand Rounds technique should also be researched. Although computer-assisted instruction has become more popular in recent years, the cost factor of creating one or for a school to purchase a computer-based learning environment is relatively high. Therefore, it would be interesting to examine the effectiveness of the Grand Rounds method when it is employed without computer-based learning. Notably, would case-based learning in conjunction with oral and written discourse yield the same outcomes as the Grand Rounds technique employed in this study? If not, this may suggest a need for increased investment by the educational system in CBLEs which can serve to complement the contribution of teachers in the classroom. It may also be valuable to assess the individual contributions of the other three instructional methods which form the Grand Rounds technique.

Fourthly, in order to formulate any generalizations as to the appropriateness of this new instructional method, further research is required to investigate its usefulness in different areas such as physics, chemistry, mathematics, and perhaps even literature. It may also be important to assess whether this technique would be suitable for different populations including primary, secondary, and university level students. In addition, the participants in this study were students attending an all-girls private high school. It is possible that private school students are generally surrounded in school environments that promote more achievement motivation to learn and excel academically. Likewise, from a practical point of view, private schools tend to have more funds to allocate towards ensuring that cutting edge technology, such as interfaces for computer-based learning systems, are available to their students. Hence, the Grand Rounds method might have been more appropriate for this type of student population and school environment. Therefore, it would be interesting to evaluate the effectiveness of this new technique on different types of school environments and populations such as learning disabled populations or disadvantaged populations, and how it can be modified to accommodate them. It would also be interesting to examine its effectiveness and appropriateness with male students, since females tend to be more advanced in their verbal communication skills.

Lastly, the present investigation also has implications for the domain of medical education and medicine, in general. The findings revealed that participants employed the use of diagnostic heuristics without any awareness of engaging in this cognitive behavior. In other words, students did not realize they were using so-called mental tricks to aid their problem solving process. Although the repercussions of this phenomenon are not serious in the case of high school biology where real lives are not at stake, it may have severe consequences in the medical field. Heuristics, as with any mental "short-cuts", can be helpful problem solving strategies. However, they are not foolproof.

If physicians use diagnostic heuristics without complete awareness of it and their diagnosis is incorrect, detection of the erred diagnosis may be more difficult. This may, in turn, place patients' lives at risk. Research should be done to examine whether medical professionals recognize if, when, and why they are employing heuristics reasoning during their diagnostic process. Furthermore, instruction regarding the use of heuristics, when they are primarily employed, and the potential diagnostic errors that can result when using such heuristics should be introduced into the medical school curriculum. Making this information available to students and practitioners will help establish an awareness amongst the medical community about the cost benefits of utilizing such cognitive strategies.

Final Thoughts

To conclude, the potential impact of the present investigation is two-fold. Firstly, placing high school biology students in a context where they could engage in scientific reasoning and argumentation comparable to real-life physicians, revealed they not only began to "talk the talk" but they also began to primitively "walk the walk". The implications of this phenomenon for the educational system alone are boundless. However, of equal importance, are the implications the findings have on the fields of educational and cognitive psychology.

This investigation highlighted that much can be learned from comparisons between novice behaviour and expert-like behaviour. Although this notion is not new to the behavioural sciences, emphasis in these domains has predominantly been placed on how experts and novices differ. However, this study implicates that examining expert-novice cognitive patterns more closely has the potential to lessen the traditionally held gap between these two groups. If the expert-novice division can, in fact, be represented as a continuum then observing novice behaviour may prove to be quite valuable in modelling how expertise is developed. Indeed time may reveal that, with more extensive research, the distinction between experts and novices will shift from black and white to white and grey.

References

Alvarez, M. C. (1990, November). Case-based instruction and learning: An interdisciplinary project. Paper presented at the 34th annual conference of The College Reading Association, Nashville, Tennessee.

Alvermann, D. E., O'Brien, D. G., & Dillon, D. R. (1990). What teachers do when they say they're having discussions of content area reading assignments: A qualitative analysis. Reading Research Quarterly, 25, 296-322.

Alverman, D. E., & Hayes, D. A. (1989). Classroom discussion of content area reading assignments: An intervention study. Reading Research Quarterly, 24, 305-335.

Anderson, J. R. (1983). The architecture of cognition. Cambridge, MA: Harvard University Press.

Bjorkman, M. (1984). Decision making, risk taking and psychological time: Review of the empirical findings and psychological theory. Scandinavian Journal of Psychology, 25, 31-49.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18, 32-42.

Brufee, K. A. (1984). Collaborative learning and the "conversation of mankind". College English, 46, 635-652.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. Review of Educational Research, 65, 245-281.

Cazden, C. B. (1988). Classroom discourse. Portsmouth, NH: Heinemann Educational Books.

Cognition and Technology Group at Vanderbilt. (1996). Looking at technology in context: A framework for understanding technology and education research. In D. C. Berliner and R. Calfee (Eds.), Handbook of educational psychology, (pp. 807-840). New York: Macmillan.

Cohen, E. (1994). Restructuring the classroom: Conditions for productive small groups. Review of Educational Research, 64, 1-35.

Coulter, D., Williams, H., & Schulz, H. (1981). Formal operational ability and the teaching of science processes. School Science and Mathematics, 81, 131-138.

Dale, H. (1992, April). Toward an understanding of collaborative writing. Paper presented at the Annual Conference of the American Research Association, San Francisco, CA.

Doise, W., & Mugny, G. (1984). The social development of the intellect. Oxford, England: Pergamon Press.

Gick, M. L. (1986). Problem-solving strategies. Educational Psychologist, 21, 99-120.

Goodlad, J. (1984). A place called school: Prospects for the future. New York: McGraw-Hill.

Hackling, M., & Treagust, D. (1984). Research data necessary for meaningful review of grade 10 high school genetics curricula. Journal of Research in Science Teaching, 21(2), 197-209.

Helm, H., & Novak, J. (Eds.). (1983). Proceedings of the international seminar on misconceptions in science and mathematics. Ithaca, NY: Cornell University.

Howard, V. A. (1988). Thinking on paper: A philosopher's look at writing. In V. A. Howard (Ed.), Varieties of thinking: Essays from Howard's Philosophy of education research center (pp. 84-92). New York: Routledge, Chapman & Hall.

Hughes, K. K., & Young, W. B. (1990). Decision making stability of clinical decisions. Nurse Educator, 17, 12-16.

Irby, D. M. (1994). Three exemplary models of case-based teaching. Academic Medicine, 69(12), 947-953.

Johnson, M. A., & Lawson, A. E. (1998). What are the relative effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry classes? Journal of Research in Science Teaching, 35(1), 89-103.

Jones, J. A. (1988). Clinical reasoning in nursing. Journal of Advanced Nursing, 13, 185-192.

Kletzien, S. B., & Baloche, L. (1994). The shifting muffled sound of the pick: Facilitating student-to-student discussion. Journal of Reading, 37(7), 540-545.

Kuhn, D. (1989). Children and adults as intuitive scientists. Psychological Review, 36(4), 674-689.

Kuhn, D. (1991). The skills of argument. Cambridge, MA: Cambridge University Press.

Kuhn, D. (1997). Constraints or guideposts? Developmental psychology and science education. Review of Educational Research, 67(1), 141-150.

Lajoie, S. P. (1993). Computer environments as cognitive tools for enhancing learning. In S. P. Lajoie & S. J. Derry (Eds.), Computers as cognitive tools (pp. 261-288). Hillsdale, NJ: Erlbaum.

Lajoie, S. P., Greer, J. E., Munsie, S. D., Wilkie, T. V., Guerrera, C., & Aleong, P. (1995). Establishing an argumentation environment to foster scientific reasoning with BioWorld. In D. Jonassen & G. McCalla (Eds.), Proceedings of the International Conference on Computers in Education (pp. 89-96). Charlottesville, VA: Association for the Advancement of Computing in Education.

Lajoie, S. P., Lavigne, N. C., Guerrera, C., Munsie, S. (2000). Constructing knowledge in the context of Bioworld. Instructional Science, 00, 1-32.

Langer, J. A. (1986b). Children reading and writing: Structures and strategies. Norwood, NJ: Ablex.

Langer, J. A., & Applebee, A. N. (1987). How writing shapes thinking. A study of teaching and learning (NCTE Research Rep. No. 22). Urbana, IL: National Council of Teachers of English.

Liedtke, W. (1988). Let's talk about talking mathematics. Arithmetic Teacher, 35(8), 2.

Metz, K. E. (1995). Reassessment of development constraints on children's science instruction. Review of Educational Research, 65, 93-127.

Metz, K. E. (1997). On the complex relation between cognitive developmental research and children's science curricula. Review of Educational Research, 67(1), 151-163.

Mitman, A. L., Mergendoller, J. R., Packer, M. J., & Marchman, V. A. (1984). Scientific literacy in seventh-grade life science: A study of instructional process, task completion, student perceptions and learning outcomes. San Franscisco, CA: Far West Laboratory for Educational Research and Development.

Nelson, T. O. (1999). Cognition versus metacognition. In R. J. Sternberg (Ed.), The nature of cognition (pp. 625-641). Cambridge, MA: MIT Press.

O'Neill, E. S. (1995). Heuristics reasoning in diagnostic judgement. Journal of Professional Nursing, 11(4), 239-245.

Piaget, J. (1950). The psychology of intelligence. London: Routledge & Kegan Paul.

Regan-Smith, M. G. (1987). Teaching clinical reasoning in a clinical clerkship by use of case assessments. Journal of Medical Education, 62, 60-63.

Resnick, L. B. (1987). Learning in school and out. Educational Researcher, 16, 13-20.

Resnick, L. B. (1991). Shared cognition: Thinking as social practice. In L. B. Resnick, J. M Levine, & S. D. Teasley (Eds.), Perspectives on socially shared cognition (pp. 1-20). Washington, DC: American Psychological Association.

Sanford, J. P. (1987). Management of science classroom tasks and effects on students' learning opportunities. Journal of Research in Science Teaching, 24(3), 249-265.

Scardamalia, M., Bereiter, C., Lamon, M. (1994). The CSILE project: Trying to bridge the classroom into World 3. In K. McGilly (Ed.), Classroom lessons:

Integrating cognitive theory and classroom practice (pp. 201-228). Cambridge, MA: MIT Press.

Sherman, S. J., & Corty, E. (1984). Cognitive heuristics. In R. Wyer & T. Srull, (Eds.), Handbook of social cognition, Vol. 1 (pp. 189-287). Hillsdale, NJ: Erlbaum.

Stake, R. E., & Easely, J. A. (1978). Case studies in science education (Vols 1-2). Urbana: University of Illinois, Center for Instructional Research and Curriculum Evaluation and Committee on Culture and Cognition.

Sternberg, R. (1985). Beyond IQ: A triarchic theory of human intelligence. Cambridge, England: Cambridge University Press.

Tasker, R. (1981). Children's views and classroom experiences. The Australian Science Teacher's Journal, 27(3), 33-37.

Tversky, A., & Kahnemanm D. (1973). Availability: A heuristic for judging frequency and probability. Cognitive Psychology, 5, 207-232.

Vygotsky, L. S. (1962). Thought and language. Cambridge, MA: MIT Press.

Ward, B., & Tikunoff, W. (1982). Lessons from the junior high school transition study: How can we restructure schools to make them more successful for all students? Paper presented at the annual meeting of the American Educational Research Association, New York.

Wilen, W. W, & Phillips, J. A. (1995). Teaching critical thinking: A metacognitive approach. Social Education, 59(3), 135-138.

Williams, S. M. (1992). Putting case-based instruction into context: Examples from legal and medical education. The Journal for the Learning Sciences, 2(4), 367-427.

Winne, P. H. (1997). Experimenting to bootstrap self-regulated learning. Journal of Educational Psychology, 89(3), 397-410.

Wolters, C. A. & Pintrich, P. R. (1998). Contextual differences in student motivation and self-regulated learning in mathematics, english, and social studies classrooms. Instructional Science, 26, 27-47.

Zeakes, S. J. (1989). Case studies in biology. College Teaching, 37(1), 33-35.

Zimmerman, B. J. (1994). Dimensions of academic self-regulation: A conceptual framework for education. In D. H. Schunk & B. J. Zimmerman, (Eds.), Self-regulation of learning and performance: issues and educational applications (pp. 3-21). Hillsdale, NJ: Erlbaum.

Appendix A

Parental Consent Form

Rowena Espinosa
M.A. Student
April 28, 2000

Dear Parent and Student,

I am a Masters student at McGill University in the Educational and Counseling Psychology Department under the supervision of Dr. Susanne P. Lajoie, an Associate Professor in the department. In the recent past, Dr. Lajoie has worked with Ms. Brass on special projects that extend her existing Biology curriculum. I will be conducting an extension of these projects. The project will deal specifically with teaching students both factual knowledge about diseases and how to apply such knowledge to specific cases. These cases deal with each of the body systems in their textbooks, i.e. respiration, digestion, etc. Students who are successful in school (as reflected by tests of factual and conceptual knowledge) often fail to use these facts and concepts on appropriate occasions in everyday life. My research aims to curtail this problem by engaging students in problems that reflect real-world practice and provide more meaningful, challenging, and richer learner experiences that foster the development of reasoning abilities. One way to provide such opportunities is through the development of computer tutors that can coach students while they are attempting to solve problems. Dr. Lajoie has designed a computer tutor that tutors students about infection. This computer tutor will be used in this project. In addition to using the tutor, students will be given the opportunity to engage in activities that real-life medical practitioners engage in. They will create a written report incorporating the knowledge they acquired while working with the technology and they will present this report to their fellow class members and instructor, opening an arena for interactive discussion and knowledge construction. The technology portion of the project allows students to get instruction that is adapted to their learning levels. The type of knowledge skills that students can acquire include specific knowledge about disease and infection, as well as more general higher level skills such as learning to reason about science in a way that could generalize to other science learning. The written and oral portion of the project allows students to organize and reflect on their knowledge as well as dynamically advance their knowledge and receive constructive feedback from peers. The purpose of this study is to evaluate the effectiveness of this type of instruction. I would like your permission to video tape students so that we can learn about the effectiveness of this type of learning situation. After the videotape data has been analyzed, the tapes will be kept by the researcher for reference purposes only. Participation in this project is voluntary and will not affect academic standing in any way. Participation will also be kept strictly confidential. Each participant will be assigned a number and will be referred to by that number only in all discussion of the results (verbal and written). The data (text only) from this project may be published. If so, the identity of participants will not be divulged. Subject numbers only will appear in any published results.

Thank you for your time. I hope that you will agree to let your daughter participate in this special project.

Sincerely,

Rowena Espinosa
(Principal Investigator)

I hereby give my consent for ______________________ to participate in the special project conducted by Rowena Espinosa

____
Signature of Parent or Guardian

____
Print Name

____
Signature of Student

I do not give my consent for ______________________ to participate in the research.

Signature of Parent or Guardian

Print Name

Signature of Student

Appendix B

Pre and Post Knowledge Test

Name: ____________________________

BioWorld Exercise

1) How do infectious diseases spread in humans and what can one do to prevent the contraction of an infectious disease? What methods have medical practitioners developed for determining the best diagnosis of infectious diseases? Please keep your answer brief (1 or 2 paragraphs).

2) What problems could arise with the digestive system? How would you know you had a problem with your digestive system? What methods could medical practitioners use to diagnose a digestive problem?

Appendix C

Pre and Post Attitude Questionnaire

For the following questions, please circle the response most appropriate to you.

1) What is your favorite subject?

a. English
b. Science/biology
c. Math
d. Language
e. Art
f. Other ________________

2) Compared to other subjects I like biology:

A	B	C	D	E
much less	less	about the same	better	much better

3) In terms of level of difficulty, compared to other subjects I think biology is:

A	B	C	D	E
much less difficult	less difficult	about the same difficulty	more difficulty	much more difficulty

4) Compared to other subjects I work ____________ in biology.

A	B	C	D	E
much less	less	just as much	more	much more

5) I am ___________ motivated to do well in biology as in other subjects.

A	B	C	D	E
not at all	not	just as	more	much more

6) Do you enjoy working in group projects?

A	B	C	D	E
not at all	not really	somewhat	yes	a great deal

7) Do you enjoy making oral presentations?

A	B	C	D	E
not at all	not really	somewhat	yes	a great deal

8) Do you enjoy classroom discussions with your peers?

A	B	C	D	E
not at all	not really	somewhat	yes	a great deal

9) Do you enjoy writing reports?

A	B	C	D	E
not at all	not really	somewhat	yes	a great deal

10) My knowledge of biology is:

A	B	C	D	E
not very good	not good	average	good	very good

11) My interest in biology is:

A	B	C	D	E
very low	low	average	high	very high

12) Which, if any, of the extra curricular activities do you participate in with regards to biology? (You may choose more than one answer.)

a. Read articles or books or watch TV shows about biology
b. Play with computer games
c. Belong to a biology club
d. visit museums or other science exhibits
e. None of the above
f. Other ____________________

13) Your biology teacher is going out of town for one week. She is letting the class decide what to do during that week. What would you most like to do?

A. Have each student design and conduct any experiments she wants.
B. Have the teacher outline an experiment before she leaves and each student will conduct the experiment while she is gone.
C. Have each student write a research paper on a topic of their choice.
D. Have each student write a research paper on a topic predetermined by the teacher.
E. Let each student do whatever she wants as long as it is biology related.

14) Of the choices in Question #13, which activity would you least like to do?

Choice __________

THANK YOU !!

Appendix D

Rounds Group Case Write-up Instructions

BioWorld Grand Rounds

Your task is to prepare a patient report of the last patient you treated (2 pages max.) which you will use to describe and explain your case to other physicians.

Please include in your report:
1) A brief summary of your patient (name, age, interesting symptoms)
2) State your final diagnosis
3) Explain the steps you took to diagnose the disease (i.e., what tests were run and what were the results, what symptoms you thought were particularly important, any other hypotheses/diagnoses you may have come up with before arriving at the correct diagnoses).
4) Explain and justify why you took those steps.

N.B. You may also include any past experiences and/or previous cases, which may have helped you, diagnose this particular case.

***** Remember to see this as a role-playing activity where you take the role of a physician who is describing one of her patients to other physicians.**

Appendix E

Post Questionnaire of Students' Interest in BioWorld

1) Did you enjoy participating in this project? Why? Or Why not?

2) Did you enjoy working in groups? Why? Or Why not?

3) If you had the possibility of changing anything regarding this project what would you change or do differently?

THANK YOU FOR YOUR EXCELLENT WORK!!!!

Appendix F

Post Summary Questionnaire

Group Number:

Class:

Date:

Time:

Summary Question:

What types of things did you learn from using BioWorld?

Appendix G

List of Digestive System Diseases, Symptoms, and Diagnostic Tests in BioWorld

Diseases

1. Ciliacs Disease
2. Cirrhosis
3. Hepatitis A
4. Hepatitis B
5. Hepatitis D
6. Salmonella
7. Peptic Ulcer
8. Shigellosis

Symptoms

1. Malabsorption of food
2. Bloatedness
3. Vomiting
4. Weakness
5. Dysuria
6. Headache
7. Jaundice
8. Weight loss
9. Sionosis
10. Nausea
11. Anorexia
12. Diarrhea
13. Fatigue
14. Lactose intolerance

15. Photophobia
16. Malaise
17. Fever
18. Common forms
19. Typhoid fever
20. Abdominal pain
21. Severe diarrhea with enterocolitis constipation
22. Irritability
23. Drowsiness
24. Abdominal extension
25. Pus, mucus, and/or blood in stool
26. Small or enlarged liver
27. Spider angiomes
28. Perforation in the stomach lining

Diagnostic Tests

1. Total bilirubin
2. Folic acid
3. Iron
4. Carotene
5. Gluten protein
6. SGOT
7. SGPT
8. Hepatitis A titer
9. WBC (white blood cell count)
10. RBC (red blood cell count)
11. hemoglobin
12. hematocrit

13. SITE
14. Stool
15. Gram stain
16. Cirrhotic liver
17. Platelet count

Appendix H

Coding Scheme for Heuristics Reasoning

DIAGNOSTIC HEURISTICS:

1. Availability Heuristic: coded instances included referencing familiar cases as a means for selecting a given diagnosis, diagnosing a disease as either salmonella or any of the hepatitis illnesses, and immediately concluding that the diseases encountered were digestive problems.

Examples: See no, this is the drinking disease I think.

"Severe diarrhea and vomiting" um um salmonella, "small traces of blood in his diapers". Ya,it's salmonella. I'm changing it. Yes, we're done.

uhm, but I don't know why I think it's hepatitis A

It must be a digestive problem because of the diarrhea and the vomiting and problems with the stool.

We thought it was shigellosis because from previous experience uh we specifically remembered that one of the symptoms for shigellosis was high fever in children.

2. Anchoring and Adjustment Heuristic: coded instances consisted of quickly forming an initial diagnostic hypothesis (an anchor)followed by adjusting this tentative judgment until a final diagnosis was arrived upon.

Examples: S1: okay, you know what? I think it might be um salmonella...

.

.

.

S1: okay. So wait. BUN. Let's try the BUN.

S2: okay

S1: and it's normal.

S2: normal okay

S1: She definitely doesn't have it. Okay, let's go back to our library. Okay, I really don't think she has salmonella. Um

S2: Oh! Remember the one we got yesterday? Oh I think it's salmonella diarrhea.

.

.

.

S2: Salmonella? Uhm they don't have it.

S1: I thought they did - that's odd.

S2: ...So, let's go back to the problem statement and change our salmonella.

Appendix I

Coding Scheme for Discourse Communities

Communities of Discourse: coded instances included all instances where two or more students engaged in a discussion that involved any issues learned throughout the course of the investigation. Specifically, discussions concerning digestive system complications, diseases, symptoms, and medical tests; group work; the field of medicine; and personal digestive health problems were coded as instances of discourse communities.

Examples: S1; ya, the blood in the stool.

S4; And I would say the high fever

S1: the high fever. And they also wrote fussiness

S4: ya

S6: There was also the gram stain that that was important

S4: ya, we're just talking about the symptoms

S1: that was a test. That was an important test, right.

Teacher: But just to think not even in the terms of the medical world but just in general, when you're trying to solve something are you as effective alone?

S12: you can be

S6: well, it's because others have different ideas and it's better to put those all together.

S2: And make you think of things that perhaps you might not have

S10: or sometimes it could throw you off though.

S12: ya, exactly.
S5: ya, cuz you think something and then they bring up a point which you didn't find as important and
S12: makes you think
S5: ya

Appendix J

Example of Rounds Group Case Write-up Submission

Ciliacs Disease
Raymond, 27 year old male
His symptoms:
bloatedness
nausea
severe sweating
diarrhea
vomiting
lost weight
jaundice
*most sick an hour after eating, especially after having eaten cereal and bread.

Final Diagnosis: Ciliacs Disease

Steps We Took to Diagnose:
We looked the disease up in the library and we compared Raymond's complaints to the symptoms of Ciliacs Disease. After realizing that the symptoms were similar we ran a Gluten Protein test, the results were high. After we ran a Total Lubrication test and the results were high. The following tests we ran, Folic Acid and Carotene test had low results, and finally we ran an Iron test and the results were low.

Explain and Justify Why:
We researched Shigellosis and Salmonella previously and knew it was not them. Then we did the Hepatitis titer test, the results were negative and we realized that it had to be Ciliacs Disease.

Appendix K

Sample No Rounds Group Web Search Submission

Ciliacs Disease

1) http://www.celiac.ca/eframes.htm

2) Definition: Ciliacs disease is a medical condition in which the absorptive surface of the small intestine is damaged by a substance called gluten. (Gluten is a protein found in wheat, rye, tritical, barley, and oats.) The gluten results in an inability of the body to absorb nutrients: protein, fat, carbohydrates, vitamins and minerals, which are necessary for good health.

1:200 persons in Canada are affected by Ciliacs Disease. Symptoms of untreated Ciliacs Disease indicate the presence of malabsorption due to the damaged small intestine.

At present there is no cure, but Ciliacs Disease is readily treated by following the gluten-free diet.

Symptoms include vomiting, jaundice, nausea, diarrhea, bloatedness, and exhaustion.

3) It explains and defines Ciliacs Disease giving statistics and explaining Gluten. It depicts the area in which Ciliacs Disease affects. It also lists the symptoms of Ciliacs Disease. It also states that there is no present cure, but it can be treated through a gluten-free diet. This is interesting because it is the main facts of Ciliacs Disease. It is vital to know what this disease is before treating it.