Examining The Effectiveness of Instructive Animation:
A Computer Learning Environment For Teaching
Learning Disabled Students Biology

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ABSTRACT

A computer animated learning environment, INFECTRON, was developed to teach learning disabled (LD) and non learning disabled (NLD) students a biology lesson. INFECTRON uses two different modalities, auditory (narration) and visual (animation), exposing students to dual information processing codes (verbal, spatial), allowing them the flexibility to use a learning style they prefer. INFECTRON teaches students how the body protects itself from invading germs. Students were presented the animation and oral narration concurrently, successively and compared to a control group. Subjects were 30 LD and 30 NLD in grades 7 and 8 attending a large comprehensive high school in Montreal. Measures included a pretest, posttest, reasoning tasks, and a retention test. Results indicated that students (LD and NLD) in the computer conditions (concurrent and successive) outperformed students (LD and NLD) in the control condition on the pre, post and reasoning tasks. No significant differences were found between students (LD and NLD) in the concurrent group and students (LD and NLD) in the successive group on the post test and reasoning tasks. No group differences were found between the LD and NLD students in the computer conditions. It was confirmed that INFECTRON benefits both LD students and NLD students, allowing LD students to perform at par with NLD students on these biology measures.

RÉSUMÉ

INFECTRON, est un programme informatisé d'animation portant sur l'environnement et destiné à l'enseignement d'un cours de biologie à des étudiants avec problèmes d'apprentissage (LD) et des étudiants sans problèmes d'apprentissage (NLD). INFECTRON utilise deux différentes méthodes, l'une auditive (narration) et l'autre visuelle (animation), exposant ainsi les étudiants à une dualité (verbale, spatiale), leur donnant le choix d'utiliser le style d'apprentissage désiré. INFECTRON leur enseigne la façon que possède le corps humain pour se protéger des germes environnants. Les étudiants ont été soumis àla visualisation et à l'auditif, conjointement une première fois, la seconde de façon consécutive et, après, furent comparé au groupe contrôle. Le groupe témoin a été composé de 30 étudiants avec problèmes d'apprentissage et de 30 étudiants sans problèmes d'apprentissage, de niveaux 7 et 8, inscrits dans un collège d'enseignement supérieur à Montréal. Les mesures d'évaluation inclurent le pré-test, le post-test, le raisonnement et aussi un test de mémoire. Les résultats indiquèrent que les étudiants (LD et NLD) dans le test informatisé (simultané et consécutif) ont surpassé le groupe d'étudiants (LD et NLD) dans les conditions de contrôle lors du pré-test, post-test et du raisonnement. Aucune différence significative ne fut trouvée entre les étudiants (LD et NLD) du groupe simultané et entre celui (LD et NLD) du groupe consécutif lors du post-test et celui du raisonnement. Aucune différence entre les groupes d'étudiants LD et NLD lors de l'utilisation de l'informatique. Il en fut déduit que INFECTRON profite aussi bien aux étudiants avec difficultés d'apprentissage qu'aux étudiants sans difficultés d'apprentissage, permettant ainsi aux étudiants avec difficultés d'apprentissage (LD) d'exécuter, à même égalité avec les étudiants sans problèmes d'apprentissage (NLD), le test de biologie.

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CHAPTER I

Introduction and Review of The Literature

Why is it that in the traditional classroom some students do well and others do not? Since classrooms generally represent a wide range of individual differences it is impossible to design one form of instruction that is meeting the instructional needs of all individuals (Snow, 1989). Meeting the instructional needs of learning disabled (LD) students is particularly difficult since there is a problem in defining learning disabilities.

A LD means many things depending on the audience, parents, researchers, or government. Definitions exist for practical purposes rather than representing what is true or false for a certain individual. Such definitions are accepted because they allow research to continue and educational programs to develop, not because they enhance our scientific understanding of LDs (Kavale, Forness, Lorsbach, 1991). With this caveat in mind we provide a working definition provided by the Ontario Ministry of Education (1980):

> Learning disabilities are disorders in one or more of the processes involved in understanding or using symbols of spoken language. The disorders result in significant discrepancy between academic performance and assessed intellectual ability, with deficits in at least one of the following areas; receptive language, language processing, expressive language, and mathematical computations. (p.23).

As this definition of learning disabilities suggests difficulty in school does not necessarily reflect lower intelligence. Rather, such difficulties could suggest that the material being taught is not represented in a way that promotes learning for LD students. Teaching methods must be designed to meet these individual differences in order for learning to occur.

A popular choice for meeting such differences is to "ability group" students so that teaching can be made easier by creating homogeneous groups. Unfortunately, such grouping does not result in more effective instruction for LD students. Bryan, Bay, and Donahue (1988) suggest that classroom modifications alone are insufficient to meet the complex needs of this heterogeneous population, regardless of teacher's pedagogical skills. Another alternative would be to provide a variety of service configurations, for example, self-contained classes, resource rooms, and total mainstreaming (Hallahan, Keller, McKinney, Lloyd, and Bryan, 1988). Another alternative, which has not been considered to date, is the use of computers as teaching tools to meet the needs of this special population in the content area subjects, i.e. math or science.

The group of LD students who will be examined in this study are a sub-population typically referred to as dyslexic. Dyslexia is typically defined as a reading and spelling problem that cannot be accounted for by sensory or neurological damage, lack of education, or low intelligence (Stanovich, 1986; Vellutino, 1979). One hypothesis is that dyslexics' reading and spelling problems are related to a deficit in phonological language skill. This hypothesis is supported in that dyslexic students have difficulty with word recognition but not with reading comprehension (Conners & Olson, 1990; Perfetti, 1985).

Dyslexics have difficulty in traditional classrooms where reading is the main modality for acquiring knowledge. Verbal skills are highly correlated with success in schools (Hunt, 1983; Cattell, 1971; Vernon, 1950). Thus, dyslexics are at a disadvantage. Perhaps a multi-sensory instructional approach would be more effective for dyslexics. Such an approach can provide identical information through different modalities. Since we know that there are individual differences in learning, a multi-sensory approach can increase the likelihood of information being processed and remembered by more students.

The following study describes such a multi-sensory approach. A computer animated learning environment was developed to teach students (LD and NLD) a biology lesson. The computer environment, INFECTRON, uses two different modalities, auditory and visual, exposing students to both modalities, allowing them the flexibility to use a learning style they prefer. INFECTRON presents the identical biological information through multiple modalities: narration for the auditory modality and animation for the visual modality. The major research question posed in this study is; Can LD students with reading disabilities perform at par with non learning disabled (NLD) students given this multi-sensory computer environment?

Theoretical Framework

With the onslaught of new technology and the increase in accessibility of computers in the classroom, the possible benefits of this instructional medium are unknown. Since LD populations are often at a disadvantage in the strictly text-based world we need to empirically study the effects of a multi-sensory instructional approach for this population. INFECTRON provides us with a medium for testing the effectiveness of computer animated instruction for LD students studying biology.

In this study we adapt Mayer and Anderson's (1992) dual-coding approach to the investigation of instruction for LD students. Using computers as a medium of instruction, Mayer and Anderson (1992) used a multi-sensory approach, which they referred to as dual-coding (Clark & Paivio, 1991; Paivio, 1990) to teach NLD college students how to operate physical devices. Dual coding theory assumes that the learner uses two distinct information processing systems, one which represents the auditory system and one which represents the visual system. Mayer and Anderson (1992) tested the dual coding theory to see whether one modality was more effective than another, or whether two modalities of representation used concurrently were more effective than 2 modalities presented successively. They did this by building 3 treatment conditions into their experiment: (a) auditory modality alone or visual modality alone- instruction using the auditory modality used narration of text to describe the operation of a bicycle pump, whereas, the instruction using the visual modality used computer animation to demonstrate how to operate a bicycle pump; (b) concurrent- animation plus narration presented together in time or space; (c) successive- animation followed by narration or vice versa. A control group received no instruction. The results of this research indicated that the concurrent group outperformed every other condition. These results have been supported by others who have studied the effects of illustration and text (Mayer & Anderson, 1992; Mayer & Anderson, 1991; Mayer & Gallini, 1990; Levin, 1981, 1983; Rohwer & Harris, 1975; Rohwer & Matz, 1975).

An instructional implication of Mayer & Anderson's research is that two modalities presented simultaneously, such as the use of animation and narration, are more effective than any one modality presented alone or in succession. The present research examines the dual coding theory with regard to students with learning disabilities. The present study is distinct from Mayer and Anderson's (1992) in several ways. First, this study is not looking at physical devices in terms of operation, but of the human body and how it physically defends itself from infection. Second, this study involves grade 7 and 8 students, rather than college-level. The third and most important difference is that this study compares the performance of LD and NLD students on a biology lesson.

Review of The Literature

Several important areas of concentration are covered in this literature review. First, an examination of how LD has been defined is presented, followed by an analysis of why computer learning environments could be effective for this population. A multi-sensory approach to LD instruction is proposed and thus part of the review is dedicated to describing visual depiction's and it's relationship to computer animated approaches to instruction. A theoretical justification for the use of a multi-sensory computer-animated approach to instruction for an LD population is provided in the form of the dual-coding theory.

Learning Disabilities

Students with LDs are often assumed to differ from those without LDs in their inability to learn information from typical classroom instruction (Crank & Bulgren, 1993). This difference seems to be most pronounced when students reach the secondary level where instruction is often designed to promote mastery in a content subject (i.e., science) as opposed to the mastery of general skills (i.e. learning colors), which may be the focus in elementary school (Deshler, Schumaker, Alley, Warner, & Clark, 1982). At the secondary level success in mastering content subjects directly relates to general academic success. It is frequently the case that students with LDs are unable to master the information presented to them in class which often leads to failure and sometimes withdrawal from school (Deshler & Schumaker, 1988; Levin, Zigmond, & Birch, 1985). Many LD students perform poorly on tasks requiring active information processing (Torgesen & Wong, 1986). Many explanations have been provided as to LD students inefficient use of organized strategies (Torgesen & Wong, 1986), however, researchers continue to be challenged to search for ways to enhance their learning of LD students.

Having a learning disability means that a student is different from his or her peers in some specific ways. If one were to examine the results of an IQ test such as the Wechsler Intelligence Scale for Children, third edition (WISC-III) or the Wechsler Adult Intelligence Scale, Revised (WAIS-R), a classic LD profile would reflect a discrepancy between verbal and performance scores and or significant scatter within the verbal and or performance scales. The IQ results would often indicate that the student is bright, however the student is not achieving in school to the potential that the standardized test suggests is possible for that student. It is impossible for LD students to become NLD, however it is possible for LD students to be taught in a way that capitalizes on their strengths. For example, a LD student may have tremendous visual-spatial abilities that are not being tapped in the traditional school setting (Lajoie, 1986). One way to capitalize on spatial ability is to make instruction visual. Holley and Dansereau (1984) support this concept by suggesting that information acquisition does not necessarily occur in a linear manner (i.e. text based). Concepts may be more readily learned if they are visually arranged in a nonlinear fashion during learning.

Many psychologists at the Learning Center of Montreal have noted the discrepancy of spatial and verbal abilities among students with learning disabilities. Some students are skillful in handling spatial concepts and have great difficulty with verbal learning, other students have strong linguistic ability and difficulties with spatial tasks (Stevens & Shenker, 1992). Are these ability differences in the learner or in the environmental experiences of that learner?

When an assessment is done on a student who is having problems at school sometimes the problem is not so much a learning problem, but more of a teaching problem (Stevens & Shenker, 1992). How can a student be unmotivated and unsuccessful with one effective teacher and then be animated and productive with another. One explanation is the way these students learn is different from other students, no matter how skilled their teachers or how responsive the setting (Stevens & Shenker, 1992). Often their learning styles are different in the content area subjects (i.e., reading, writing, calculating, science). It is often the case that with a flexible adaptation to their idiosyncratic learning needs, at the right time, a student can be a successful learner (Stevens & Shenker, 1992). How do these findings relate to some of the more cognitive studies conducted?

Studies conducted since the mid-1970's indicate that the linguistic and cognitive functioning of LD students differs from their NLD peers in several ways. Studies indicate that LD students make less efficient use of language to categorize and remember what they are learning, and to extract meaning from text (Beck &

Carpenter, 1986; Schwartz, 1990). In order to understand these findings we turn our attention to the reports from the Dyslexia Laboratory in Boston's Beth Israel Hospital.

Findings from the Beth Israel Hospital suggest that some learning disabled learners have an innate predisposition for learning disabilities (Galaburda, 1987; Humpherys, 1990). Although these studies involved very few subjects their findings suggest interesting possible explanations of learning disabilities. When the researchers of the Dyslexia Laboratory autopsied the brains of diagnosed dyslexics, they found the brains to be heavy and to have similar clusters of unusually developed neurons. They also found asymmetry between hemispheres of the brain. Unlike most brains, which have a larger left hemisphere, the brains of dyslexics were symmetrical. The researchers hypothesized that early fetal development of language functioning was affected, possibly by common maternal medical conditions during pregnancy, leading to LD's. It is suggested that perhaps this early interference in development causes subsequent adaptive neuronal development which permits language development to continue, leaving the developing child with an increased predisposition for later learning problems (Stevens & Shenker, 1992). Neurological research is diverse, however, it seems reasonable to suggest that both interference with embryonic development and genetic structure can influence the development of the fetal brain.

As researchers we need to be aware that learning problems are not necessarily due to poor teaching or lack of student interest. LD students come to the learning situation with different strengths than their peers. LD students' success or failure at school depends on how we can effectively bridge the learning gaps. If the demands of the environment match the ability of the student, there is no limit to the success a student can achieve. An individual who has high spatial aptitude and low verbal aptitude may learn more from instruction that is visual rather than textual. In the next section, the use of computers as instructional tools for LD students is explored. The use of computers as a visual means of instruction is also examined.

Connecting Computers and an LD Population

Motivation is the key to learning for all individuals (Lepper, 1988). This is especially the case for those who have been faced with continuous frustration and discouragement in their academic endeavors (Dweck, 1986). LD students are often labeled as inattentive and lazy rather than LD. How can we reduce the frustration of learning and increase positive learning outcomes?

Computer-based instruction can increase motivation and learning by providing students with a sense of self control, self-efficacy, and autonomy (Wepner, 1987; Malone, 1981). When students have some control over their learning motivation increases. As students advance at their own rate, they are actively and independently learning, which helps them to improve their self-esteem. The emotional neutrality of computers can help minimize the students' learning anxieties. Computers have the distinct advantage of being immensely flexible in comparison to other educational tools (Torgesen & Wong, 1986). They allow students to advance at their own pace without displaying failure to their peers or teachers. Computers can provide LDs with privacy, patience, and practice (Lerner, 1993). According to Lerner (1993) computer technology has the potential of drastically altering the educational experience of LD learners. It allows extraordinary people (LDs) to do ordinary tasks (Lerner, 1993).

Computers can involve students in ongoing activities which evaluate their responses and adjust instructional strategies to meet the individual needs of the student (Geisert, Dunn, & Sinatra, 1990). Furthermore, as Kolich (1985) suggests, computer's can provide feedback in a non-threatening manner. Computer-based learning environments have the flexibility and capacity for individualizing instruction, as many of them are versatile, patient, and non-judgmental. A study conducted by Short, Schatscheider, Cuddy, Evans & Basili (1991) concluded that in comparison to average achieving students, LD students were more dependent on adults for assistance and had trouble defining problems. Computers can assist researchers in providing the necessary feedback to learners.

The rapid growth of computer graphics have become an integral part of computer software and has tended to motivate students (Short et al., 1991). According to Kolich (1985) an effective computer program, written for LD students should direct the students' attention through the use of color cueing, underlining, arrows, animation, and varying print sizes so that students can remain on-task. Smith and Tompkins (1984) suggest that graphics should be used to support instruction by illustrating and demonstrating the concept being learned. It is important that instructions are clear, concise, and accessible for review at any point during the program (Piemonte, 1984). Since visual instruction may be important for dyslexics, the use of visual depictions and their role in computer instruction is reviewed.

Visual Depictions and an LD Population

An increasing number of studies have been conducted regarding the use of visual depictions as information organizers for enhancing achievement with special populations. The results of many of these studies indicate that visual representation of something one is trying to teach appears to be the most effective method for enhancing student learning (Crank & Bulgren, 1993).

Darch and Carnine (1986) compared instruction with visual-spatial displays as opposed to the use of text only. Their subjects consisted of 24 upper elementary level students with LDs. Subjects in the visual-spatial group were presented with an overhead projector and the teacher used a script to describe the items on display and their relationships to one another. The second group was given text material only. Students who were given visual-spatial display instruction proved superior on a post test of comprehension.

Bergerud, Lovitt, and Horton (1989) conducted a study to examine the effects of graphics and study guides for learning high school science content. Students with and without LDs were given a passage to read and a graphic organizer as an answer sheet on which they answered questions on the passage. Performance following instruction with graphics was superior to instruction with study guides or self-study.

In another study, Crank (1993) combined visual and verbal instruction to enhance learning. He examined the effectiveness of using visual depictions in lectures as compared to more traditional lecture techniques, such as outlining or listing information. He too found that the use of visual depictions resulted in higher post test scores than those who did not receive visual instruction.

A framework for using visual depictions has been created. Let us now discuss a different structure in which this framework can be used: computers and instructive animation.

Instructive Animation in Computer Assisted Learning

There are a number of reasons why computer-based instruction is an effective media choice, such as the learner has control over pacing, the computer can provide feedback, and animation of complex concepts. Animation is available in several different media formats. However, the use of animation in computer learning environments is unequaled since it often allows the learner to control various aspects of the animation during instruction (Milheim, 1993; Rieber, 1989, 1990). As reviewed earlier, learner-control can be a motivating factor.

Previous research provides mixed results on the use of animation and cautions us that care must be used when implementing animation as an instructional method in the domains of math and science. Baek and Layne (1988) demonstrated that the use of animation increased scores on a post test as compared to text-only or graphics-only groups using a computer lesson instructing students on mathematical rules. Zavotka (1987) described animation as having a positive effect in his study in the domain of geometry, using three-dimensional animation sequences to present various views of objects rotating. Reiber (1990b) confirmed the usefulness of animation. He demonstrated that animated presentations were more effective than static visuals or no visuals for students studying Newton's Laws of Motion.

On the other hand, there have been a number of studies that show animation to be of little or no instructional value within an instructional lesson. Research conducted by Tritz (1986; 1987) in the domain of microbiology, suggested that indiscriminate use of animation can be distracting. Reiber and Hannafin (1988) found no positive effect from the use of animation as compared to text, as an orienting activity within a lesson concerning Newton's Laws of Motion. Reiber (1991) also found evidence that students were more prone to develop scientific misconceptions from animated material. Another study with limited success was that of Reed (1985) who used animated simulations to improve estimating in algebra word problems. In order to decrease the number of studies conducted using animation with little or no instructional benefits, Milheim (1993) has severai suggestions.

Milheim (1993) has developed a series of twelve guidelines to follow when implementing an animation within a computer-based learning environment. The first three relate to the design of computer programs. Milheim suggests that: (a) simple rather than complicated animations should be used; (b) that animations should be presented in a way that information can be easily perceived; and (c) animations should include options for varying the speed. Milheims' next four guidelines pertain to content-related issues for animation: (a) they should relate directly to the objectives of the lesson; (b) they should be used when motion or trajectory are included in the lesson; (c) they should be used when instruction requires visualization, especially with spatially-oriented information; and (d) they should be used to show invisible events, in other words, events that are not visible to the human eye. The last five guidelines refer to the mode of use: (a) animation's should be interactive where the learner actually manipulates the graphics within the animation; (b) animation should be used to gain a learner's attention or increase motivation; (c) animations should not be distracting to the learner; (d) animation should not be used with novices who may become overloaded with irrelevant details; and (e) coaching techniques should be used to assist the learner in interpreting the animation, as well as allowing the subject time before and after the animation for better understanding.

Milheim (1993) suggestions should be considered in designing effective computer animations. We have reviewed the types of LD profiles that can benefit from visual forms of instruction and have built a rationale for how computers can be used to provide effective learning environments for LD by using visual depictions and animation. A theoretical justification is now presented as to why Mayer and Anderson's (1992) approach to instruction will benefit LD students.

Dual Coding Theory

According to Paivio's dual coding theory (Paivio, 1981; Paivio & Begg, 1981; Sadoski, Paivio, & Goetz, 1991), a learner possesses two distinct but interconnecting information processing systems. An imagery system which is specialized for representing and processing nonverbal information about objects and events and a verbal system which is specialized for representing and processing linguistic information. Both systems have different organization and processing characteristics, however, the connections between them may support parallel or integrated functioning. Information in the verbal system is organized in a sequential or syntactic way. Whereas nonverbal information (especially in the visual modality) is organized more in the form of synchronous or in a parallel manner. Paivio (Paivio & Begg, 1981; Sadoski, Paivio, & Goetz, 1991) also suggests that organization of information within a system is composed of associative relations, whereas organization between systems is composed of referential relations. Other assumptions of the dual coding theory suggest that these two separate encoding systems are additive so that stimuli encoded in both forms are more likely to be remembered (Kobayashi, 1986). Another assumption suggesting differences between the two coding systems is that the mechanisms differ, in that a picture is more likely to be dually encoded than words (Hannafin, 1983 in Reiber & Kini, 1991).

Mayer (1989) took the general principles of the dual coding theory and derived the contiguity effect. The contiguity effect suggests that students are better able to transfer new information to new situations when text and illustrations are presented next to each other on the same page, rather than when they were isolated from one another (Mayer, 1989; Mayer & Gallini, 1990). A great deal of research supports this contention, suggesting that presenting text and illustrations together can greatly enhance students' learning (Bernard, 1990; Glenberg & Langston, 1992; Guri-Rozenbilt, 1988; Reed & Beveridge, 1986, 1990; Waddill, McDaniel & Einstein, 1988). This research has led to a better understanding of the contiguity effect. More recently, research has examined the contiguity effect on computer-generated animation's and narration's (Mayer & Anderson, 1992). In this more novel approach, text has been replaced by auditory narration and static illustration has been replaced by dynamic animation. The demonstration of the contiguity effect has been found when computer-generated animation and narration are presented concurrently rather than successively (Mayer & Anderson, 1992).

The findings of Mayer (1989), Mayer and Gallini (1990), Mayer and Anderson (1992), and Mayer and Sims (1993) were interpreted within the context of a dual coding theory (Clark & Paivio, 1991; Paivio, 1990). Mayer and Anderson (1992), used visual (animation) and verbal (narration) as the two modes of information presentation. Several things happen to promote meaningful learning, which in effect, supports transfer. First, the learner must build a representational connection between the presented verbal information and the internal verbal representation. Secondly, the learner needs to build a representational connection between the presented visual information and the internal visual representation of that information. Finally, a referential connection between the verbal and visual representations needs to be made. Research conducted up to this point indicates that students will be better able to build referential connections when verbal and visual information is presented contiguously, or concurrently, in time and space (Mayer, 1989; Mayer & Gallini, 1990; Mayer & Anderson, 1992; Mayer & Sims, 1993).

It should be noted however that dual coding theory has not gone unchallenged in the literature. Farah (1989) has demonstrated through neuro-physiological research that comprehension of pictures and text focus on an amodal system of knowledge representation. Farah used aphasic and agnostic patients who seem to demonstrate a loss of this amodal system. However, the positive evidence for the dual coding theory seems to outweigh the negative evidence. Let us examine a study which interprets it's results within the context of a dual coding theory.

Mayer and Anderson Study (1992)

Mayer and Anderson (1992) created two computer environments using the information known about animation and visual imagery based on the Contiguity Principle. Students who were shown illustrations and presented with verbal descriptions concurrently were better able to solve transfer problems than those students who received the same illustration and verbal description in isolation from one another (Mayer & Anderson, 1991; Mayer & Gallini, 1990; Levin, 1981; 1983; Mayer, 1989; Rohwer & Harris, 1975; Rohwer & Matz, 1975).

In Mayer and Anderson's 1992 study, two experiments were conducted using two different computer animated programs. The students studied an animation depicting the operation of a bicycle pump or an automobile braking system. The subjects were randomly separated into one of four groups. The four groups were as follows; the concurrent group received the animation and narration at the same time, the second group received successive representation of animation and narration, the third group received either animation alone or narration alone, and the final group was the control group which received no instruction. The researchers were interested in the retention and problem solving ability of the subjects. Two predictions were made. Mayer and Anderson (1992) predicted that students in the control group would perform worse on the retention test than the treatment group. The second prediction stated that the concurrent group would perform better on problem solving than the other groups.

The researchers believed that in order to succeed on the retention test one would need to learn the information being presented. The prediction was that students in the control group would perform worse on retention than the treatment groups, which would not differ from one another. It was predicted that students who received the narration in any form (either concurrently with animation, or successively with animation, or alone) would be encouraged to build representational connections between words and an internal mental representation of words. In contrast, students in the control group had no opportunity to build representations between words and verbal items. Therefore the prediction was that more idea units would be produced by those subjects who were given the opportunity to build representations.

The problem solving test was used to determine the students' understanding of the material. The dual coding model suggests that in order for meaningful learning to take place students need to build three connections. Connections need to be made between words and verbal representations, between pictures and visual representations, and between visual and verbal representations. It is due to the limitations of working memory that the hypothesis was created that when words and pictures are presented contiguously in time and space the best representations are constructed. Items presented close in time have been shown to be more effective than far apart. The further apart one presentation is from the second, the more opportunity for interference in memory (Miller, 1956). In Mayer and Anderson's (1992) study only the concurrent group was presented with the words and pictures contiguously; Therefore the prediction was made that students in the concurrent group would perform better than all other groups in the problem solving transfer test.

Mayer and Anderson's (1992) predictions of dual coding theory were confirmed. As hypothesized in prediction one, the various forms of successive presentation of words and pictures did not produce different patterns of results. The second prediction, alsc confirmed, demonstrated that those subjects who received the concurrent presentation of words and pictures performed better than the other groups. When the animation was presented concurrently with narration, subjects demonstrated significant improvements in problem solving transfer. The researchers concluded that an important characteristic of an instructive animation is temporal contiguity between animation and narration. Both studies conducted by Mayer and Anderson (1992, 1991) found evidence of the contiguity principle in multimedia learning. They concluded that students learn best when words and pictures are presented contiguously (concurrently) in time and space.

The current study is a modification of Mayer and Anderson's (1992) which examines a LD population and determines helpful ways to improve learning in the domain of biology.

Description of the Current Study

A computer based learning environment was developed to instruct LD students about how the human body protects itself against infection. INFECTRON was designed based on the literature which suggests that: (a) LD's benefit from a multi-sensory approach; (b) computer learning environments are effective for this population; (c) visual depiction's can enhance learning for LD's; (d) dual coding promotes learning; and (e) the contiguity principle along with dual coding promotes greater learning than non contiguous information.

INFECTRON is a computer learning environment which uses animation and narration to teach five biology lessons. Animation and narration are used because dual coding theory supports a multi-sensory approach to learning. INFECTRON was designed following many of the Milheim (1993) guidelines. For example, simple animations are used where information is easily perceived. The animations involve motion which directly relates to the biological objectives of the lesson. The biology lessons require visualization therefore animation is used to enhance the spatially-oriented information. Many of the lessons demonstrate events that are not visible to the human eye, i.e. how a scab forms, therefore once again animation is an aid. Each animation within INFECTRON is used to gain the learner's attention and as a motivating factor which Milheim (1993) also supports. Finally, subjects are allowed time before and after the animation for better understanding. An additional feature, present in INFECTRON, not mention by Milheim (1993), is that each subject could review the lessons as many times as they wanted.

This study was developed based on our current understanding of LD populations and how computer learning environments can enhance their learning. This study is an adaptation of the Mayer and Anderson (1992) study which was theoretically based on the dual coding theory and the contiguity principle. The hypotheses for the current study are described below.

Research Hypotheses

Three research hypotheses are examined in the present study using the computer learning environment INFECTRON which teaches how the body defends itself against infection in five biology lessons. The first two predictions are based on previous research conducted by Mayer and Anderson (1992). The first hypothesis is that students (LD and NLD) in the computer conditions (concurrent and successive) will outperform students (LD and NLD) in the control condition on the pre and post test, which is assessing declarative knowledge in the domain of biology. The second hypothesis suggests that students (LD and NLD) in the concurrent group will outperform students (LD and NLD) in the successive group on the post test (declarative knowledge) and reasoning tasks, which assesses procedural knowledge. The third prediction hypothesizes that there will be no group difference between the students (LD and NLD) in the computer conditions on post test and reasoning tasks. Based on current research on instructive animation and its benefits with LD students, it is expected that students (LD and NLD) in the computer conditions (concurrent and successive) will perform at par with one another on the post test, reasoning tasks, and retention test. Both groups of students (LD and NLD) using the computer tool will surpass the control group because the students in the control condition are not given any instruction.

CHAPTER II

Method

Subjects

Sixty subjects were drawn from the seventh and eighth grades in an anglophone public high school in the Montreal area. The seventh and eighth grade level was chosen because they were naive subjects for the domain of biology. Two grade levels were needed in order to obtain a large enough sample of LD students. Thirty LD and thirty NLD students were equally divided into two treatment conditions and a control group. LD students had been identified by the school boards' psychologists and coded according to government criteria. The LD students who participated were coded either 01, mild learning difficulties or 02, serious learning difficulties. The students with mild learning difficulties had an academic delay exceeding one year in both the language of instruction and mathematics. The students with serious learning difficulties are classified as having a significant academic delay or specific learning difficulties. If a student is two or more years behind in either the language of instruction or mathematics he or she is classified as having a significant academic delay. Students coded 01 and 02 and who had language based learning difficulties were included in this study in order to increase the sample size. The NLD students were selected based on teacher's ratings (i.e. high or average) of each student's performance as measured by classroom exams and assignments from the beginning of the year. Twenty-seven girls and thirty-three boys participated in this study.

Design

Girls and boys were separated into two groups (LD and NLD) and randomly assigned to each condition (Concurrent, Successive, Control). The concurrent condition presented animation plus narration together in time and space; Whereas the successive condition presented the narration followed by the animation after a delay of 5 seconds. The subjects in the control group were not exposed to the computer program until after all tests were administered. The examiner felt it was important for the control group to be exposed to the computer program after the conclusion of the study so that they would have the same learning opportunities. Subjects were tested individually throughout the study.

A pretest/posttest design was used to assess change in students' declarative knowledge of biology — factual knowledge of how the body protects itself against invading germs. Reasoning tasks were then presented on the computer in order to assess change in students procedural knowledge — how they apply their knowledge to situations that require understanding of infection. Finally, a retention test of declarative knowledge was given twenty-four hours after students had been exposed to the computer program.

Materials

Computer Program: INFECTRON

INFECTRON is a computer program designed to run on the Apple® Macintosh™ LCII. The animated program was developed using Hypercard© and MacroMind Director©. The computer program was adapted from existing problems described in text books and a program developed as an introduction to a tutoring system on scientific reasoning (see Tookey, 1991; Lajoie, 1993). INFECTRON was designed to teach subjects how the body defends itself against infection. Before beginning the computer program each student was introduced to the project and told what he or she would be asked to do (see Appendix A, for instructions to respective treatment conditions). The program begins by giving the student a general introduction of how germs can lead to infection, how they allow infection to thrive, and eventually how they will perish within the human organism. Then the subjects are asked to consider the body's defenses against germs, namely the eye, ear, nose, mouth, skin and blood (see Appendix B, for the computer script). For each defense system there is an animation and narration that depicts a germ entering the body, these segments last approximately thirty seconds each (see Appendix C for a visual example). The lessons explain the underlying mechanisms of each defense and a detailed colour animation is provided. Students were able to review each lesson as many times as they would like. Students in the concurrent condition were exposed to lessons in which the narrations and animations were perfectly syncronized on the screen. The narrations were recorded directly into the Apple® Macintosh™ LCII, using an external mirophone.

Pre/post test I & test II. The pre/post test I and II were designed to measure students' declarative knowledge of how the body defends itself against infection prior to and after instruction. Each test had ten questions each. The researcher presented the questions orally then recorded the subjects answers. The corresponding questions on test I and test II are worded differently, however, they are designed to test the same declarative knowledge. Two tests were developed, that could be used as either a pretest or posttest. This was done to counter balance the difficulty and order effects of the test. Thus, test I was used as a pretest 50% of the time, and as a posttest 50% of the time. Every odd numbered subject received test I as a pretest and test II as a posttest. Every even numbered subject received test II as a pretest and test I as posttest (see Appendix D, for Test I and Appendix E, for Test II). Subjects were informed as to the respective purposes of the pretest/posttest questions and asked to listen and think carefully before answering. They were instructed to ask the researcher for clarification of questions when necessary. Scoring criteria were developed for evaluating the responses to these items.

Reasoning tasks. The reasoning tasks were designed to measure students' knowledge of how the body defends itself against infection in a real life situation. Subjects were informed that they would see an animation on the computer and that following the animation the researcher would ask them a question about how the body protects itself against infection in that situation. For example, one animation demonstrates a child stepping on broken glass and cutting his foot. A sample question would be " This boy has just cut his foot on the broken glass. How will the red and white blood cells prevent germs from entering the body and how will they help form a scab?". (see Appendix F, for reasoning questions and Appendix G, for a visual depiction of a reasoning task). Each student was presented a total of five animations on the computer, each enduring approximately five seconds. After each anaimation the student was asked one question by the researcher orally. The researcher recorded the subjects answer by hand.

Retention test. Subjects were told that the retention test, given on day two of the testing session, was to determine how much the students remembered from the day before. Subjects were notified that the questions required them to, listen and think carefully. If they were unsure of what they were being asked to do, they were encouraged to ask the researcher for assistance. Subjects were instructed to answer true or false to a series of statements asked orally by the researcher. Following each statement they would be asked how confident they were about their answer and asked to rate their confidence on a scale from 1 to 4 (see Appendix H, for the retention test).

Procedure

After consent forms were returned, and parental permission was granted, students were scheduled to work with the researcher one-on-one for twenty-five minutes on one day and fifteen minutes the next day. On day one, students in the treatment conditions were administered the pretest followed by the computer program, then the posttest and reasoning tasks. On day two students were given the retention test. Students in the control condition were given the pretest, followed by the posttest and reasoning tasks on day one and on day two the retention test was administered. After the study was completed the control group worked with the computer program. The researcher felt it was essential that all students felt part of a learning experience. The examiner and the student then spoke informally about the session and the student was asked if he or she felt they had learned something. The student was then thanked for participating.

CHAPTER III

Results

Synopsis of Results

A repeated measure ANOVA was conducted to test the research hypotheses. It was determined that students (LD and NLD) in the computer conditions (concurrent and successive) outperformed students (LD and NLD) in the control condition on the pretest and posttest. The second hypothesis suggested that students (LD and NLD) in the concurrent group would outperform students (LD and NLD) in the successive group on the posttest and reasoning task, this was not confirmed. The prediction that there would be no group difference between the students (LD and NLD) in the computer conditions was confirmed on the posttest and reasoning test. It was expected that students (LD and NLD) in the computer conditions (concurrent and successive) would perform at par with one another on the retention test. However, analysis of the retention test revealed a ceiling effect and further analyses were not considered.

Review of Analyses Conducted

Pre/post test results. A group (LD, NLD) X Treatment (Concurrent, Successive, Control) X Test (Pre, Post) ANOVA was conducted. Significant main effects were found for treatment ($F(2,54)=37.442$, $p < .05$), test ($F(1,54)=203.679$, $p < .05$), as well as an interaction effect of test by treatment ($F(2,54)=51.209$, $p < .05$) (see Table 1).

Table 1

Analysis of Variance of Pre/Posttest Scores by Group and Treatment

Source of Variance	df	Sum of Squares	Mean Squares	F Ratio	p
Between Subjects					
Group	1	0.533	0.533	0.197	0.659
Treatment	2	202.467	101.233	37.442	0.000*
Group by Treatment	2	1.867	0.933	0.345	0.710
Error	54	146.000	2.704		
Within Subjects					
Test	1	282.133	282.133	203.679	0.000*
Test by Group	1	0.000	0.000	0.000	1.000
Test by Treatment	2	141.867	70.933	51.209	0.000*
Test by Group and by Treatment	2	0.200	0.100	0.072	0.930
Error	54	74.800	1.385		

* indicates a significant finding

Upon examining the means in Table 2 the test effect reveals that there are higher mean scores in the post test than in the pre test for all treatment groups except the

Table 2

Descriptive Statistics for the Pre/Post Test and Reasoning Task

	Pretest		Posttest		Reasoning Tasks	
	M	SE	M	SE	M	SE
Group						
LD	1.067	0.226	4.133	0.292	4.983	0.273
NLD	0.933	0.226	4.000	0.292	4.467	0.273
Treatment						
Concurrent	1.350	0.277	5.750	0.357	5.875	0.335
Successive	0.950	0.277	5.750	0.357	6.450	0.335
Control	0.700	0.277	0.700	0.357	1.850	0.335
Group by Treatment						
LD x Concurrent	1.300	0.392	5.600	0.506	6.350	0.473
LD x Successive	1.000	0.392	5.900	0.506	6.600	0.473
LD x Control	0.900	0.392	0.900	0.506	2.000	0.473
NLD x Concurrent	1.400	0.392	5.900	0.506	5.400	0.473
NLD x Successive	0.900	0.392	5.600	0.506	6.300	0.473
NLD x Control	0.500	0.392	0.500	0.506	1.700	0.473

* The maximum scores on both the pre and post tests was 10.

control (see Figure 1). The treatment means indicate no significant pretest differences but the computer conditions are higher than the control condition on posttest. This result indicates that subjects' (LD and NLD) factual biological knowledge increases from pretest (concurrent, *M*=1.350; successive, *M*=0.950; control, *M*=0.700) to posttest (concurrent, *M*=5.750; successive, *M*=5.750; control, *M*=0.700) for those in the computer conditions. The findings demonstrate that the increase from pretest to posttest is only apparent in the treatment conditions (concurrent and successive) not in the control condition. The prediction that students (LD and NLD) in the computer conditions (concurrent and successive) would outperform students (LD and NLD) in the control condition on a posttest of declarative knowledge was confirmed.

There was no significant main effect for group ($F(1,54)=.197, p > .05$), or interaction effects for group by test ($F(1,54)=.000, p > .05$), or test by group by treatment ($F(1,54)=.072, p > .05$) (see table 1). Since there was not a group effect this result supports the prediction that both LD and NLD students perform at par on the test variables (see Figure 2). Means shown in Table 2 indicate that LD students scored slightly higher on the pretest (*M*=1.067) and the posttest (*M*=4.133) than NLD students on the pretest (*M*=0.933) and posttest (*M*=4.000). The fact that there is no group by test interaction indicates that these mean differences are not significant and that both LD and NLD students benefited by computer instruction in biology. In other words, there were no posttest differences in the amount of knowledge acquired by LD and NLD students. Furthermore there is no significant difference between the effects of treatment condition on group (LD, NLD).

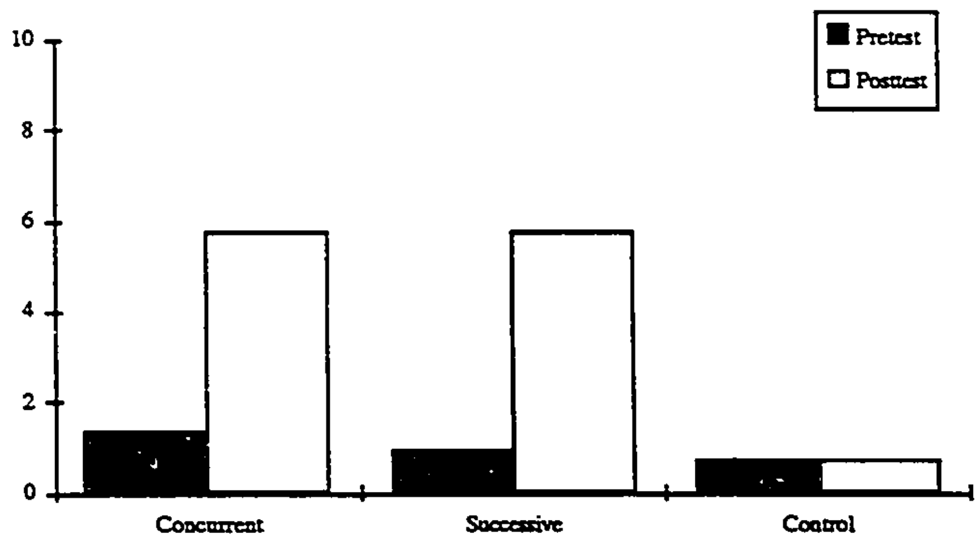

Figure 1. Pretest and posttest scores for the treatment effect

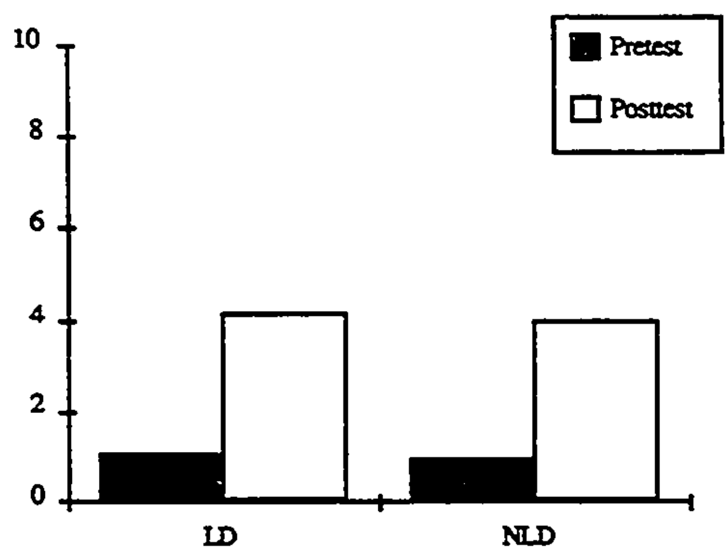

Figure 2. Pretest and posttest scores for the group effect

However, results from the analysis of variance indicate that there was no significant difference between the LD and NLD students, suggesting that the LD students benefited equally from the instruction.

Subsequent to the above findings an ANCOVA was performed that covaried the control treatment, in order to demonstrate whether or not a difference existed between the computer treatments (Concurrent, Successive) on the test variable (Pretest, Posttest). The ANCOVA revealed no treatment effect ($F(1,36)= 0.396$, $p < .05$). Results indicate no significant differences between the two computer conditions on either the pretest or posttest of biological knowledge. It was predicted that students (LD and NLD) in the concurrent group would outperform students (LD and NLD) in the successive group on the posttest. This prediction was not substantiated (see Figure 1 and Table 2).

Reasoning tasks. Reasoning tasks were developed to assess the application of student knowledge to examples they might find in the real world. A group (LD, NLD) X Treatment (Concurrent, Successive, Control) X Reasoning Test ANOVA was conducted. The only significant finding was a main effect for treatment ($F(2,54)= 56.06$, $p < .05$) (see Table 3). A Tukey HSD multiple comparison test for differences between treatments revealed no significant differences between the concurrent and successive treatments for posttest. However, two significant differences were found on the reasoning test between: (a) concurrent and control groups and (b) successive and control groups (see Table 2). Once again both LD and NLD performed similarly.

Table 3

Analysis of Variance of Reasoning Task Scores by Group and Treatment.

Source of Variance	df	Sum of Squares	Mean Squares	F Ratio	p
Between Subjects					
Group	1	4.004	4.004	1.787	0.187
Treatment	2	251.275	125.638	56.058	0.000*
Group by Treatment	2	1.408	0.704	0.314	0.732
Error	54	121.025	2.241		

* indicates a significant finding

Retention test. A retention test was administered to all subjects. The test was worth 10 points and no one scored under 8 points. Consequently no further analyses were conducted because of this ceiling effect.

CHAPTER IV

Discussion and Conclusion

Research on classroom learning continues to indicate that students with LD's experience difficulty in the classroom. It is often assumed that LD students differ from NLD students in their ability to acquire information from typical classroom instruction. This difference is most pronounced at the high school level where students are required to use more advanced knowledge (Deshler, Schumaker, Alley, Warner, & Clark, 1982). Many LD students are not able to master the content information being taught and this leads to academic failure and perhaps withdrawal from school (Deshler & Schumaker, 1988). This problem has encouraged many teachers and researchers to develop new ways to teach content-area information to all students. With the development and implementation of computer technology in the schools, the benefits of computer learning environments are being studied.

INFECTRON is a computer learning environment that was developed to assist LD students in acquiring knowledge about infection. It allows students to code the same information in two different ways, visually through animation and auditorily through narration. Multi-sensory approaches are thought to be more adaptive to individual differences since it provides multiple representations of information. It was predicted that INFECTRON would assist LD students in learning biology. The prediction that INFECTRON would assist LDs learn biology was verified.

Students (LD and NLD) in the INFECTRON computer conditions (concurrent and successive) outperformed students (LD and NLD) in the control condition.

These findings replicate many of the findings from other studies using NLD subjects (e.g. Mayer & Anderson, 1992). Studies such as Mayer and Anderson (1992) found that when subjects (NLD) were presented with two modalities learning was enhanced. Other researchers studying the effects of illustration and text also found that learning was enhanced with the use of two modalities (e.g. Levin, 1981, 1983; Rohwer & Harris, 1975; Rohwer & Matz, 1975). This study indicates that dual coding theory applies to LD as well as NLD students.

The prediction that students (LD and NLD) in the concurrent condition would outperform those students (LD and NLD) in the successive condition was not confirmed. This prediction was based on Mayer's (1992) contiguity principle, which suggests that students are better able to learn new information when text and illustrations are presented together on the same page than on successive pages. Mayer and Anderson (1992) found that concurrent representation of material was more effective than successive presentation for learning new information. However, the current study did not replicate these findings. One possible explanation for why this study did not replicate this aspect of Mayer and Anderson's (1992) research is that the delay between narration and animation (5 seconds) in the successive condition was too short. A longer delay between narration and animation might cause some interference with memory, making it more difficult to integrate the information that was heard with what was seen.

All students who received the computer treatment scored well on the posttest regardless of classification. The most exciting finding was that LD and NLD students did not differ in accuracy on the post test of declarative knowledge or on the reasoning tasks which tests procedural knowledge. LDs were as effective as

NLDs at applying their newly acquired biological knowledge to new situations. They were able to reason about the human body's defenses. Several instructional variables contribute to the success of these students: (a) the use of visual depictions; (b) the utilization of instructive animation; (c) the use of computers as learning tools; and (d) the use of a multi-sensory approach.

For years researchers have suggested that the use of visual depictions as an instructional addition is a useful practice for effecting student learning in NLD populations (e.g., Mayer & Anderson, 1992; Mayer & Anderson, 1991; Mayer & Gallini, 1990; Levin, 1981, 1983; Alvermann, 1987; Armbruster & Anderson, 1984; Rohwer & Harris, 1975; Rohwer & Matz, 1975). It is more recently that researchers have been concentrating on furthering the research on visual depictions to include subjects with LD's (e.g., Bergerud et al., 1989; Bos & Anders, 1987; Darch & Carnine, 1986; Idol, 1987; Kolich, 1985). Many of these studies have demonstrated that the use of visual depictions result in greater student learning of content or declarative information than traditional classroom instruction, that is often limited to verbal lectures.

The present study validates the literature on the usefulness of visual depictions. Visual depictions, in this study, were in the form of instructive animations and were found to enhance learning. As Milheim supports, animations are useful when they make abstract concepts concrete. INFECTRON provided animations that made invisible processes, such as white blood cells fighting infection, visible. Computers provide learners with control over viewing such animations, allowing them to learn at ones own pace. When information is presented in a way that capitalizes on an LD students' abilities to learn, they can perform at par with NLD students.

INFECTRON is a computer based learning environment which provides a multi-sensory approach to learning. This study demonstrates that narration and animation, during instruction encourages learners to build connections between their verbal and visual representations of incoming information. It is important to emphasize that INFECTRON enhances the performance of both LD or NLD students. This study holds promise for the many teachers trying to promote learning of LD and NLD students in an integrated classroom. Computer-based learning environments, such as INFECTRON, can provide opportunities for all students to advance at their own rates within the same classroom.

Future Research

Based on the findings of this study, it is clear that a computer based learning environment is an effective instructional method for LD students. This form of instruction could allow for a full model of integration in the classroom and veers away from traditional classroom instruction.

Longitudinal studies now need to be carried out to determine the strength of such computer tools. Perhaps a computer-based instructional program using animation and narration to teach a content subject like biology can be devised to teach more than a lesson on infection. A biology curriculum could be designed to promote scientific reasoning using computer tools. Longitudinal data that examines long-term gains can assist researchers in determining the effectiveness of a multi-sensory approach for LD students.

INFECTRON is a simple environment without tutoring features. It was effective for the dyslexic students who participated in this study, but other methods may be appropriate for other types of LDs. For example, complex learning situations may require going beyond the multi-sensory approach to instruction, to include adaptive forms of feedback to learners, as may be found in intelligent tutoring systems (see Lajoie & Derry, 1993). Intelligent tutoring systems (ITS) make the assumption that students' thinking processes can be modeled, traced, and corrected in the context of problem solving using computers (Derry & Lajoie, 1994). Bio-World (Lajoie, 1993) for example, is a computer coached learning environment that teaches high school students to diagnose infections. Rather than teaching declarative knowledge as INFECTRON does, Bio-World provides mechanisms for putting this declarative knowledge into practice by enabling students with the opportunity to use their knowledge in the context of realistic problem-solving tasks. A promising research endeavor is to examine whether or not INFECTRON can provide the prior knowledge students might need to promote problem solving in a situation like Bio-World. It is likely that LDs are capable of performing as well as NLDs on complex scientific reasoning tasks given the appropriate instruction. The challenge is to find appropriate forms of instruction for an LD population. This study supports the findings that computer based learning environments enhances learning for students with special needs.

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APPENDICES

Appendix A

Introduction to the Project

Concurrent Condition

In this computer program you will be learning about how the human body defends itself against infection. You will be shown how germs try to enter your body and what your body does to keep them out! The computer program will demonstrate how the eye, ear, nose, mouth, skin and blood protect themselves from dirt and grime. You will also learn how your body protects itself from germs if you cut yourself.

You will hear the information and see a picture explaining what you are hearing. The picture (animation) is used to demonstrate the body's defenses against the invasion of germs.

It is important to try to learn the facts in this lesson, but it is just as important to learn how the facts fit together. Take for example a walkman. It is a fact that all walkmans are sold with headphones, the tape player, and each one has a play button. It is all very well to know these things, but unless you know where to plug the headphones in and that you should push the play button down to hear music you won't be very happy with your walkman. It is important to understand how the system fits together. By understanding the "big picture" you will gain a greater understanding than if you just remember the facts.

At the end of the computer lesson you will be asked to answer a series of questions. So let's go!

Appendix A

Introduction to INFECTRON
Successive Condition

In this computer program you will be learning about how the human body defends itself against infection. You will be shown how germs try to enter your body and what your body does to keep them out! The computer program will demonstrate how the eye, ear, nose, mouth, skin and blood protect themselves from dirt and grime. You will also learn how your body protects itself from germs if you cut yourself.

You will hear the information and then you will see a picture explaining what you have heard. The picture (animation) is used to demonstrate the body's defenses against the invasion of germs.

It is important to try to learn the facts in this lesson, but it is just as important to learn how the facts fit together. Take for example a walkman. It is a fact that all walkmans are sold with headphones, the tape player, and each one has a play button. It is all very well to know these things, but unless you know where to plug the headphones in and that you should push the play button down to hear music you won't be very happy with your walkman. It is important to understand how the system fits together. By understanding the "big picture" you will gain a greater understanding than if you just remember the facts.

At the end of the computer lesson you will be asked to answer a series of questions. Do you have any questions? Let's go!

Appendix B

Computer Script for INFECTRON

Introduction:

-Your body is always being attacked by germs. But it can defend itself in different ways.

-Germs are tiny creatures, too small to see. If they get into your body, they make you sick. They make poisons, and grow into an army.

-Germs like warm, dark, dirty places.

-Sun and fresh air kill them.

-Good food and rest helps your body make weapons to defend against germs.

-Your body, like a castle, is well defended. (protected)

-Germs can get in your body through any opening. But each opening is defended in some way.

-Let us consider the defenses of the eye, ear, nose, mouth, skin, and blood.

Eye:

-The eye produces tears to protect itself. Tears are produced by the lacrimal glands. When you blink, tears wash your eyes and can kill the germs.

Ear:

-The ear has a number of glands which produce cerumen. Cerumen is more commonly known as ear wax. There are also tiny hairs which help protect the ear. The wax and tiny hairs together, line your ear to trap germs and dust so that they can not move deep into your ear and cause infection.

Nose:

-Your nose contains little hairs. Germs that are in the air you breath stick to these hairs and prevent them from entering your body.

Mouth:

-The mouth is an easy place for germs to get into your body.

-Glands in your mouth produce saliva which wash germs and food down into your stomach. Saliva can kill some germs while most of the others are killed by the fluids in your stomach.

Blood:

-Blood is always moving around in your body. When germs attack, your blood carries messages for help. There are three very important parts of your blood that help your body defend itself. The first are fighting white blood cells, second are red blood cells, and lastly, special repair cells called platelets.

Skin & Blood:

-Your skin protects the body from germs.

-When you hurt yourself and the skin is broken, your body is open to germs.

-When you cut yourself, special repair cells, called platelets, release a chemical that reacts with other chemicals in the blood. Theses chemicals react together and form a net that blocks the wound.

-White blood cells come to the injured area to fight the germs. Some white cells corner germs and others kill them.

-It is the red blood cells that bunch up behind the net to form a sticky plug which stops the bleeding. The sticky blood is called a blood clot. When the blood clot dries it forms a scab.

Conclusion:

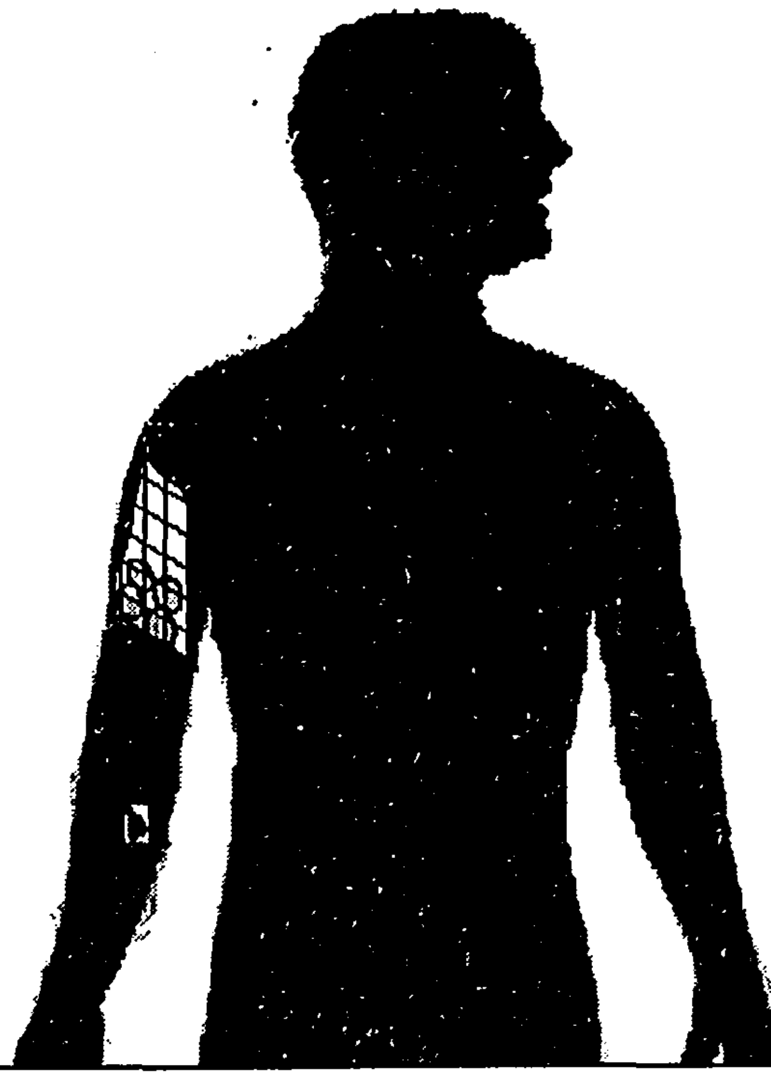
Your body is always being attacked by germs. This activity has been about how the body physically defends itself against invading germs.

The physical barriers provide the first level of defense against invasion.

Appendix C

<u>Partial animation of the blood cell lesson:</u>

In this portion of the animation one sees the white blood cells coming to the injured area to fight the germs. Students are told at this point that some white cells corner germs and others kill them.



Appendix D

Pre-Post Test I

Name:
Age:
Date:
Condition:

Purpose: The purpose of the following questions are to indicate what you already know and think about the human body's defense system.

Take Your Time: The questions require you to listen and think carefully about different situations. If you are unsure of what you are being asked to do, please ask for help.

Instructions: You will be asked to answer a series of questions. Take your time and answer as best as you can.

A. How do white blood cells fight against incoming germs at a cut site?

B. How does ear wax help defend the body?

C. A sticky plug is formed at an injured site, what cells are involved in this process?

D. When you cut your skin a net is formed from chemicals and special repair cells. What are these repair cells called?

E. How does our body prevent germs from being inhaled through our nose?

F. What does the eye do in order to defend the eye?

G. Saliva helps to kill germs in two ways, what are they?

H. Where in the body would you expect to find the Lacrimal gland?

I. What is another name for ear wax?

J. A sticky plug and a blood clot are the same thing. What do you call a blood clot when it dries?

Appendix E

Pre-Post Test II

Name:

Age:

Date:

Condition:

Purpose: The purpose of the following questions are to indicate what you already know and think about the human body's defense system.

Take Your Time: The questions require you to listen and think carefully about different situations. If you are unsure of what you are being asked to do, please ask for help.

Instructions: You will be asked to answer a series of questions. Take your time and answer as best as you can.

1. What does the Lacrimal gland produce that helps the body defend against infection?

2. When your skin is cut special repair cells called platelets go to the injured area and combine with other chemicals. What do they form?

3. What purpose does ear wax serve?

4. When the skin is cut cells rush to the injured area. Which cells form a sticky plug?

5. How do tears help defend the eye?

6. What is cerumen?

7. What does the hair in our nose do to help defend the body?

8. What two roles does saliva play in killing germs?

9. A sticky plug can also be called a blood clot. When the blood clot dries what is it called?

10. When the skin is broken white blood cells rush to the area to fight the germs. They can do this in two ways, name one. (corner or kill).

Appendix F

Reasoning Questions

1. The fly just hit the persons eye. How do you think the eye will protect itself against germs from the fly?

2. Dust is being swept by the broom into the ear. How will the ear protect itself?

3. You have just seen and heard a person sneeze. How do you think the nose will protect itself from incoming germs?

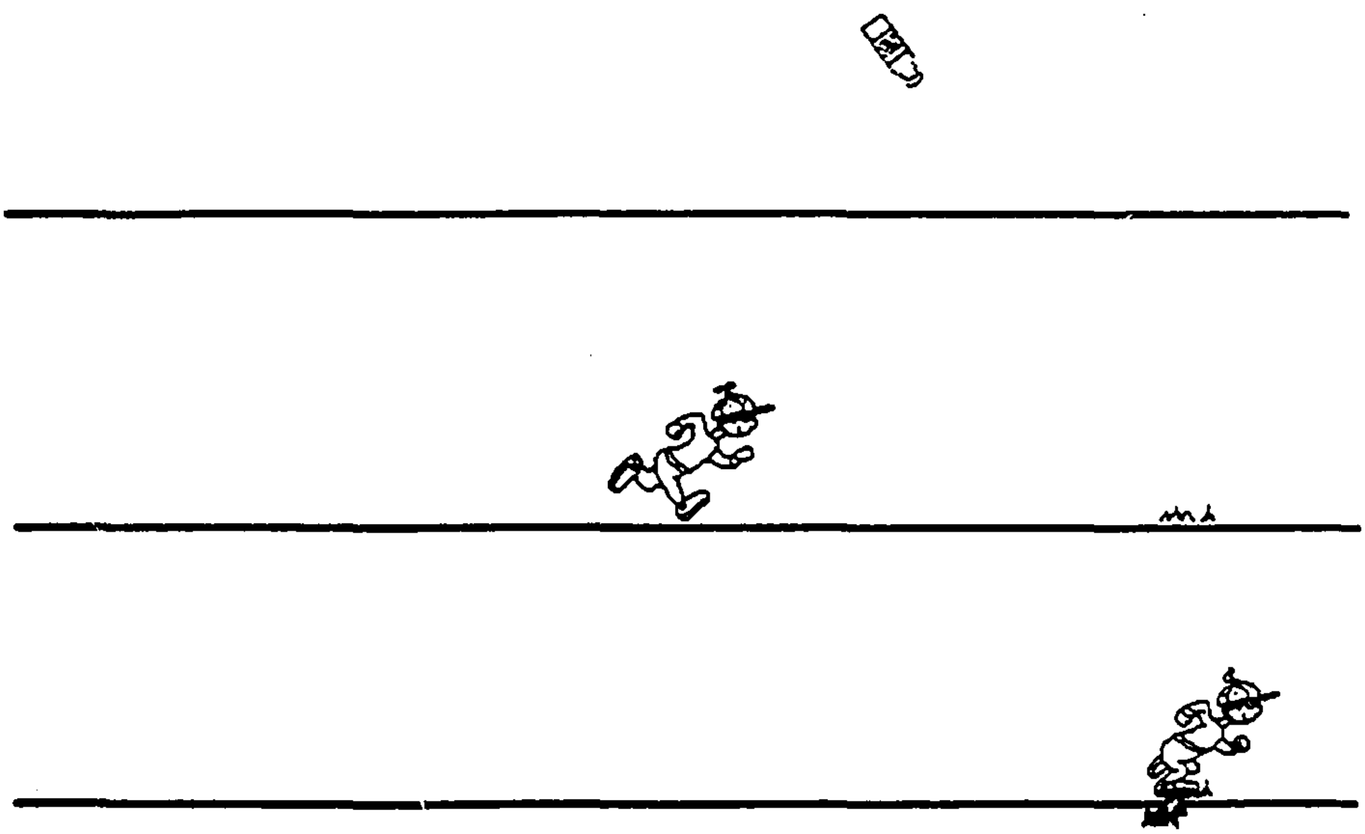
4. This baby is sucking on a dirty shoe. How will the body defend itself against the germs getting into the babies mouth?

5. The boy has just cut his foot on the broken glass. How will the red and white blood cells prevent germs from entering the body and how will they help form a scab.

Appendix G

A Visual Depiction of a Reasoning Task

"The boy has just cut his foot on the broken glass. How will the red and white blood cells prevent germs from entering the body and how will they help form a scab."



Appendix H

Retention test

Name:
School:
Age:
Date:

Purpose: The purpose of the following questions are to indicate what you already know and think about the human body's defense system.

Take Your Time: The questions require you to listen and think carefully about different situations. If you are unsure of what you are being asked to do, please ask for help.

Instructions: You will be asked to answer true or false to a series of statements. For example;

(a) When getting dressed in the morning it is a common practice to put your shoes on and then your socks.
TRUE OR FALSE?

1. Tears help the body wash away dirt so it does not irritate or damage the eye.

TRUE OR FALSE?

2. Lacrimal glands produce tears to wash dirt from the eye.

TRUE OR FALSE?

3. Ear wax causes infection to start in your ear.

TRUE OR FALSE?

4. Cerumen is produced in the ear to trap germs.

TRUE OR FALSE?

5. Germs heading into our body can be caught by the hair in our nose.

TRUE OR FALSE?

6. The purpose of sneezing is to get rid of germs that have entered our nose.

TRUE OR FALSE?

7. When you swallow the saliva carries the germs into your body causing infection.

TRUE OR FALSE?

8. The saliva in your mouth wash away germs.

TRUE OR FALSE?

9. Your skin has pores which are small openings in your body which let germs in.

TRUE OR FALSE?

10. Sweating is not a good defense against germs.

TRUE OR FALSE?

11. When you get a cut white blood cells attack the germs that try to enter the body.

TRUE OR FALSE?

12. When blood flows from minor cuts the white blood cells attack the germs.

TRUE OR FALSE?

13. Red blood cells carry oxygen to heal cuts.

TRUE OR FALSE?