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THE UNIVERSITY OF ALBERTA

THE EFFECTIVENESS OF CAI IN BIOLOGY

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled The Effectiveness of CAI in Biology submitted by Norma Maria Nocente in partial fulfillment of the requirements for the degree of Master of Education.

....
Supervisor

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Jim Parsons ....

Date Jan. 14/88 ....

To my brother Frank

Abstract

The purpose of this study was to compare two media used to deliver self-paced instruction. Achievement scores of students using CAI to review the Biology 20 genetics unit were compared to achievement scores of students using handouts to review the same unit. Concept maps were used as an evaluation instrument. A student questionnaire was used to gather information about student perceptions of the instructional material, student attitude of computers and self-paced instruction, and previous microcomputer experience.

A group of 71 students enrolled in Biology 20 were administered a pre-review concept map test. The students were arbitrarily assigned to one of two groups. One group received the genetics review through CAI. The other group received the review through handouts. Following the instruction, students from both groups completed a multiple choice achievement test, a post-review concept map test, and a student questionnaire.

A two factor repeated measures ANOVA was used to analyze the pre-review and post-review concept map scores. The student questionnaire consisted of 17 Likert-scale items and four open-ended items. The Likert-scale items were analyzed with t-tests and a correlation matrix was generated.

Results from this study indicate that there was no significant difference in achievement between the two groups. Significant differences were found in attitude towards the ability of the computer to teach. Students using CAI had a more positive attitude towards computers and wanted to see more use of CAI in the classroom. Students from both groups showed a strong preference for attributes of self-paced instruction.

It was concluded that CAI is as effective as handouts in delivering a review of a unit. More use of CAI should be implemented into biology classes because it can add variety to classroom learning activities. Reviews at the end of a unit provide an ideal opportunity for the implementation of CAI in the biology class.

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CHAPTER I

THE PROBLEM

1. Introduction

Microcomputers have infiltrated almost every aspect of society. The field of education is no exception. The number of microcomputers in Alberta schools has risen from 256 in 1981 to an estimated 26,955 in 1987 (Petruk,1986). This growth rate is similar to the one experienced in the United States. Becker's (1986) survey indicates that in 1985 there were at least one million microcomputers in schools in the United States. This is four times the number he reported in his 1983 survey. In 1986 there was an average of 15.3 microcomputers per school in Alberta (Petruk, 1986). The statistics are much more impressive if we look only at high schools. Alberta high schools had approximately 68.2 microcomputers per school (Petruk, 1986). Projections for 1987 estimated that there would be 10.3 students per microcomputer (Petruk, 1986). These microcomputers have been put to a variety of uses by both students and school staff.

In the school system, the microcomputer can be used in three general ways. These are as an administrative tool, as an object of instruction, and as a tool of instruction. An example of the administrative role of the microcomputer would be through the use of application programs such as word processors, spreadsheets, and data bases. Word processing claims the highest usage of the microcomputer as an administrative tool (Petruk, 1986). Almost all Alberta schools that have microcomputers in their administrative offices use them primarily for word processing (Petruk, 1986). In addition to this role as an administrative tool, the microcomputer has served a valuable and irreplaceable part in school budgeting, timetabling, and student record keeping (Petruk, 1986). Few would criticize the important role the microcomputer plays as an administrative tool. As well, many students use it to complete assignments in a variety of subject areas.

Computer courses are often referred to as Computer Literacy, Computer Processing or Computing Science. These courses have made the microcomputer the object of instruction. Becker (1986) reported that the amount of time students spend on a microcomputer averages one hour and 45 minutes per week. Approximately 85% of this microcomputer time was devoted to using the microcomputer as an object of instruction (Becker, 1986; Bork, 1984; Carey & Gall, 1986). Computer Literacy and Computer Processing can be considered as the same type of course. In both these courses students usually learn how to use the application programs mentioned earlier. A Computer Literacy or Computer Processing course may emphasize programming in one school while another school may put more emphasis on application programs (Alberta Curriculum Guide; 1984, 1985). Computing Science, for the most part, deals with programming.

Computing courses that dealt mostly with programming were once very popular but, as results from a recent survey in the United States indicate, student enrollment in these courses is beginning to decline (Becker, 1986). This decline is attributed to many reasons. The most significant reason seems to be the lack of knowledge teachers have in this area. Quite often teachers with minimal experience in computer programming are placed in the uncomfortable situation of teaching programming courses. In addition, researchers are questioning the use of the technology in teaching programming.

> Compared with the clearly important goals of developing broad verbal and mathematical fluency among students, including writing and problem-solving skills, and compared with the importance of teaching other culturally valued knowledge, such as that from scientific, historical and literacy domains, how necessary is it that schools spend valuable instructional time teaching students about computers, and specifically, about how to program them in general purpose computer programming languages like BASIC or Pascal? (Becker, 1984, p.24)

The use of microcomputers as an object of instruction in the schools has raised some controversy but this aspect of microcomputer use will not be the focus of this study, nor will the use of the microcomputer as an administrative tool. Instead this research will look at the microcomputer when used as a tool of instruction.

The microcomputer has been used as a tool of instruction for almost 30 years. This use, however, had been restricted mostly to large universities with main frame computers. Advances in microchip technology led to the creation of the affordable microcomputer. Computer Assisted Instruction (CAI), also referred to as Computer Based Instruction (CBI), was generally introduced to the elementary and secondary school system in the late 1970s (Alessi & Trollip, 1985).

CAI is available in several forms. Generally these fall into four categories: tutorial, drill and practice, simulations, and games. Tutorial programs are the most basic form of CAI (Alessi & Trollip, 1985). In its simplest form tutorial CAI presents information followed by several questions. In its highest quality form a tutorial will assess the student's prior knowledge, determine which areas need to be taught, present the necessary information followed by questions, and determine the next sequence of events dependent upon the student's responses. Drill and practice are the most frequently used CAI programs in school. These programs are popular because they can provide endless questions for students to practice on until they reach a predetermined proficiency level. Simulations usually imitate real life situations. Students are allowed to manipulate one or more variables and then observe the outcomes. These programs are used to develop higher levels of thinking. Games are programs that have an instructional component and are entertaining. Usually instructional games are entertaining drill and practice type programs. There is not equivalent CAI development in the four categories. Most of the CAI developed falls into the tutorial or drill and practice category.

2. Statement of the Problem

There have been volumes of studies that indicate the effectiveness of CAI. Yet, very few teachers have taken the opportunity to integrate CAI into their curriculum. Becker's (1985) survey reveals that students spend only 16% of their computer time on CAI. Petruk (personal communication, 1988) estimates an even lower percentage of CAI computer time in Alberta schools. It may seem probable that microcomputers are so heavily utilized as an object of instruction and as an administrative tool that it is not likely for a teacher to get CAI computer time. However, in Petruk's (1986) study respondents from high schools estimated ideal numbers of microcomputers for their schools that were lower than the actual number. Only 4.8% of the teacher population at the high schools responding to the survey made extensive use of the microcomputers (Petruk, 1986). It seems that microcomputers may be underutilized in the high schools, especially if enrollment in computing courses continues to decline.

Even with the availability of microcomputers, high school teachers are reluctant to use CAI in their classes. The use of CAI in science decreases as students go from junior high school to senior high school (Becker, 1986). One reason is the criticism that CAI is of poor quality and not exciting (Bork, 1984; Hofstetter, 1985; Komoski, 1984). However, recent reports indicate that the quality of CAI is improving (Dudley-Marling & Owston, 1987). Bangert-Drowns, Kulik, and Kulik (1985) instead feel the problem is that teachers are not convinced of CAI's effectiveness. Clark (1985) suggests that problems with the experimental design of CAI research has led to this lack of trust in CAI effectiveness.

Critics contend that some important variables are not controlled in the research that is aimed at determining the effectiveness of CAI (Clark, 1985, 1983). Of particular concern to Clark is the number of studies that compare achievement of groups receiving CAI to groups receiving lecture-based instruction or other forms of traditional instruction.

These studies are comparing two different methods of delivery. CAI delivers instruction in a self-paced mode. Lecture-based instruction delivers instruction in a group-paced mode. Carlson Perez and White (1985) suggest that it is quite possible that the gains made in achievement are not due to the computer medium but, rather, to its self-pace nature.

Bork (1986) and Clark (1985) believe that identical content is not being used when one medium of instruction is being compared to another medium of instruction. Bork (1986) expresses this concern by saying: "One issue that I think must be addressed, when one looks at microcomputers in learning, is that of standard of comparison. That is, what other curriculum material, used in what type of environment, is being compared with computer based learning material?"(p. 66). If CAI and other instructional media are to be compared, Clark (1985) suggests only one designer produce both treatments. This single production would provide the greatest control of all but the CAI aspects of the main treatment.

Four other concerns about research in CAI effectiveness became apparent after reviewing the literature. First, recent research has reported results opposite to those of earlier CAI studies (Fox, 1986; and Wainwright, 1985). This discrepancy suggests that the positive effects of CAI may have been partly due to the novelty of the medium. Second, most CAI studies were done in the area of mathematics (Waugh, 1985). More research needs to done in other disciplines to determine the effectiveness of CAI in various subject areas. Third, the instruments used to measure achievement are usually multiple choice tests and there is some question of the ability of these tests to measure how much the student really understands (Kracjik, Simmons, & Lunetta, 1986). Fourth, few studies that compare CAI effectiveness to another method measure student attitudes (Johnston, 1987).

3. Purpose and Research Questions

The purpose of this study was to determine the effectiveness of CAI when used to review the genetics unit of the Biology 20 curriculum. The above concerns were taken into consideration in the design of the study. A CAI program was compared to another method of self-paced instruction such as print-based handout materials. Both instructional media used in this study were designed by the researcher. The first research question was:

1. Would there be a difference in achievement between students using the microcomputer and those using the handouts to review genetics?

Achievement scores were used to answer this question but it was also important to this researcher to determine what student perceptions were towards the instructional material. Peard (1983) suggests that there are "great differences between what the student says he knows and what he can show that he knows" (p. 172). Therefore the second research question was asked to determine student perceptions of the genetics unit and the instructional material.

2. What were the students' perceptions of their understanding of this unit?
   a) Did students feel they understood this material?
   b) Did students feel they understood the relationship between meiosis, Punnett squares, and genetics?
   c) Did students find this material useful?

One of the concerns mentioned was that student attitudes often are not measured in CAI effectiveness studies. Therefore the third research question was:

3. What were the students' attitudes towards the medium used and the delivery method of instruction?

   a) Was there a preference for one of the media?

   b) What were the students' attitudes towards using the microcomputer for instruction?

   c) What were the students' attitudes towards self-paced instruction versus traditional instruction?

4. Definitions of Terms

The following terms are defined to clarify their use in the context of this study:

Computer Assisted Instruction (CAI). Any computer delivered instruction that requires student interaction. CAI falls into four general categories, tutorial, drill and practice, simulations, and instructional games.

Delivery Method. Refers to the way in which instruction is delivered, for example, group-paced or self-paced.

Group-Paced Instruction. Rate of instruction is determined by the instructor and is delivered at the same rate to a group of students.

High Quality Software. Software that effectively provides individualized instruction and/or develops higher cognitive processes.

Higher Cognitive Processes. Refers to the higher levels of Bloom's Taxonomy for the cognitive domain. The higher levels are analysis, synthesis, and evaluation.

Instructional Design. A cyclic and systematic approach to designing instructional materials.

Medium of Instruction. The mechanism used to deliver the instruction, for example, handouts or microcomputer.

Self-Paced Instruction. Any instruction delivered in such a manner that a student may progress at his/her own rate.

Traditional Instruction. A delivery method that controls content, sequence, and pace of instruction.

5. Significance of the Study

This study has taken into consideration some of the experimental design problems apparent in other research. The CAI software which was developed for this study reflects the type of software currently in use in the school system. If it can be established that this type of CAI is at least as effective as other instructional techniques in providing a review and that students appreciate this method, then perhaps biology teachers will consider making more use of the microcomputer as a tool of instruction.

6. Delimitations

The focus of the study was on student achievement, student perceptions of the instructional materials, and attitudes towards the method and medium of instruction. For this reason, no effort was made to measure gender differences, time differences in completion of material, or changes in attitude towards biology. Although these are important aspects, they were beyond the scope of this study.

Only Biology 20 students were used as subjects for this study, even though Biology 30 students would have also been suitable. The Biology 30 students however, were not available. Biology 20 students would benefit directly from the treatment because it would review part of the Biology 20 curriculum.

7. Limitations

The study was restricted to two sixty minute classes. These classes were two days apart from each other. Since only two class periods were used it was not possible to have each group experience both the microcomputer and handout treatment. As a result, differences in achievement and attitude may have resulted because one group felt privileged. The pre-review concept map test and post-review concept map test were both given within a two day period. Therefore, achievement gains made may be due to familiarity with the test (Borg & Gall, 1983).

Gains in achievement may have been limited by the CAI developed for this study. Although the quality of the CAI program is typical of software on the market, there may be higher quality CAI programs in this subject area that could result in higher achievement gains. Another factor that could have affected achievement gains pertain to the fact that these students were not familiar with concept maps. The unfamiliarity with concept maps may lead to an inaccurate assessment of the students' higher cognitive skills. The results of this study are not generalizable to all Alberta high school biology students since the school chosen is not representative of this group.

It was assumed that, since microcomputers have been in Alberta schools for at least eight years, these students would have had some prior exposure to the medium. However, the microcomputer may still be a novelty to many students and this novelty could affect the results. For this reason, an additional question was added to the student questionnaire, asking students about their previous experiences with microcomputers.

8. Summary

Secondary science teachers are not integrating CAI into the curriculum despite the fact that microcomputers and CAI software are available. One reason for this non-use may be that teachers are not convinced of CAI's effectiveness. Many studies indicate CAI is effective. However, these studies are mostly in the mathematics area and failed to control variables such as content and method of delivery. Almost all of these studies use multiple choice tests to measure student achievement. The intent of this study is to control the variables mentioned above and to use concept maps in addition to a multiple choice test as measures of achievement. This procedure is discussed in Chapter 3. This study should help determine if CAI is a viable tool in assisting students to review units in high school biology.

CHAPTER II

REVIEW OF THE LITERATURE

1. Introduction

This chapter is divided into four sections. The first section addresses the unique capabilities of the microcomputer to deliver instruction. The second section reviews the quality of CAI software. The third section examines CAI comparison studies, focusing specifically on results related to instructional effectiveness and attitude. Problems with experimental design are also examined. The fourth section describes the use of concept maps as an evaluation tool.

2. Capabilities of the Microcomputer

There have been many hopes for the potential of CAI and the improvements it could bring to learning outcomes (Linn & Fisher,1984). Many of these hopes are tied to the microcomputer's unique capabilities. The microcomputer has been credited for its ability to provide self-paced instruction, individualized instruction, and immediate feedback (Bangert-Drowns, Kulik, & Kulik, 1985; Bork, 1986; Forman, 1982; Keuper, 1985; Lieberman & Krendl, 1987). The terms self-paced instruction and individualized instruction are sometimes used synonymously; however, in this study a distinction will be made between the two terms. The self-paced method of delivering instruction will refer to instruction in which students are all progressing through the same material but at a different pace. The term individualized instruction refers to a method of delivery that is self-paced but with students each receiving different instruction based on their performance on previously presented material.

Other capabilities associated with the microcomputer are patience and an ability to reassure or encourage the student on a consistent basis (Lieberman & Krendl, 1987). Another advantage of the microcomputer is the capability to store student responses (Alessi & Trollip, 1985). All these capabilities are available provided that a CAI program has been written to take advantage of the microcomputer's information processing ability.

Immediate Feedback

Immediate feedback is an important feature of CAI. It can be broken down into two categories: corrective feedback or attribute isolation feedback (Merrill, 1987). Corrective feedback informs the students of the correctness or incorrectness of their answers. In some cases it provides students with the correct answer if they answered the question incorrectly. Attribute isolation feedback goes one step further. After an incorrect answer, students are provided with variable information depending on the error they made. Bork (1986) feels that attribute isolation feedback is a valuable learning technique because it can provide learning material.

Immediate feedback is also provided to the teacher in regard to student progress by CAI management systems. The capability of the microcomputer to store student responses to disk is a great advantage to the teacher. In some cases all the teacher wants to know is how many correct responses the student has made. However, there is also the capability to isolate the specific area that problems are occurring (Godfrey & Sterling, 1982). Management systems by themselves are capable of saving teachers a great deal of time (Alessi & Trollip, 1985; Hannafin, Dalton, & Hooper, 1987).

Self-Paced Instruction

Most classrooms consist of a fairly heterogeneous group of students. A problem that faces many teachers is trying to meet individual needs in such heterogeneous groups. Self-pacing instruction is one way of accommodating individual learning differences (Belland, Taylor, Canelos, Dwyer, & Baker, 1985). Oxley (1984) says:

> A feature of the computer, which is said to contribute greatly towards high sensitivity (learners requirements), is the facility for self-paced learning. In this respect it differs fundamentally from the classroom situation where the teacher may be going too fast for some students and at the same time too slow for others., (p. 176).

Becker (1985) found that teachers believe microcomputers are effective because students have the opportunity to work independently from adults.

Self-paced instruction, however, is not solely restricted to the microcomputer. Any instructional process that presents students with the objectives they must meet, the content and activities needed to meet those objectives, the test that measures the achievement of those objectives, and that also allows them to move through the material at their own pace can be considered self-paced instruction (Fox, 1986). Such instruction can be accomplished in a variety of forms. Individuals can be given print-based materials, such as study guides, or they can receive their instruction via computer (Fox, 1986).

Walker, Hendrix and Mertens (1980) found that undergraduate biology students who received genetics instruction through sequenced, self-paced, print-based materials scored significantly higher than those receiving the genetics instruction in the traditional manner. These researchers felt that logical sequencing of instructional materials could "effectively facilitate students' abilities to apply Piagetian formal thought patterns to genetic analysis." (p. 108). These findings are supported by meta-analysis research performed by Kulik, Kulik, and Cohen (1979) on 75 studies at the college level, comparing achievement scores of self-paced instruction to achievement scores of traditional instruction. In addition to higher grades, there were also significant improvements in the students' attitudes towards the course. However, none of these gains were found in a meta-analysis of secondary schools (Bangert & Kulik, 1982).

After Keuper (1985) extensively reviewed the literature she stated that five factors made the microcomputer an effective instructional tool. These are as follows: "1) immediate feedback; 2) lack of external variables; 3) the specific directions given to the learner by the computer; 4) the one-to-one teaching relationship; and 5) the success the learner experiences." (p. 51). Of the five factors, only "immediate feedback" is not found in self-paced print-based materials. Study guides occasionally contain self-quizzes with the answers in the back of the study guide. These quizzes provide some immediate, corrective feedback but not in the same capacity as that generated by the microcomputer since students using study guides can simply flip to the answers before even attempting to answer the questions.

Individualized Instruction

Individualized instruction can occur via a variety of forms. Two possible forms include human tutoring and the microcomputer. Individualized instruction is not a new technique but it has become more realistic with the advent of the microcomputer. Icabone and Hannaford (1986) measured achievement in reading by comparing a microcomputer connected to a speech synthesizer, with a human tutor. Students using the microcomputer read a paragraph and underlined terms they did not recognize. The computer would pronounce the term for the student and then present the student with two other similar terms. Each student received different information depending on the words underlined. The second group of students went through the same process except the human tutor provided the same role as the microcomputer. The researchers found no significant differences in performance between the two groups and therefore concluded that students can work independently with a microcomputer for certain classroom activities. Icabone and Hannaford speculated that teachers' time could be used more efficiently if CAI programs were used more often.

Heinze-Fry, Corvello and Novak (1984) suggest the development of individualized instructional CAI in Biology which is capable of determining a student's preconceptions and then presenting content to confront any of the diagnosed misconceptions. One such system has been developed for first-year university physics students. CAI was used in a remedial physics program by both Hewson (1984) and Zietsman and Hewson (1986). The CAI software diagnosed the conceptual problems and then presented remedial material. Both studies found more accurate conceptions and that misconceptions had been successfully modified. This type of CAI is also capable of varying the amount of practice and continuing on to a more challenging area once the student demonstrates proficiency in the task at hand. However, CAI that offers individualized instruction is rarely produced.

When Linn and Fisher (1984) talk of the large gap between the promise and the reality of the instructional uses of the microcomputer, they are referring to the lack of CAI software to provide individualized instruction. The capability of the computer to present individualized instruction makes it truly unique from other forms of instructional delivery (Bork, 1986). Yet the microcomputer is used to deliver self-paced instruction rather than individualized instruction. Reasons for the lack of CAI that offers individualized instruction will be discussed in the next section.

3. Quality of CAI Software

Early reports on CAI criticized it for lack of quality. Becker (1984) asks, "...where is the computer-based instruction that deals with thinking and understanding?" (p. 31). Many researchers (Bork, 1984, 1986; Hannafin, Dalton & Hooper, 1987; Hofstetter, 1985; and Linn & Fisher, 1984) believe that CAI is capable of fostering higher cognitive skills because it offers more interaction, precision, consistency, challenge, complexity, and provision for multiple solutions. Most software however, was mundane, simply a page turner, or offered only drill and practice. Bork (1984) found CAI quality very low and felt that little had gone into the education or design process. In fact, Komoski (1984) found that CAI software developers devote only about 5% of their time to the aspect of educational quality.

Recent reports, however, claim that the quality of CAI software has improved. Dudley-Marling and Owston (1987) found that software had improved since 1980, but that 70% of the software can still be considered poor. According to their estimates, there are over 11,000 educational software packages available. Of these 5% are exemplary; this means that approximately 550 exceptional CAI programs are available. About 25% of the available CAI software meets minimal requirements, thereby providing another 2750 packages for school use.

Even though much of the CAI software has been rated as deficient, Dudley-Marling and Owston (1987) caution that the CAI software has been evaluated by adults and that their views are not necessarily those of the students. Another aspect to consider is that when Dudley-Marling and Owston (1987) reveal that the Alberta Computer Clearinghouse rejects 90% of the CAI software that comes in for evaluation, this rejection does not imply that the rejected software was of poor quality. For example, some of the CAI software packages were rejected because the content was outside the guidelines of Alberta's curriculum (Alberta Education, 1985).

Some useable CAI seems to be available in the software market. An interesting finding from Becker's (1985) survey supports this notion. When Becker (1985) asked teachers in the United States to identify "the most important problems in effectively using the computer in school"(p. 27), software problems were at the bottom of the list. Software problems such as "poor quality and software not yet written for topics for which it is needed" (Becker, 1985, p. 28) were least likely to be named.

Poor instructional software does exist and, unfortunately, is still being purchased by schools (Komoski, 1984). Dudley-Marling and Owston's (1987) research indicated two reasons for this high percentage of poor software. First, CAI is often written by people lacking expertise in either instructional theory or computers. Second, software is rarely field tested with target students for which the material is intended.

Granted, a large portion of CAI software on the market is disappointing, especially when one considers the capabilities of the computer and what should be going on in the classroom. Only a small percentage of the available CAI software offers individualized instruction or develops higher cognitive processes, as opposed to simply reinforcing factual information. Two reasons for this lack of individualized CAI software became apparent after reviewing the literature and these reasons indicate why more of this type of CAI software will not be developed for some time.

The first reason is that the highly interactive, cognitive processing, individualized CAI that is being demanded by teachers is difficult to produce and requires a great deal of time and money to develop. Walker (1984) estimates that anywhere between 100 to 800 hours are needed just to design and program a one hour CAI package. The developmental cost of this one hour program may be anywhere between $2000 and $100,000, depending on the complexity of the program. This type of software is not likely to be developed by one person. Rather it requires a team of experts; one in the subject area, one in instructional design, and one in programming (Hallworth & Brebner, 1980). It is highly unlikely that software publishers will invest a large amount of effort and funding on a piece of software that is not likely to return their investment (Bork, 1984; Walker, 1984). Only educational institutions are interested in the development of software without profit.

A second reason for the delay in developing high quality software, especially individualized CAI, is that the traditional school system itself is not prepared for the higher cognitive instructional capabilities of microcomputers (Becker, 1984). The content, sequence, and pace, are controlled by the teacher. CAI has been developed to teach in this same directed manner. Kozma (1987) says: "Given the uniqueness of the medium, it may be that we have yet to fully exploit our understanding of computers or explore their untapped potential. If we are honest with ourselves, we have to admit that with rare exception what we are doing with computers is in many ways like what we have been doing all along" (p. 21). It seems then that software is developed to meet the traditional approach of teaching. Waldrop (1984) suggests that microcomputers, for the time being, are best suited to teach concepts at the lower levels of Bloom's Taxonomy in a self-paced mode.

A whole new approach to education may create the demand for more high quality CAI. High quality CAI could meet the goal of individualized, open education approaches where the student would be in control of the content, sequence and pace (National Institute of Education, 1984). However, it seems that few teachers are prepared for this new approach.

4. Comparison of CAI to Traditional Instruction

Several extensive reviews of the literature have been written over the past six years (Forman, 1982; Keuper, 1985; Lieberman & Krendl, 1987; and Tolman & Allred, 1984). Each came to similar conclusions. One conclusion is that CAI is more effective than traditional means of instruction. A second conclusion is that students could finish lessons in less time; and a third conclusion is that CAI is more motivating than traditional techniques. A further assessment of CAI effectiveness has been done by using meta-analysis techniques to review similar studies and generate some generalizations of all the data collected. The process used in these meta-analyses involved locating the CAI instructional comparison studies through objective and replicable searches; coding the studies for salient features; using a common scale to describe study outcomes; and applying statistical methods to relate study features to outcomes (Bangert-Drowns, Kulik, & Kulik, 1985). These meta-analysis studies confirm the findings described above.

An analysis of 51 studies by Kulik, Bangert, & Williams (1983) showed that CAI raised secondary school students scores on standardized tests from the 50th percentile to the 63rd percentile. Long term retention studies indicated smaller increases than the short term outcomes but the effect on achievement was still positive. In addition to increases in achievement, subjects were taught in less time and students developed more positive attitudes towards their coursework and the computer. One of the more recent meta-analyses of 42 studies by Bangert-Drowns, Kulik, and Kulik (1985) confirmed that computer based education had positive effects in both junior and senior high school. These results are similar for all levels of education. (Kulik, Kulik, & Cohen, 1980; Kulik, Kulik, & Bangert-Drowns, 1984).

Clark (1985) calculated that meta-analysis studies indicated on the average a fifteen point advantage on a 100-point exam for students using CAI. However, Clark (1983, 1985) feels the results exaggerated the effectiveness of the microcomputer and emphasized that there is a confounding of medium and method of instruction. Clark suggested that

> the claim here is that methods such as the use of examples and matched non-examples, individualized pacing, corrective feedback after response and a close correspondence between instruction and test items tend to be used in the design of CBI lessons but not by teachers in comparison treatments. (p. 250)

The problem of confounding becomes apparent if some early studies in the area of biology are examined.

Biology Studies

CAI instruction is used mostly in mathematics and with participants at all age levels (Gardner, McEwen, & Curry, 1986), usually because mathematics programs are more available than other programs. The next largest category for CAI use is in the sciences (Gardner, McEwen, & Curry, 1986); physics in particular, because of its basis in mathematics. CAI has been put to a number of uses in biology as well, but most of these examples come from post-secondary institutes.

Several studies using CAI in biology have been performed. Bunderson, Olsen, and Baillio (1981) compared interactive videodisc enhanced CAI to lecture-based instruction and found that undergraduate students using CAI program finished 30% faster and had significantly higher scores on the achievement test. Positive results were attributed to the highly visual features of the videodisc and the ability to maintain attention for a longer period of time. The experimental treatment also gave students a more positive view towards science. Self, Self, and Rahaim (1984) found that poor readers in an undergraduate biology course received higher marks using CAI than poor readers taught the same lesson by a teacher. Similar findings were reported by Samuels (1984). These studies used CAI, a novel technique, to deliver self-paced instruction and compared it to group-paced instruction delivered by the traditional lecture technique. Neither the content nor the method of delivery were controlled.

A series of studies were conducted with undergraduate biology students (Leece, 1982; Shaltz, 1982; Soldan, 1982). These researchers were members of the Single-concept User-adaptable Microcomputer-based Instruction Technique (SUMIT) at Michigan Technological University. The SUMIT group developed 20 biology programs for post-secondary institutions but only eight were finally marketed (Spain, 1985). These programs were used in a variety of studies by the developers.

Contrary to the many studies in mathematics that indicate CAI is more effective than lecture, Shaltz (1982) found that there was no difference in achievement between a group that received instruction via lecture mode and a group that received CAI. Leece (1982) and Soldan (1982) confirmed Shaltz's results and, in addition, found that achievement scores from students using CAI were significantly higher than achievement scores from students using print-based materials. Tsai and Pohl (1978) had similar results. They also indicated that there was a significant difference in achievement scores when CAI supplemented traditional methods rather than replaced them. Solden's (1982) results, however, indicated no significant difference occurred in achievement between a group that used traditional methods supplemented by CAI and a group that used only CAI. The quality of instructional materials used for comparison in each of these studies varied and may have led to the contradictory results.

An analysis of one of the SUMIT studies in more detail suggests that variables such as content and novelty were not controlled. Leece (1982) compared CAI to worksheets and found that the CAI group retained more knowledge. The actual textual content of these two mediums was identical but the CAI program contained many more visuals and animation sequences. Clark (1985) suggests that much more effort is placed in the development of CAI than in the development of traditional materials. At the time of the study, the computer was a novelty for the undergraduates. Such novelty may also have affected the results. Clark (1983) indicates that gains in achievement diminish as students have become more familiar with the microcomputer.

One group that has closely monitored the use of CAI is from the Open University of the United Kingdom. Hodgson and Murphy (1984) used biology CAI developed at the Open University and conducted a study with their students that involved the use of a simulation program called EVOLVE. As a part of their course, biology students were expected to independently complete a biology project. Students had four choices for a topic. Those that chose the evolution topic were to use the simulation program EVOLVE to generate data and then apply their interpretations. Students that chose one of the other three projects conducted the actual experimental or field work. Data for this research study was collected over a three year period. Results from the four projects were compared. No significant differences in grades for the various projects were found. Researchers also found that the quality of work for the EVOLVE project was higher than they expected. Although the simulation was compared to another self-paced means of instruction, the content of the each project being compared was different.

In an attempt to control for pre-treatment differences, Ybarrondo (1984) prepared an instructional unit on population genetics and delivered it to a group of high school biology students. This group of students was divided into a control group and an experimental group. The experimental group received a CAI simulation package and an additional CAI tutorial, while the control group received the traditional lab, bean-counting, for this unit. The CAI and lab approaches were used to provide review and remediation on the 15 day instructional unit. No significant differences in achievement were found but the experimental group showed interest in the CAI and wanted more CAI lessons in the future. The activities of the control group in the traditional bean counting lab were not well described. It seems that the experimental group received more instruction and that this instruction was probably more interesting than a bean counting lab.

Other Studies

Some studies appear to have controlled variables other than the treatment, but additional problems become apparent. Carrier, Post, and Heck (1984) compared worksheets to CAI in three areas of grade four arithmetic. Their study involved 144 students. Students using the microcomputer demonstrated either the same or higher retention in the various areas taught. This large sample meant that the students each had a different teacher presenting the introduction to the content material. Clark (1986) points out that when different teachers present the material greater effects occur than if the same teacher presented the material.

Wainwright (1985) divided four high school chemistry classes, each taught by the same teacher, into two groups. The experimental group used a CAI package on writing/naming chemical formulas and balancing equations. The control group used worksheets that were developed from the CAI packages. The worksheet group scored significantly higher than the CAI group in a posttest. Clark (1985) suggests that in some studies the CAI treatment is consciously or unconsciously reduced by the teacher so that a lower result will be obtained by one group. Clark believes the reduction of the CAI treatment is partly due to the threat felt by teachers that the computer will replace them. Kracjik, Simmons and Lunetta (1986) believe this treatment reduction was the case in the Wainwright study. These researchers point out that although the content was identical in Wainwright's study, the worksheet group received extra tutoring from their teacher. In addition, they suggest that Wainwright did not use high quality software. Carrier, Post, and Heck (1984), and Hale (1986) defend the use of this type of software in a study by pointing out that such software is typical of what teachers are using and, therefore, is more generalizable to common classroom situations.

Several studies have successfully controlled content and method of instruction and have used the same teacher for pre-treatment instruction. Harper and Ewing (1986) compared reading comprehension scores between workbook and CAI with learning disabled and mild mentally handicapped children. They found no significant differences in achievement but found students had a strong preference to use the computer. The weakness of this study was that it had only nine subjects.

Spraggins and Rowsey (1986) found that simulation game CAI can be effective in teaching factual material. High school biology students were used to compare simulation game CAI with worksheets containing identical questions but without the entertainment factor of the simulation game. The CAI game, as a review, was as effective in promoting achievement as the worksheets. Achievement was measured using multiple choice tests.

Clark believes that studies controlling all non-medium variables need not even be conducted since achievement learning changes attributable to the medium will not occur. Some of the studies described in this section have indicated that even though there is no significant difference in achievement some changes in attitudes have occurred. Clark is ignoring the effect such a medium may have on motivation and attitude.

Motivation and Attitudes

Johnston (1987) found that few studies measure student attitudes on the use of microcomputers in the curriculum. Johnston suggests that "pupil attitudes are of crucial importance to the success or failure of educational approaches and media, for negative reactions will inhibit learning whereas positive ones will make pupils more receptive to the learning activities." (p.47). Her survey and interviews with secondary school English students revealed that they believed CAI to be effective, but impersonal. They also stated that CAI could not replace the teacher. As a group, these students felt more in control of their learning with the microcomputer. These students were more concerned with the sound pedagogy of CAI than its technical aspects. McEwing and Roth (1985) verify this last point. These researchers suggest that CAI motivates only if it has sound educational objectives.

Knight and Dunkleberger (1977) found that grade nine science students using self-paced CAI developed a much more positive attitude towards science than their teacher-taught counterparts. Butcher and Murphy (1983) used two biology CAI tutorial programs to collect data on student attitudes towards the medium. Reactions to the tutorials were mostly favourable. In fact, these students found such tutorials helpful and wanted to see more of them in their biology courses.

Carlson Perez and White (1985) investigated differences in motivation between students using the microcomputer and those involved in two other class activities. The class activities involved having the students individually respond to tape recorded math problems followed by the introduction of a new concept to the group by the teacher. The second class activity involved having the students work in pairs on paper math drill and practice questions and then listen to a teacher explanation of a new concept. Each student participated in two of the three activities. Students responding to the questionnaire stated that the microcomputer was more motivating because of characteristics such as graphics and animation. The researchers concluded that "a computer learning environment introduces and increases usage of varied and motivational factors which have the potential to improve learning as well as academic interest." (p. 42). Even though students were more motivated, they did not feel there was any difference in what they learned through each of the teaching methods. One of the limitations stated by the researchers of this study was that the study did not control for the self-paced attribute of the CAI and that the motivational quality of self-paced instruction may have accounted for the results obtained. This limitation has been recognized by other researchers (Kulik, Bangert, & Williams,1983; Keuper,1985) who suggested that motivational factors could be due to the self-paced mode of instruction.

5. Evaluation and Concept Maps

Frequently the techniques used to evaluate achievement in CAI studies receive little attention. Bangert-Drowns, Kulik and Kulik (1985) found that most instructional outcomes were measured through achievement tests, locally developed tests, or standardized multiple choice tests. Kracjik, Simmons and Lunetta (1986) question whether such tests can "discriminate among the important learning outcomes that did occur." (p. 468). They suggest that more appropriate tools should be used for assessing learning outcomes. Oxley (1984) successfully used CAI to teach structured analysis; but, in his conclusion he suggested that a variety of tests should be used to measure understanding and not just application of the content.

Multiple choice tests are not always capable of revealing student understandings or misconceptions because these tests tend to assess the student's factual knowledge (Novak, 1981). There are a number of techniques used to find out what the student actually knows. Short answer questions, interviews, and concept maps are among a few of these techniques (Novak, 1981; and Peard, 1983). Each of these techniques, however, is usually more time consuming to mark than multiple choice tests but provide valuable information that normally is not attained.

Concept maps have been used as research, learning, and teaching tools since they were developed by Novak and colleagues in the mid-seventies (Peard, 1983). Novak (1981) describes concept mapping as:

> a process that involves the identification of concepts in a body of study materials and the organisation of those concepts into a hierarchical arrangement from the most inclusive concept to the least general, most specific concept. (p. 13)

In addition, the hierarchically arranged concepts form a two-dimensional framework that has lines running vertically or horizontally (crosslinks) connecting concepts. These lines contain linking words to form propositional phases (see Figure 1). A system for evaluating these maps was developed by Novak and staff (Peard, 1983). An example can be seen in Appendix A.

A number of researchers have used concept maps (Cleare, 1983; Feldsine, 1983; Malone and Dekkers, 1984; Martin, 1983; Novak, 1983; Peard, 1983). Novak (1983) reported on the many uses of concept maps at Cornell University. He and his colleagues have used concept maps to analyze interview data and have implemented concept maps as an instructional technique. As an instructional tool, concept maps can be used to show students conceptual relationships. Novak reports several studies in which students who were exposed to concept maps in their classes were better able to integrate concepts than those who only received traditional instruction. Novak suggests that used as an instructional tool, concept maps can help some students "learn to learn" (p. 125).

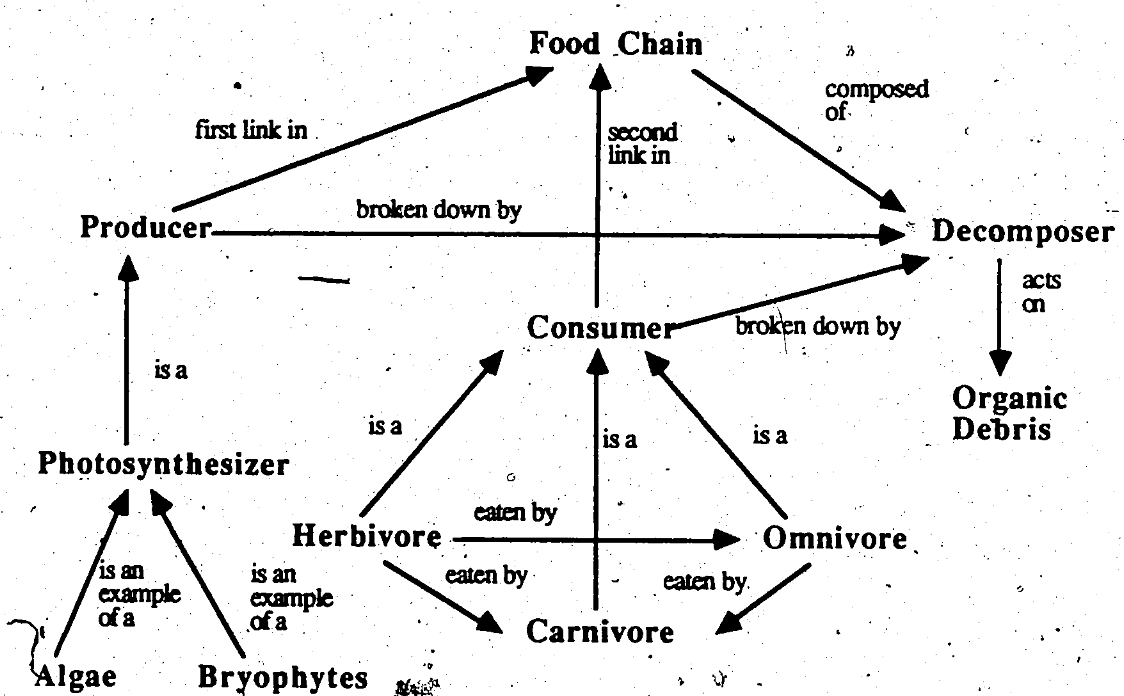


Figure 1. Example of a Food Chain Concept Map

Feldsine's (1983) research also demonstrated the effectiveness of concept maps as both an instructional and evaluative tool. He used concept maps to teach an undergraduate chemistry course. Students were asked to draw concept maps regularly throughout the term as part of their assignments. The maps grew in complexity as the semester progressed. Towards the end of the course the students were expected to draw a concept map on a general concept that was related to the more specific concepts taken in the course. Feldsine found that the concept maps helped isolate misconceptions that normally would be undetected through the usual testing procedure. Once the misconceptions were isolated students were able to reason a new understanding of the concepts.

Some researchers (Malone & Dekkers, 1984; Stewart, Van Kirk & Rowell, 1979) suggest using concept maps as an evaluative tool. Cleare (1983) used concept maps with pre-service elementary science method students to determine which teaching activities improved the students' understanding of science concepts. She found that concept maps were a valid measurement tool in pretest/posttest studies. Peard (1983) used concept maps as one of the analytical tools to assess first-year university students' understanding of genetic concepts. Martin (1983) demonstrated the use of a concept map question on a final external exam. Two different examiners awarded marks within a very narrow range of each other for the question. Stewart, Van Kirk and Rowell (1979) believe that concept maps can be used in biology as evaluative tools. In this capacity concept maps can be used to assign grades; but, more importantly in evaluation, they can be used to determine the student's "knowledge or gaps of knowledge" (Stewart, Van Kirk & Rowell, 1979, p. 175).

6. Summary

This review focused on four areas: the capabilities of the microcomputer, the quality of software, CAI comparison studies, and concept maps. The ability to offer self-paced instruction and immediate feedback were identified as unique features of the microcomputer. The quality of microcomputer software is improving but two factors prevent the mass production of software that can develop higher cognitive processes. First, there is the high cost of development in terms of financial and human resources. Second, individualized instruction and instruction of higher cognitive processes do not play a major role in the traditional school system. CAI comparison studies are confounded by the lack of controlling such variables as content and method of delivering instruction. In addition, only a few studies compared the use of CAI in biology. Most of these biology studies were at the post-secondary level. Few studies which compared achievement through CAI with other instructional media assessed student attitudes. Finally, this chapter discussed the use of concept maps as an evaluation tool to measure student understanding.

CHAPTER III

METHODS

1. Design

The study was modelled after Campbell and Stanley's (1966) pretest-posttest control group design (see Table 1). Subjects were volunteered by their teacher. After drawing their pre-review concept map the students were divided into two groups. One group used the microcomputer and the other group used handouts to review a part of the Biology 20 genetics unit. The independent variable was the microcomputer delivery of the genetics unit. The dependent variable was the post-concept map scores. A short multiple choice test and a student questionnaire were also administered for the purpose of gathering additional information.

2. Subjects

An urban high school located in a middle to upper middle class neighborhood in Edmonton, Alberta was selected for this study. Four Biology 20 (grade 11) classes taught by the same teacher yielded 71 participants. This small sample was used because of the importance of having a group of students that received instruction on the genetics unit from the same teacher. All students were in Grade 11. The students were volunteered by their teacher who felt that the genetics review would be beneficial since they had completed their genetics unit two months prior to this study and were preparing for the final examination.

Table 1

Pretest-Posttest Design of this Study

First Meeting	In-Between Meetings		Second Meeting			
				Post-Review Instruments		
Pretest: 85 students draw genetics concept map	Students placed into one of two groups: micro-computer or handouts	Micro-computer Group N = 42	Microcomputer program used to review Biology 20 Genetics unit. N = 36*	Redraw concept map	Write 10 item multiple choice test	Answer student question -naire
		Hand-outs Group N = 43	Handouts used to review Biology 20 Genetics unit. N = 35*	Redraw concept map	Write 10 item multiple choice test	Answer student question -naire

*Note: 14 students did not complete the second part of the study.

3. Materials

Instructional Materials

Hardware

For this study, a CAI program was developed for the Macintosh Plus computer. Hofstetter (1985) believes that students shouldn't have to take their eyes off the screen because this tends to disrupt concentration. He suggests the use of touch screens or a mouse. The mouse is an easy to use input device and comes as part of the Macintosh hardware. Hofstetter further indicates that the "Macintosh will have significant impact upon the design of educational materials. Icons, windows, pull-down menus, clicking and dragging will become part of the CBI designer's everyday vocabulary." (p. 5). These Macintosh features were implemented into the CAI program developed for this study. The school provided the use of a sufficient number of Macintosh Plus microcomputers so that each student in Group I had access to a microcomputer.

Genetics Lesson - CAI Program

The computer program was first developed and evaluated as a part of a university course in instructional design. The instructional design cycle described by Kearsley (1977) was implemented in the development of this program. Kearsley outlines several steps in the instructional design cycle. They are as follows: a needs assessment, definition of instructional objectives, preparation of instruction, evaluation of instruction, and implementation. Definition of the instructional objectives requires a task analysis (the "what" dimension of instruction) and a learner analysis (the "who" dimension of instruction). The preparation of instruction requires a learner analysis and a means analysis (the "how" dimension of instruction). A description of how these steps were applied to the development of this program is given below.

Needs assessment.

Genetics is an area that gives Biology 20 students a great deal of difficulty. From my own teaching experience I have observed that the genetics unit leaves a large number of students completely confused while others seem to have mastered the unit. Other biology teachers have reported the same problem (Allen & Moll, 1986; Radford & Bird-Stewart, 1982; Tolman, 1982). Alleviation of this confusion was identified by this researcher as the educational need. The goal of the instructional material to be developed was to focus on possible problem areas while reviewing the genetics unit. In order to define the specific instructional objectives that would meet this goal, a task analysis was performed, keeping in mind that this was instructional material for Biology 20 students.

Definition of instructional objectives.

In the task analysis, determining what specifically should be taught required some consideration as to why the current teaching of genetics is not as successful as biology teachers would like it to be. This difficulty of understanding genetic concepts has prompted a great deal of research by biology educators. The research has indicated several reasons for these difficulties or misconceptions. They are as follows:

1) The terminology used is confusing (Barrass, 1984; Cho, Kahle, & Nordland, 1985; Longden, 1982; Thomson & Stewart, 1985). For example, no clear distinction is made in texts between allele and gene or between how dominant and recessive are related to homozygous and heterozygous.
2) There is a failure by texts and curriculum to relate the meiosis unit to the genetics unit. Students do not understand that meiosis is related to the development of Punnett squares (Cho, Kahle, & Nordland, 1985; Thomson & Stewart, 1985; Tolman, 1982). Students fail to recognize the connection between these topics and treat them as separate entities. The learning of one topic, however, is highly dependent upon the other.
3) The mathematical aspect of this topic causes some difficulties. Students frequently have difficulties dealing with ratios and probabilities (Radford & Bird-Stewart, 1982).
4) The frequent use of Punnett squares and their associated probabilities leads to rote learning (Hackling & Treagust, 1984; Kinnear, 1983). Kinnear believes that misconceptions of genetic traits develop because students are forced to memorize rather than integrate the new knowledge into an existing conceptual framework. The students' responses indicate that the appearance of a trait is deterministic rather than probabilistic.

Identification of the above possible reasons for the difficulties and misconceptions in genetics lead to the definition of the instructional objectives.

Based on the task analysis and needs assessment the following objectives were written for a two part CAI lesson - meiosis and monohybrid crosses. The objectives were then used as the basis for the development of test items to determine achievement. For meiosis the objectives and test items were:

The student will:

1. identify the various stages of meiosis.
   (Meiosis test questions 6, 9 and 10)
2. outline the purpose of meiosis.
   (Meiosis test questions 1 and 2)
3. distinguish between a haploid cell and diploid cell.
   (Meiosis test questions 5, 6 and 10)
4. distinguish between a gamete and a zygote.
   (Meiosis test question 4)
5. determine the chromosome number of the resulting haploid cell given the chromosome number of the diploid cell and vice versa.
   (Meiosis test questions 3 and 6)
6. distinguish between a chromatid and a chromosome.
   (Meiosis test question 7)
7. distinguish between a gene and a chromosome.
   (Meiosis test question 8)

For monohybrid crosses the objectives and test items were:

The student will:

1. define the following terms: gene, allele, monohybrid cross, Punnett square, dominant, recessive, homozygous, heterozygous, genotype, and phenotype.
   (Monohybrid crosses test questions 1-10)

2. distinguish between:

   a) an allele and a gene.

      (Monohybrid crosses test questions 1 and 2)

   b) homozygous and heterozygous.

      (Monohybrid crosses test questions 2 and 6)

   c) recessive and dominant.

      (Monohybrid crosses test questions 1, 3, and 9)

   d) genotype and phenotype.

      (Monohybrid crosses test questions 3, 6, and 8)

3. given the parent's genetic make-up, determine the probability of the appearance of a particular characteristic in their offspring.

   (Monohybrid crosses test questions 7, 8, 9, and 10)

4. identify the relationship between meiosis, Punnett squares and genetics.

   (Monohybrid crosses test questions 4, 7, 8, 9, and 10)

Preparation of instruction.

With the objectives identified, the next step was to examine in more detail the learner characteristics and perform a means analysis. In the means analysis the objectives to be taught are analyzed and a decision is made on which process or procedures will be used to meet these objectives. The instructional material in this study was designed for Biology 20 students who were between 15 and 16 years old. The material was written at a grade nine reading level. The material was prepared on the assumption that the learners had prior instruction in genetics. One of the purposes of this CAI program was to provide a review so the amount of time spent on each concept was minimal because the students were already familiar with the material. Since learners have a wide range of abilities, especially in the genetics unit, a self-paced instructional package would best meet their needs. Both handout and microcomputer reviews are self-paced but the microcomputer can provide immediate feedback.

Another consideration in the means analysis is organizing the presentation of content so that instruction will meet the desired learning outcome. The concepts presented in the CAI program used in this study are of complex inter-relationships. Therefore as a means of effective delivery many graphical representations were used in relation to specific objectives.

Graphics are used as a remedial measure because images help to present information in a more meaningful way as well as convey particular meanings to students (Kearsley, 1977; and MacLachlan, 1986), and focus attention and increase motivation (Grover, 1986; Kearsley, 1977). To help achieve this graphical representation, videodisc was initially used to give students actual micrograph pictures of the various stages in meiosis.

With the "what," "who," and "how" identified, an appropriate sequence of instruction was planned. The goal of the instructional material was to offer a review of the genetic concepts and to focus mainly on the four specific problems stated earlier. One of the identified problems is the separate treatment of the two units, genetics and meiosis, by texts and curriculum (Cho, Kahle, & Nordland, 1985; Thomson & Stewart, 1985; Tolman, 1982). Salisbury (1984) suggests that similar concepts be presented in close proximity and that relationships or differences be emphasized. Since many students do not recognize the relationship between meiosis and genetics, the instructional material developed had to present the two concepts together, in one sitting, and then show the relationship between the two.

The CAI program started with a brief review of meiosis that paid specific attention to aspects that would be used in the monohybrid crosses section. The meiosis review was followed by an introduction to genetic concepts and principles. In this section the material was presented graphically, showing cell division with a focus on the chromosomes carrying specified genes. The male and female gametes were lined up horizontally and vertically on the screen respectively, forming a matrix (see Figure 2). This matrix was then simplified into a Punnett square. This matrix was used to demonstrate the inter-relationships among meiosis, Punnett squares and genetics.

The instructional material was designed within a linear model rather than allowing sequence control. Students had to follow the designated sequence but were given the option to bypass information if they felt it was too easy. In the meiosis lesson students could go directly to a short ten-item multiple choice self-test and then to the monohybrid crosses lesson. The option of going directly to the test was offered in the monohybrid crosses lesson as well. Gray (1987) found that, when undergraduate students were required to control the sequence of CAI, they developed a negative attitude towards that specific CAI exercise. In a study with low achievers, Goetzfried and Hannafin (1985) revealed that linear control of CAI resulted in more efficient learning. Although students in this study were not low achievers, most, based on the pre-review concept maps, seemed to be having difficulties understanding genetic concepts. In such situations, students need more direction to determine an appropriate sequence of instruction (Allen & Merrill, 1985; Belland, Taylor, Canelos, Dwyer, & Baker, 1985; Duchastel, 1986; Goetzfried & Hannafin, 1985; Vockell & Rivers, 1984).

A script was written for the program and then a flowchart for the CAI program was developed. Subsequently, two different types of screen displays were designed according to recommendations made by Alessi and Trollip (1985). Screen displays that presented content consisted of three windows (see Figure 2). The top window displayed the lesson title and page number. The main window presented concepts. The bottom window indicated the student's choices and was activated to accept their responses when they used the mouse to click on their choices.

The second screen display was designed for the presentation of embedded questions or test questions. The top window displayed the lesson title or test title and the question number. The main window presented the questions with directions at the bottom. The third window was located to the left of the alternatives. Students had to use the mouse to click on the letter of their choice (see Figure 3).

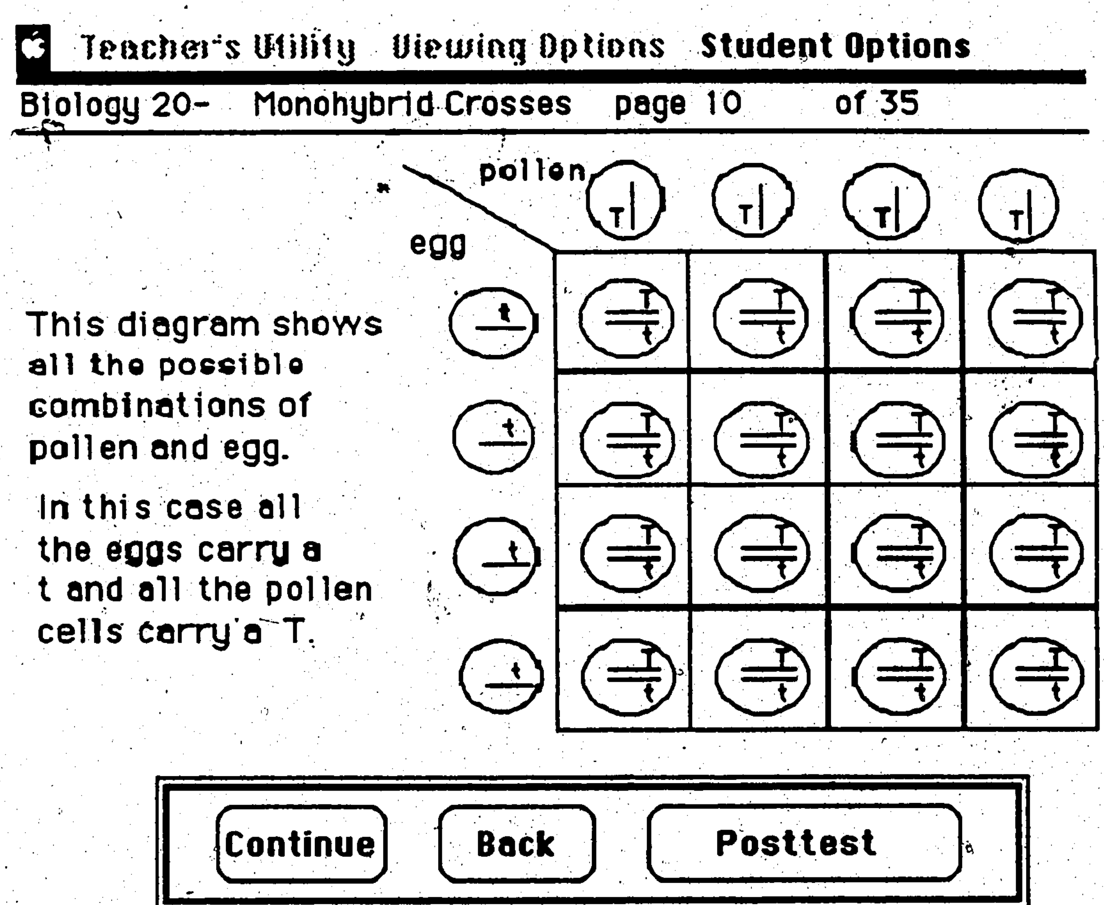


Figure 2. Sample of Screen Display Showing Gamete Matrix

The CAI lessons were coded in Microsoft BASIC (decimal version) on the Macintosh microcomputer with the assistance of several individuals. Structured BASIC programming techniques were used. Each screen was entered as a subroutine. This CAI program allowed for back paging in the program in which the user can move backwards to review earlier screens. Back paging is an important feature that is not always found in CAI materials. Carrier and Sales (1987) found in their discussions with teachers that students become annoyed when they can not review earlier screens.

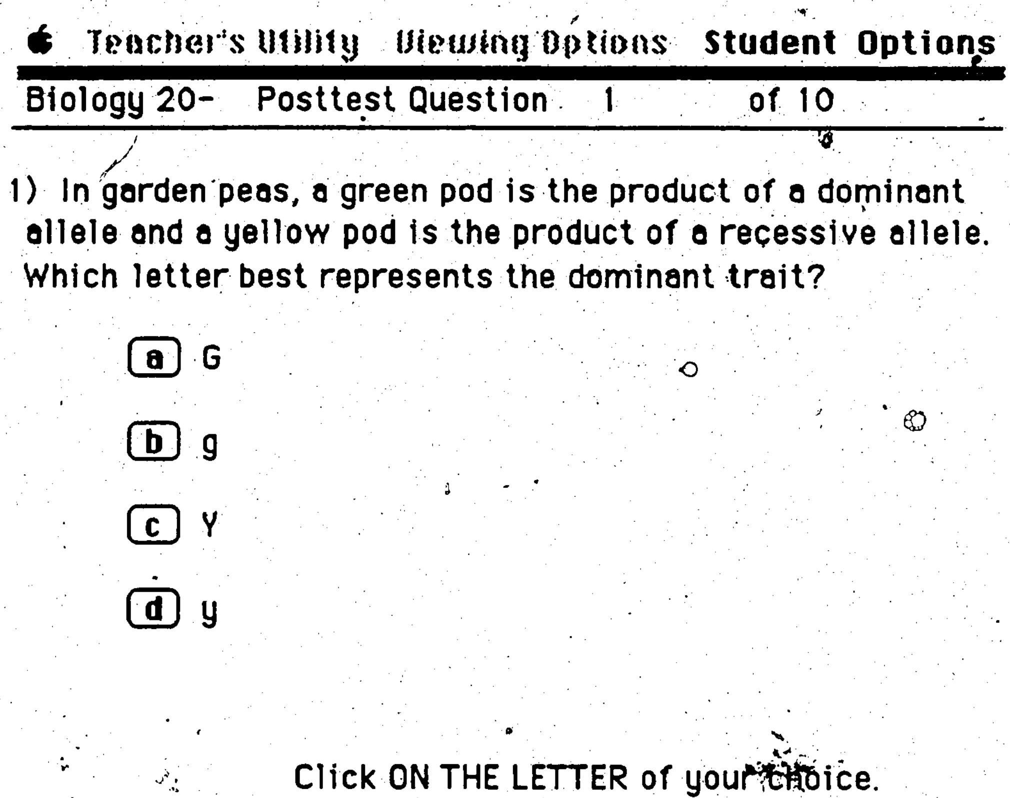


Figure 3. Sample of a Screen Display for a Test Question

Several other features were incorporated into the program that are not typical of most CAI programs. As mentioned earlier, students could bypass the instructional material and go directly to the testing section. The students were also given the opportunity to answer test questions and then go back to these questions to either review or revise their choices (see Figure 4). The asterisk indicated the student's answer. In fact, the students could continue changing their answers until they were ready to have their answers evaluated. Once the decision to have their answers evaluated was made, no further revision could be made. This feature was incorporated because one of the problems with CAI tests is that, typically, they cannot be written like a paper and pen test. Good tests should not give away answers to a question; but, at times key words can jog students' memories and they may want to go back to change an answer. Therefore the test on this CAI program has the advantages of a paper and pen test and the advantages of CAI. It was instantly marked and gave immediate feedback. The immediate feedback presented students with their percentage and showed them which questions they got wrong with an asterisk beside their choice and two asterisks beside the correct answer (see Figure 5).

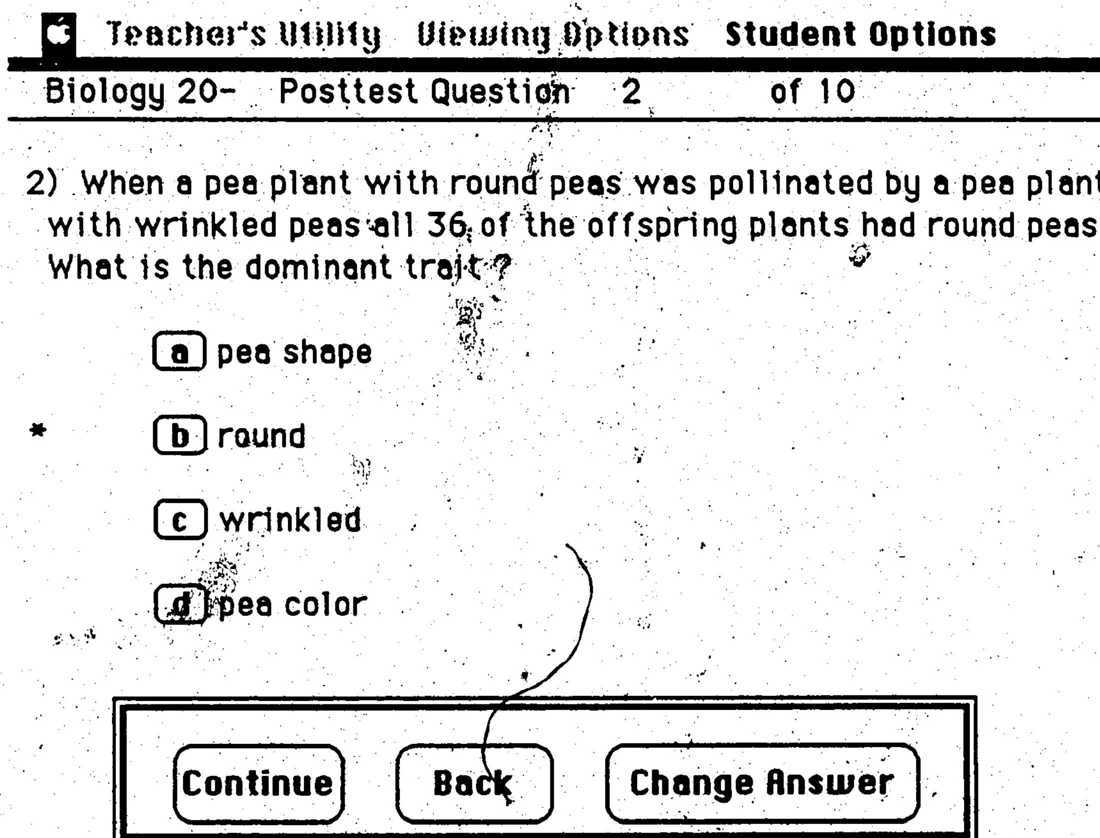


Figure 4. Sample of Options Available After Student has Selected an Answer

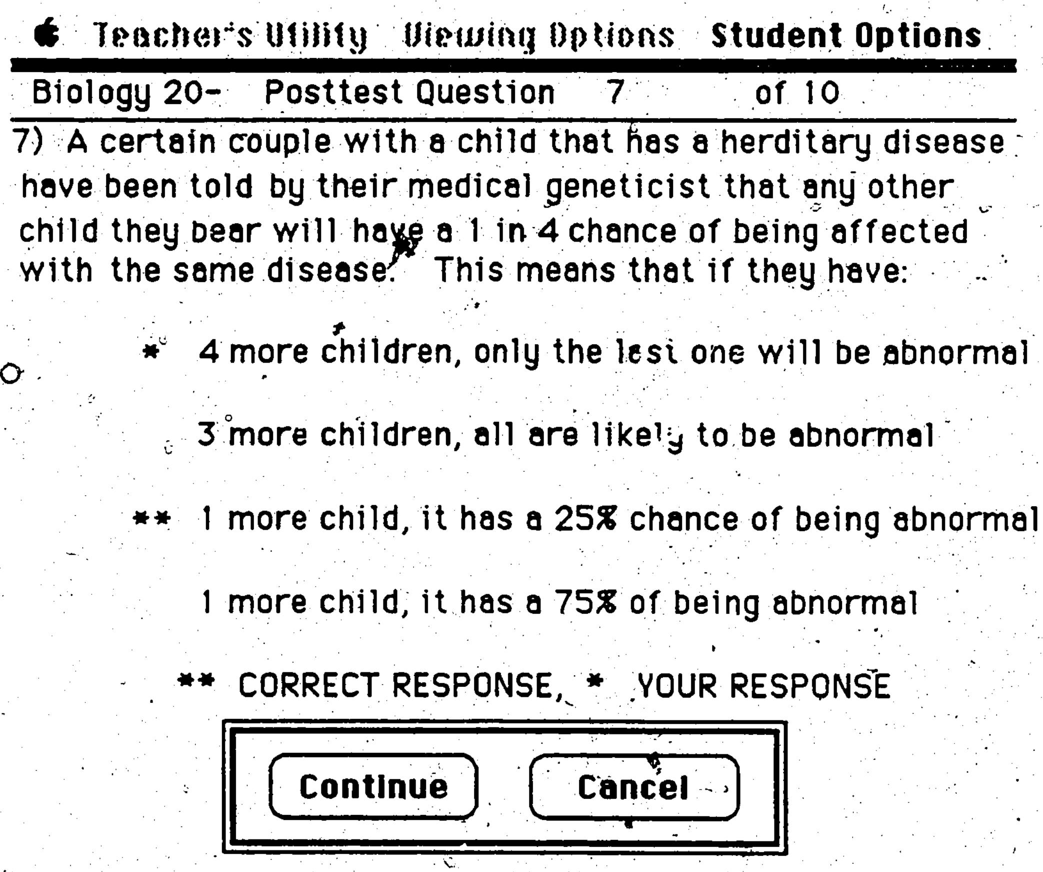


Figure 5. Sample of Corrective Feedback Screen Display

Evaluation and implementation of instruction.

Three approaches were used to evaluate the CAI program. The content and instructional sequence was reviewed by three biology teachers and confirmed as being correct. The CAI program was tested for logical flow and bugs by three graduate students from the faculty of education and then pilot tested with five Biology 20 students from a city high school. The comments and criticisms made by the participants were noted and used to make revisions to the program. For example, one unforeseen problem was the students' responses to the Punnett square question. Initially the computer played a short sequence of the Twilight Zone tune if the student got three wrong responses in a row. Some students deliberately input wrong responses to hear the music. This unexpected motivator was removed. Instead a short tune was played for positive reinforcement when the correct answer was received. Other modifications led to the replacement of one test item and in the rewording of several other test items.

The CAI program was tested a second time with three students from another high school and comments and criticisms were noted. Several more revisions were made to the CAI program after this evaluation. These subjects were a little more familiar with computers and they became more impatient with the loading of graphics into memory. To remedy this, the CAI program was compiled and then copied from two 400K disks to one 800K disk. The CAI program took only about thirty minutes, but these students were bored with the limited interaction. To remedy this problem, more embedded questions were incorporated.

In a third trial with five Biology 20 students, more interaction had been incorporated into the program with questions that provided feedback. Attribute isolation feedback, as suggested by Merrill (1987), was developed for each of these questions. Appropriate feedback was given based on the student's response. For example, one embedded question asked students to identify the heterozygote from the following list: Yr, Yy, YY, Y. If students picked Yr, a message would appear saying "Although Y and r are different alleles they are not for the same gene. Try again." If students chose YY the message would be "Both alleles are identical here therefore this is an example of a homozygote." If students chose Y the message was "Remember that TWO alleles are required for a genotype." These responses were based on common mistakes that this researcher's students had made in the past.

In the evaluation of the instructional material test results from the ten item multiple choice exam indicated that the CAI program was successful. A mastery level set at 80% was attained by the students participating in the three trials. Casual interviews with the students afterwards also indicated that they felt they had learned something from the program. The CAI program was considered to be successful in accomplishing its goal.

The videodisc section was deleted because only one student at a time could be tested. In order to facilitate large group testing, diagrams were drawn on the microcomputer and incorporated into the program to replace the videodisc frames. The replacement of videodisc frames with computer graphics did not affect the content of the CAI program in any way. Another reason for eliminating the videodisc section was that it was too much of a novelty for these high school students and this may have influenced the results.

Genetics Lesson-Handouts

The handouts (see Appendix B) were developed by converting the BASIC code into an ASCII file and then transferring it over to a word processing program. All basic commands were deleted leaving only the textual content material. Each diagram was screen dumped onto disk and then incorporated into the word processed document. The handouts were then identical to the CAI program in content and method of delivery. The only significant difference between the two mediums was the feedback. The attribute isolation feedback from the embedded questions and the corrective feedback in the monohybrid crosses test were not available to the group using the handouts.

Instruments

Test Questions

The test items were all based on the objectives stated earlier for the monohybrid crosses lesson. Test items (see Appendix C) were written after the objectives had been determined. These questions tended to overlap, requiring students to sometimes meet several objectives in order to answer one question. Discussion of the development of these test items follows below.

This instrument measured the success of the students to achieve the specific objectives. In total there were 20 multiple choice test items, 10 for the meiosis self-test and 10 for monohybrid crosses test. Each item had four alternative answers. The content of the questions and the alternatives were based on my experience as a Biology 20 teacher in Alberta. Test items ranged in difficulty from simple memory tasks to more difficult problem-solving tasks. These items were evaluated for content validity by four biology teachers. Minor rewording revisions were made before the items were tested with the thirteen Biology 20 students who volunteered to pilot the CAI program. Student comments and test results led to the replacement of one question in the meiosis lesson and several other rewordings. To determine the monohybrid crosses test's reliability, an item analysis was performed on the test questions after the results from the 71 students were obtained. The Kuder-Richardson Formula No. 20 Reliability was 0.77. The Corrected Point Biserial Correlation was greater than .22 for each item. Only the results from the monohybrid crosses lesson were analyzed for this study because these results were to be compared to the concept map scores.

Concept Map

A concept map gives a visual representation of cognitive structures and provide valuable information about student understanding of concepts (Novak 1983). The concept map test used in this study was adapted from a study done by Peard (1983). Some concepts were removed because they were not required to meet the stated instructional objectives for the CAI program used in this study. Peard's instrument measured the level of understanding a student has of selected genetic concepts and an understanding of the relationships between concepts.

Concept maps have been used by other researchers and found to be valid tool for assessing students' understanding (Cleare, 1983; Feldsine, 1983; Martin, 1983; Novak, 1983). As well, Peard (1983) compared the concept map technique to other means of measuring student understanding and found it to be an effective assessment tool that is easier to mark and provides valuable information about possible misconceptions. Peard's (1983) marking scheme was slightly modified for this study (see Appendix A) and served as the key for evaluating the students' concept maps. Three biology students were given the concept map assignment before it was administered to the participants of the study so that a time estimate could be made.

Student Questionnaire

A student questionnaire (see Appendix D) consisting of 17 five-point Likert-scale items, ranging from strongly agree to strongly disagree, and four open-ended items was developed by the author to assess student perceptions of the content material, to assess student attitudes towards the medium of instruction and the delivery method of instruction, and to assess how much computer experience the participants had. Seven Likert-scale items were taken from a survey developed by Richards (1983). The remaining 10 Likert-scale items and the open-ended items were developed using guidelines outlined by Abdel-Gaid, Trueblood, and Shrigley (1986). The questionnaire was piloted on five graduate students from the Faculty of Education. Their comments on the items were used to make the appropriate revisions and remove ambiguity in the items.

The randomly sequenced questionnaire items pertained to the research questions. It was felt that determining students' perceptions of their knowledge of the genetics material would provide valuable information that could generally be related to the concept maps. Therefore the questionnaire items for the second research question are as follows:

2. What were the students' perceptions of their understanding of this unit?

a) Did students feel they understood this material?

Item 4 I understood this material before the review.

Item 8 I need more time than my classmates to understand genetics.

Item 11 I find genetics to be a difficult subject.

b) Did students feel they understood the relationship between meiosis, Punnett squares, and genetics?

Item 10 Understanding the process of meiosis is important when learning about genetics.

Item 13 There is a relationship between meiosis and genetics.

Item 17 There is a relationship between meiosis and Punnett Squares.

Open-Ended Item 3 Do you feel this program pinpointed any difficulties in genetics of which you were unaware? (Yes or No)____ If you answer Yes, be specific in describing these difficulties.

c) Did students find this material useful?

Item 2 This program helped to clarify some of the concepts in genetics that confused me.

Item 14 This material was easy to understand.

Open-Ended Item 2 In what way or ways, if any, did you feel this program helped you learn genetics?

The third research question dealt with student attitudes towards the medium used for delivery and the method of delivery. The questionnaire items associated with this research question are as follows:

3. What were the students' attitudes towards the medium used and the delivery method of instruction?

a) Was there a preference for one of the media?

<u>Item 9</u> I would prefer doing this type of review on the computer.

<u>Item 16</u> I would prefer doing this type of review from a set of handouts.

b) What were students' attitudes towards using the microcomputer for instruction?

<u>Item 3</u> Teachers can not be replaced by machines.

<u>Item 5</u> I would rather learn this material from a person.

<u>Item 7</u> More topics should be taught by computer.

<u>Item 12</u> Computers can help people learn.

c) What were students' attitudes towards self-paced instruction versus traditional instruction?

<u>Item 1</u> I prefer learning in the traditional classroom.

<u>Item 6</u> I like to have control over my own learning.

<u>Item 15</u> People should be allowed to learn at their own speed.

<u>Open-ended Item 1</u> Did you enjoy working with this program? Yes or No ___ Why or Why not? What did you like or dislike? Be specific.

One open-ended question was asked so that previous microcomputer experience could be determined. This information was used to determine if computer use was a novelty experience for these students. The question asked was as follows:

<u>Open-ended item 4</u> Have you ever had any experience with a computer? (Yes or No)___ If you answer Yes, describe how often you have used the computer and for what purposes.

4. Procedure

The researcher approached a biology teacher at an Edmonton high school that had the microcomputer hardware required for this study. The teacher agreed to have four of her Biology 20 classes participate in the study. Appropriate measures were taken to obtain permission from the school board and school administration.

Students were told about the study by the teacher a week before it was conducted. The researcher met with the students on the day of pretesting. The students were told that they would be part of a comparison study during the review of a unit of study they had already completed. The procedure was explained to each class involved in the study in the same way by this researcher.

The students were also informed of the extent of their participation and the amount of cooperation expected. Each student knew that he/she would prepare two concept maps, take a short 30 minute review lesson in genetics, write a ten item multiple choice test and complete a questionnaire. The students were informed that their participation was voluntary and that they could withdraw from the study at any time. Eighty-five students began the study but only 71 completed all the requirements. Each of the 71 students who completed the study invested two 60 minute biology classes in the study.

In the first class the pre-review concept map was given to the students in their regular classroom. Students were given several examples of concept mapping and an instruction sheet (see Appendix A). It took approximately 30 minutes to explain concept mapping and provide examples. In the remaining 20-25 minutes the students were asked to draw a concept map which included 18 genetic terms (see Appendix A). Students were asked to use a code name on their concept map. The name had to be something they would remember. This process of code names was done to maintain anonymity of the students.

Students in each of the four classes were randomly divided into two groups. The microcomputer group received the CAI genetics instruction and the handouts group received the genetics instruction using the more conventional method of handouts. For each class the students' code names were written out on small slips of paper and placed in a container. As names were blindly drawn out from the container they were alternately assigned to the two groups until all the slips were gone. The mean scores for the pre-review concept map test for the microcomputer group was 9.314 and for the handouts group the mean was 8.472. Results from the two factor ANOVA (see Table 3) indicates that there was no significant difference in achievement on the pre-review concept map between the two groups [F (1,69) = .889, p<.3491)].

In the next class, which was two days after the first meeting, the students' code names were called as they were assigned to one of the two groups. The microcomputer group was sent to the microcomputer lab while the handouts group remained in their regular classroom.[1] Many students had been to the microcomputer lab before, so the use of the microcomputer was not a novelty. The microcomputer group received instructions from the researcher's assistant on how to sign on to the program. It took no more than five minutes to get all students onto the program. After completing the CAI program, this group received the ten item multiple choice test via microcomputer and corrective feedback was given. When the students were finished they were asked by the assistant to draw the same concept map as in the last class and then to complete the student questionnaire before leaving. Students had to write their established code name on both their concept maps and tests so that comparisons could be made.

The handouts group went through the same procedure except they were given the handouts. When they finished the handouts, students were given, as a paper-pen test the same ten item multiple choice test as the microcomputer group. After completing the test, the students were asked to draw the same concept map as last class and then to complete the student questionnaire.

CHAPTER IV

RESULTS

1. Statistical Analysis

All statistical analyses were performed using the program StatView on the Macintosh Plus microcomputer. Concept map scores were analyzed by two factor repeated measures ANOVA. The Likert-scale items of the student questionnaire were scored in the following manner: Strongly agree (SA) = 5, Agree (A) = 4, Undecided (U) = 3, Disagree (D) = 2, Strongly disagree (SD) = 1. The mean for each Likert-scale item was calculated for each group and for the two groups combined. Any mean greater than 3 was considered as agreement with the statement and any mean less than 3 was considered as disagreement. Pagano (1986) suggests the use of t-tests to determine differences between two groups. Therefore, a t-test was administered to determine if there was a significant difference in responses to an item between students in the microcomputer group and the handouts group. A correlation coefficient matrix was generated for the Likert-scale items to determine if the items used to answer a research question were correlated. Any correlation coefficient greater than .5 was considered to be a high value. Student comments for open-ended items 1, 2, and 3 are presented in Appendix D. This chapter will present a summary of those comments.

2. Results

Determining if Review Instruction Material was Effective

Before addressing the first research question it had to be ascertained if the review instructional material was effective in meeting its stated objectives with a sample of students. The overall mean for the monohybrid crosses multiple choice test for both groups combined was 77%. Students in the high to mid range of scores had an average greater than the 80% required for mastery of the review material (see Table 2). Students in the lower 27.5% range of scores had an average of 50.5%. According to the multiple choice test the review instructional material proved to be effective for 72.5% of the students involved in this study because they exceeded the criterion level for mastery.

Table 2

Mean for Monohybrid Crosses Test for Both Groups Combined

	High Group	Mid Group	Low Group	Total
Mean	97%	81.3%	50.5%	77%

Table 3 shows the two factor repeated measures ANOVA used to determine if there was a significant increase in all subjects post-review concept map scores from the pre-review concept map scores. The results ($F\ (1, 69) = 6.214$, $p < .0151$) indicate that the review instructional material increased student understanding of the genetic concepts. However because the highest score attained was 50 out of a possible 125 points, the instructional material could not be considered successful in helping students reach higher levels of understanding. Figures 6 and 7 are examples of the concept maps drawn by a student in the higher grouping of scores. Some propositional links changed but others did not. The trivial propositional links indicated that there was not a clear understanding of how the concepts were related.

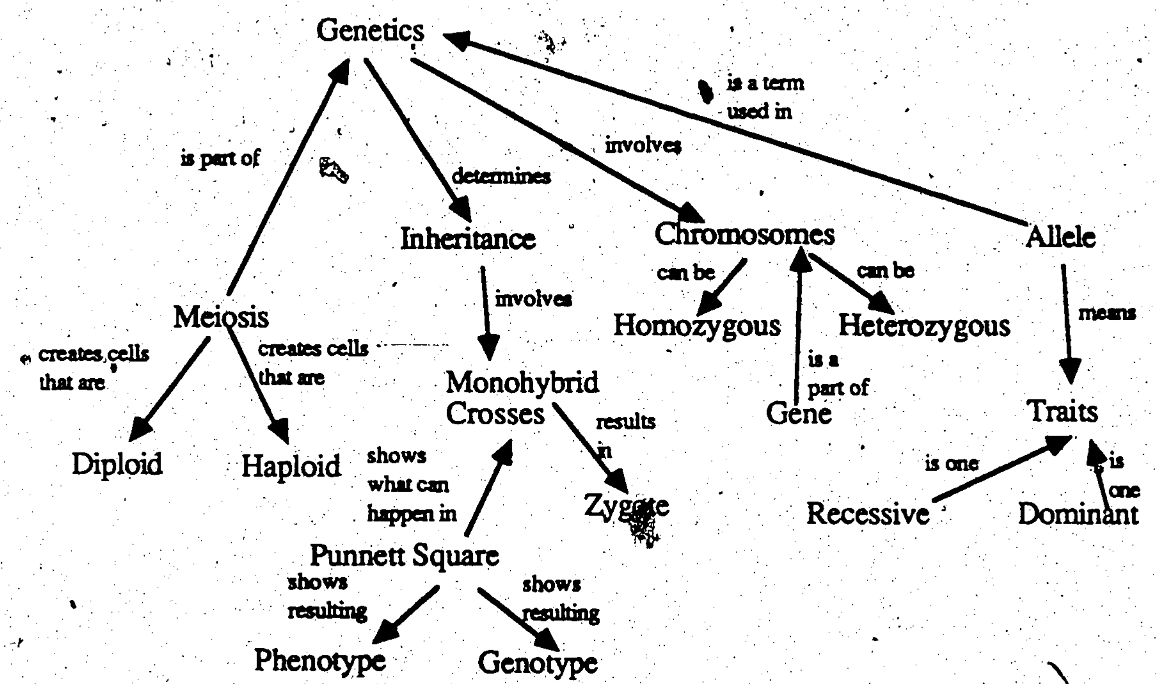


Figure 6. Pre-Review Concept Map Drawn by Student with Code Name Portnoy

<u>Supplementary Question</u>

The following supplementary question arose from the data given above.

Did students who did well on the multiple choice test do equally as well on the post-review concept maps?

In order to answer this question the post-review concept map scores were correlated to the multiple choice test scores. A correlation coefficient of .31 was found between the two types of tests indicating that only 9% of the variance was predictable. The two tests were measuring different learning outcomes and success in one test did not necessarily mean success in the other test. It seems that the instructional material was effective in presenting factual material but not entirely successful in developing higher level learning outcomes such as understanding inter-relationships of concepts.

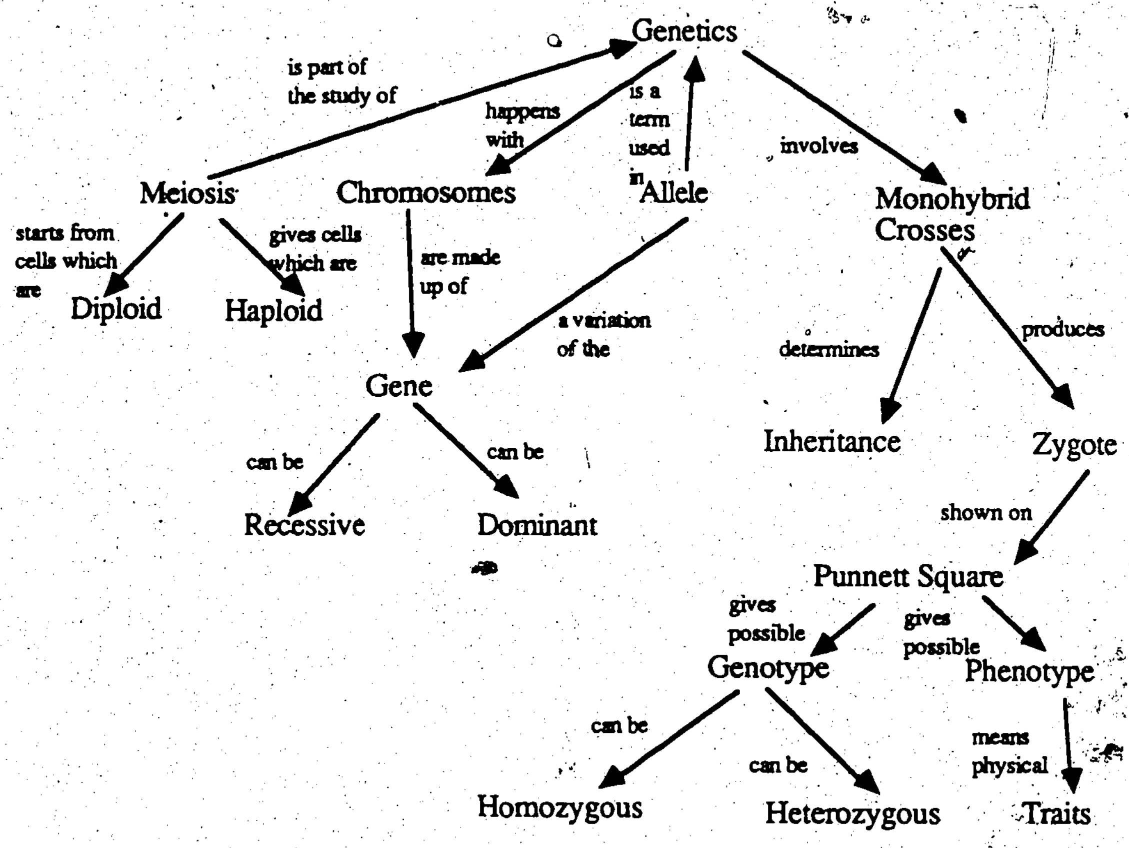


Figure 7. Post-Review Concept Map Drawn by Student with Code Name Portnoy

First Research Question

The purpose of this study was to determine the effectiveness of CAI when compared to another means of self-paced instruction. The first research question stated in Chapter I was:

> Would there be a difference in achievement between students using the microcomputer and those using the handouts to review genetics?

The two factor ANOVA reported in Table 3 was used to determine if any significant differences for the post-review concept map scores existed between the microcomputer group and the handouts group. There was no significant difference between the two groups [F(1,69) = .889, p< .3491]. A t-test was applied to determine if any differences existed between groups for the monohybrid crosses multiple choice test and no significant difference was found (t = .428, p< .6703).

In summary of the results for the first research question, it was found that students in the two groups showed no significant differences in multiple choice test scores or in post-review concept map scores. These results indicate that the CAI used in this study was as effective as the handouts in delivering the genetics review. The concept map test and the multiple choice test did not measure the same learning outcomes as indicated by their low correlation.

Table 3

Two Factor ANOVA of Groups and Concept Map Tests

Means

Group	Pretest	Posttest	Totals
Microcomputer	9.314	14.057	11.686
Handouts	8.472	10.111	9.292
Totals	8.887	12.056	10,472

Source	DF:	Sum Squares:	Mean Square:	F-test	P value
Groups (A)	1	203.427	203.427	.889	.3491
Tests (B)	1	356.514	356.514	6.214	.0151
AB	1	85.49	85.49	1.49	.2263

Second Research Question

Student perceptions of their learning are also important in determining the success of the instructional material. Therefore the second research question was:

What were the students' perceptions of their understanding of this unit?

This question was broken down into three specific questions. Information obtained from the student questionnaire was used to answer each of these questions. The first question asked was: Did students feel they understood this material? Questionnaire items 4, 8, and 11 pertain to this question. A t-test indicated no significant difference in responses to these items was found between the two groups (see Table 4). Students from both groups were on the agree side (mean=3.239) of the scale for item 4. Students tended to disagree with items 8 and 11. Item 8 and 11 were both used to determine students' perceptions about the level of difficulty in the genetics unit (correlation coefficient = .713). A correlation matrix (see Table 5) indicates that if a student responded on one end of the Likert-scale for item 4, he/she would tend to respond on the other end of the scale for items 8 and 11. These results indicate that these students felt they understood the genetics unit and did not perceive themselves to have any major problems with the unit.

Table 4

t-tests: Differences in Mean Rating of Groups for Items 4, 8, and 11

Item #	Item	Micro-computer Group Mean	Handouts Group Mean	Both Groups Mean	Prob.
4	I understood this material before the review.	3.176	3.303	3.239	.5785
8	I need more time than my classmates to understand genetics.	2.794	2.939	2.866	.6271
11	I find genetics to be a difficult subject.	2.559	2.906	2.727	.284

Table 5

Correlation Coefficient Between Items 4, 8, and 11

Items	Micro-computer Group	Handouts Group	Both Groups
4 & 8	-.434	-.663	-.533
4 & 11	-.379	-.615	-.470
8 & 11	.745	.675	.713

Questionnaire items 10, 13, and 17 and open-ended question 3 pertain to the second question: Did students feel they understood the relationship between meiosis, Punnett squares, and genetics? There were no significant differences between the two groups for items 10, 13, and 17. As the results in Table 6 indicate, students agreed that there was a relationship between meiosis, Punnett squares, and genetics. However, Table 7 indicates that only items 10 and 13 are highly correlated.

Open-ended item 3 asked: Do you feel this program pinpointed any difficulties in genetics of which you were unaware? (Yes or No)___. If you answer yes, be specific in describing these difficulties. Of the 71 students participating in the study, 56 answered this item. There was no significant difference in the open-ended responses between the two groups. No was the answer given by 54% of the students answering this item. The remaining 46% answered Yes and further elaborated on their answers. For the most part these students felt that the program clarified definitions such as allele and chromosome and had clarified the relationship between terms. Some found that meiosis had been clarified. None of the students specified that the relationship between meiosis, Punnett squares, and genetics had been clarified. Further examination of the post-review concept maps indicated that only 4% drew crosslinks between these concepts with a significant propositional statement.

These means from the questionnaire items indicated that the students believed a relationship exists between meiosis, Punnett squares, and genetics. However, the belief that meiosis is related to Punnett Squares was not as high as the belief that a relationship exists between meiosis and genetics. The concept maps and the correlation coefficient between items 10, 13, and 17 indicated a lack of understanding of these relationships. Students recognize there is a relationship between these concepts but were unable to explain the relationship.

Table 6

t-tests: Differences in Mean Rating of Groups for Items 10, 13, and 17

Item #	Item	Microcomputer Group Mean	Handouts Group Mean	Both Groups Mean	Prob.
10	Understanding the process of meiosis is important when learning about genetics	4.353	4.242	4.299	.4379
13	There is a relationship between meiosis and genetics	4.206	4.061	4.134	.3803
17	There is a relationship between meiosis and Punnett Squares	3.706	3.394	3.552	.2509

Table 7

Correlation Coefficient Between Items 10, 13, and 17

Items	Microcomputer Group	Handouts Group	Both Groups
10 & 13	.698	.576	.639
10 & 17	-.063	.154	.043
13 & 17	.220	.280	.259

Students were asked questionnaire items 2 and 14, and open-ended item 2, to answer the third question: Did they find this material useful? No significant differences were found between the two groups for this question. Students agreed with both these items (see Table 8) but there was a low correlation between the two items (see Table 9).

Open-ended item 2 asked: In what way or ways, if any, did you feel this program helped you learn genetics? Of the 71 students participating in the study, 53 responded to this item. Both groups gave positive comments on this item. They felt that the instructional material provided them with a good review but that it really did not present them with any new material. Some felt the instructional material which was provided, clarified certain concepts in genetics. Two students, one from each group, commented that they appreciated being able to move through the material at their own rate. Several comments were made by the microcomputer group that were not made by the handouts group. Students using the CAI program commented positively about the graphics component, the attribute isolation feedback, and the corrective feedback. Overall, items 2 and 14 and open-ended item 2 indicated that the students participating in this study found the instructional material useful as a review of genetics.

Table 8

t-tests: Differences in Mean Rating of Groups for Items 2 and 14.

Item #	Item	Micro-computer Group Mean	Handouts Group Mean	Both Groups Mean	Prob.
2	This program helped to clarify some of the concepts in genetics that confused me.	3.706	3.818	3.761	.602
14	This material was easy to understand.	3.706	3.636	3.672	.7327

Table 9

Correlation Coefficient Between Items 2 and 14

Items	Micro-computer Group	Handouts Group	Both Groups
2 & 14	.194	.090	.134

To summarize the results for the second research question, it was found that students felt they understood the instructional material and that they [illegible]zed that there was a relationship between meiosis, Punnett squares, and geneti[illegible]wever, these relationships were not correctly drawn on the concept maps. Students found the instructional material easy to understand and useful. There was no difference in the students' perceptions towards the instructional material.

Third Research Question

The third research question in this study dealt with student attitudes. The question asked was:

> What were the students' attitudes toward the medium used and the delivery method of instruction?

This question was split into three more specific questions. Questionnaire items 9 and 16 pertain to the first question: Was there a preference for one of the media? A significant difference (see Table 10) was found between the two groups for both item 9 ($t = 5.175$, $p < .0001$) and item 16 ($t = -1.08$, $p < .0001$). The microcomputer group had a strong preference towards using the microcomputer and the handouts group did not. The microcomputer group disagreed with the use of handouts while the handouts group agreed with this use. The microcomputer group showed a stronger preference to using the microcomputer (4.088) than the handouts group showed towards using handouts (3.182). A high inverse correlation (see Table 11) was found between items 9 and 16 indicating that students who showed a preference for one medium did not show a preference for the other medium. This high inverse correlation is attributed mostly to the responses from students in the microcomputer group.

Table 10

t-tests: Differences in Mean Rating of Groups for Items 9 and 16

Item #	Item	Micro-computer Group Mean	Handouts Group Mean	Both Groups Mean	Prob.
9	I would prefer doing this type of review on the computer.	4.088	2.727	3.418	.0001
16	I would prefer doing this type of review from a set of handouts.	2.000	3.182	2.582	.0001

Table 11

Correlation Coefficient Between Items 9 and 16

Items	Micro-computer Group	Handouts Group	Both Groups
9 & 16	-.704	-.489	-.687

Questionnaire items 3, 5, 7, and 12 pertain to the second question: "What were students' attitudes towards using the microcomputer for instruction?" There was no significant difference in responses to item 3 between the two groups (see Table 12). Students from both groups agreed that teachers can not be replaced by machines. Both groups agreed with item 5; but, there was a significant difference in the level of agreement ($t = -3.571$, $p < .0007$). The microcomputer group was very close to being undecided (3.059) on this item while the handouts group rated it more highly (3.879).

A significant difference between groups was found for item 7 ($t = 4.058$, $p < .0001$) and item 12 ($t=3.632$, $p<.0006$). The microcomputer group agreed that more topics should be taught by computer while the handouts group disagreed with the statement. Both groups agreed with item 12 but the microcomputer group showed stronger agreement than the handouts group for this item. Table 13 shows that there is a high inverse correlation between items 3 and 7, and between items 5 and 7. Items 7 and 12 showed a high correlation. A large difference between groups exists for the correlation coefficient for items 3 and 7. The handouts group was much more likely to agree with item 3 and then disagree with item 7 than was the microcomputer group. Therefore students who felt that teachers could be replaced by machines were more likely to feel that computers could help people learn and should be used to teach more topics. Overall, results from items 3, 7, and 12 indicate that students who used the CAI program had a more positive attitude towards using the microcomputer as a medium of instruction and had more confidence in its ability to teach.

Table 12

t-tests: Differences in Mean Rating of Groups for Items 3, 5, 7, and 12

Item #	Item	Micro-computer Group Mean	Handouts Group Mean	Both Groups Mean	Prob.
3	Teachers can not be replaced by machines	3.471	3.909	3.687	.0867
5	I would rather learn this material from a person.	3.059	3.879	3.463	.0007
7	More topics should be taught by computer	3.824	2.697	3.269	.0001
12	Computers can help people learn.	4.353	3.727	4.045	.0006

Table 13

Correlation Coefficient Between Items 3, 5, 7, and 12

Items	Micro-computer Group	Handouts Group	Both Groups
3 & 5	.287	.456	.429
3 & 7	-.189	-.726	-.528
3 & 12	-.245	-.484	-.431
5 & 7	-.653	-.476	-.635
5 & 12	-.327	-.080	-.314
7 & 12	.450	.613	.627

Questionnaire items 1, 6, and 15, and open-ended item 1 pertain to the third and final question: What were students' attitudes towards self-paced instruction versus traditional instruction? There was no significant difference between groups for these items (see Table 14). Both groups strongly agreed with the ability to have more control over their learning and to work at their own speed. Students, as a whole, tended to disagree but were very close to being undecided about a preference for the traditional approach of teaching. Table 15 shows a low correlation between items 1, 6, and 15.

Open-ended item 1 asked: Did you enjoy working with this program? Yes or No ____. Why or why not? What did you like or dislike? Be specific. Of the students participating in this study, 62 answered this item. Of the 62 students answering, 55 (29 from the microcomputer group and 26 from the handouts group) responded Yes. One student from the handouts group was undecided and the remaining six, three from each group, answered No. Students from both groups commented that the instructional material provided a good review and was easy to understand. Both groups commented on the ability to move through the instructional material at their own pace with most of these comments made by students in the microcomputer group. Students in the microcomputer group commented that they liked the change from the regular classroom and found that the computer provided an interesting means of delivering instruction. The microcomputer group also commented favourably on the immediate feedback and graphics presented in the CAI program. Dislikes mentioned by the microcomputer group were that they could not ask the computer questions and one student found the frame-by-frame presentation too choppy.

Overall, the results from items 1, 6, and 15 and open-ended item 1 indicated that students from both groups had a strong preference for the self-paced approach to learning. Those students using the microcomputer found that the CAI added variety to their class. In the open-ended responses students re-emphasized their appreciation of being able to progress through the instructional material at their own rate.

Table 14

t-tests: Differences in Mean Rating of Groups for Items 1, 6, and 15

Item #	Item	Micro-computer Group Mean	Handouts Group Mean	Both Groups Mean	Prob.
1	I prefer learning in the traditional classroom.	2.706	3.152	2.925	.0907
6	I like to have control over my learning.	4.176	4.03	4.104	.4239
15	People should be allowed to learn at their own speed.	4.265	4.061	4.164	.3165

Table 15

Correlation Coefficient Between Items 1, 6, and 15

Items	Micro-computer Group	Handouts Group	Both Groups
1 & 6	.249	-.092	.073
1 & 15	.061	-.003	.001
6 & 15	.554	.290	.422

In summary of the results of the third research question, students who used the CAI program indicated a preference for using the microcomputer to review genetics. The microcomputer group had a more positive attitude toward using the microcomputer to deliver instruction. Both groups had a positive attitude toward self-paced instruction.

Microcomputer Experience

Open-ended item 4 was asked to determine if microcomputer use was a novel situation for these students. Students were asked: Have you ever had any experience working with a computer? (Yes or No?) ___. If you answer Yes, describe how often you have used the computer and for what purpose. Of the 71 students in the study 67 answered this item, of those students only seven had no experience with microcomputers. The remainder had been using microcomputers for word processing, programming, or games. Over half had taken a computer literacy course either in high school or in junior high school. Of the seven students who had never used a computer, two were in the microcomputer group and five were in the handouts group. Therefore, 94% of the students in the microcomputer group had some previous experience with microcomputers.

CHAPTER V

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

This chapter is divided into three sections. The first section discusses the results presented in Chapter III. The second section presents a conclusion on the practical implications of this study for a high school biology teacher. The final section presents recommendations for further research.

1. Discussion

Achievement

Clark (1985) suggested that there would be no significant difference in achievement if CAI was compared to another medium of delivering self-paced instruction. The results of this study support Clark's assertions. In this study, CAI was as effective as handouts in delivering a review of the Biology 20 genetics unit. The only major difference between the media used in this study was that the CAI offered corrective and attribute isolation feedback while the handouts did not. Bork (1986) believes the immediate feedback characteristic of CAI is responsible for the effectiveness in achievement reported in other studies. This study, however, indicated that the immediate feedback offered no advantage.

The results of this study are supported by Farragher and Szabo (1986). They placed the students registered in an undergraduate science course into one of five groups. All groups were introduced to a new topic through a CAI program. The CAI content was identical for each group except for the variation in presentation of embedded questions and immediate feedback. One group received no embedded questions. The other groups received embedded question with the feedback ranging from none to specific attribute isolation feedback. The results of the Farragher and Szabo study indicated that there was no significant difference in the overall achievement between the groups. These researchers suggested that undergraduate students already have sufficiently well-developed information processing skills that embedded questions and feedback do not provide any advantages in learning.

It is possible that the students in this study did not need the attribute isolation feedback since it was a review of material with which they were already familiar. Students' responses to the questionnaire items indicated that they believed they understood the material before the review. Most students probably answered the embedded questions correctly the first time and hence did not need or use the attribute isolation feedback. Even though the feedback in this CAI program did not appear to help students make greater gains in achievement, several students expressed their appreciation for the feedback. One student believed that the CAI helped because "it clarified and gave immediate praise or correction for short quizzes." It is also possible that the students did not pay serious attention to the feedback since achievement scores obtained in the study would not be included in their final grade.

An interesting result generated from this study was the difference in scores between concept maps and multiple choice tests. Students performed well in the multiple choice test but poorly on the concept map. Part of the problem could have been due to students unfamiliarity with concept maps. Most students found the concept map frustrating because it required different cognitive skills. The multiple choice test evaluated knowledge and application of genetic concepts. The concept maps evaluated understanding of genetic concepts. The concept maps were also capable of determining specific areas where students had problems.

As indicated in Chapter II many studies use multiple choice tests to measure achievement. However, these studies are only measuring knowledge and application skills and not understanding. This study demonstrated that knowledge and application of genetic concepts was high even when an understanding of the these concepts and their relationship to one another was low. The instructional material helped students review but did not help students understand the relationships among meiosis, Punnett squares, and genetics.

A major portion of the instruction was designed to demonstrate the relationship among meiosis, Punnett squares, and genetics. Although a significant increase between pre-review and post-review concept maps was obtained, the gain was not sufficient to conclude that the instructional material was effective in developing an understanding of this relationship. This result is not an unusual result for the genetics unit even with carefully designed instructional material. Peard (1983) observed similar results when he used instructional material prepared to meet objectives similar to the ones used in this study. His use of concept maps indicated that students still maintained the same conceptions after the treatment as they did prior to the study.

Part of the reason for the lack of understanding of genetic concepts may be that the genetics unit is too abstract for high school students. Another problem is that, once students have developed misconceptions, it is very difficult to alter their misconceptions (Brumby, 1984; Peard, 1983; and Osborne, 1980). One-time instruction is not sufficient to alter conceptions. Repetitive instruction has done little to change student misconceptions (Osborne, 1980) so that a short review, even if it focused on the problem areas, would likely do very little in the way of developing understanding.

Student Perceptions of the Genetics Review

The questionnaire item responses also suggest a lack of understanding of the genetic concepts. If students had understood the relationship of genetic concepts they would have rated items 10 (Understanding the process of meiosis is important when learning about genetics.), 13 (There is a relationship between meiosis and genetics.), and especially 17 (There is a relationship between meiosis and Punnett squares.) higher than they did. Also, all these items should have had high intercorrelations. Instead, students who agreed that understanding meiosis is important when learning about genetics did not always agree that there was a relationship between meiosis and Punnett squares. This result may have occurred because these students probably felt that a relationship between the terms must exist since the terms were presented in the same review. However, the students were not certain of the exact relationship and therefore did not answer the questions with the same amount of agreement.

Students agreed that the instructional material was easy to understand (item 14) and that it helped clarify certain concepts (item 2). The low correlation coefficient between these two items can be explained through the open-ended responses. Some students did not feel that they learned anything new. Instead the CAI program and handouts simply reviewed material that they already knew and they did not feel that they had any problems with the genetics unit in the first place. Therefore, if students disagreed with item 2 it was not because the program did not provide adequate instruction but because the students felt they knew the instructional material.

Attitudes

One aspect of this study investigated differences between the two groups in their attitudes towards the medium used for instruction and the delivery method. These students rated attributes of self-paced instruction highly and lacked preference for a traditional classroom. The low correlation for these items indicates a lack of consistency in the students' responses. However, it is likely that students who agreed with item 1 (I prefer learning in the traditional classroom.) also agreed with items concerning attributes of self-paced instruction (I like to have control over my learning and people should be allowed to learn at their own speed.). Students may want a little more control over their learning but traditional instruction is probably the only means of instruction with which they are familiar. The students seemed to be hesitant to entirely give up one method of instruction for another. These students may want some self-paced instruction integrated into the traditional classroom. Johnston (1987) reported similar findings. In her study, students wanted to have more control over their learning but did not believe the computer could replace the teacher.

Student attitudes toward the attributes of self-paced instruction were positive. Students preferred the opportunity to learn at their own pace. Some comments were:

> I enjoyed the change and the ability to work at my own speed thus enabling me to more clearly understand the material at hand.
>
> Liked the speed at which you can take information in compared to teaching by people.
>
> I liked the fact that I was more in control of what I was doing.

Regardless of the treatment, these students had the same attitude towards traditional instruction and self-paced instruction.

Even though there was no difference in achievement, students using the microcomputer showed a strong preference to reviewing the genetics material through CAI. The microcomputer group seemed quite satisfied with their experience and firmly disagreed with using handouts to review. These students probably had experience using handouts and could give a more definite answer about their preference since they had experienced both media. The microcomputer group's experience with both types of media could explain this group's higher inverse correlation for items 9 and 16. The handouts group on the other hand did not know what CAI was capable of and disagreed with the use of the microcomputer; yet some were somewhat uncertain about their preference to using handouts.

The microcomputer group placed more confidence in the ability of the microcomputer to deliver instruction than the handouts group. Although most of the students had been using computers in the past, it seems evident that they were not aware of its instructional component. None of the students commented on using the microcomputer for CAI. The experience the microcomputer group had with CAI in this study convinced them that CAI is a viable instructional tool. The handout group could only go by what they knew.

The microcomputer group agreed with item 5 (I would rather learn this material from a person.) although not as strongly as the handouts group. The agreement with item 5 by the microcomputer group may [illegible] because students found using the microcomputer too impersonal. Two stu[illegible]d:

I disliked not being able to clarify a point - can't ask a computer..

It would be nice to be able to ask questions about what you got wrong.

Based on the results given by the students about their previous microcomputer experience, it seems likely that the handouts group had no idea what CAI would be like on the microcomputer. They felt that more topics could not be taught by computer; whereas, the microcomputer group was fairly confident more topics could be covered. Johnston's (1987) study revealed similar findings. Students exposed to CAI developed a positive attitude but did not feel it could replace the teacher because CAI was too impersonable.

The positive attitude developed by the microcomputer group can be attributed to the CAI experience.. Since students were randomly placed into the groups, it is probable that both groups shared the same attitudes towards computers before the treatment. Similar conclusions were reported in Keuper's (1985) literature review which indicated that students exposed to CAI had a more positive attitude towards learning with the computer.

Even though the handouts group missed the CAI experience they still agreed, although not as strongly as the microcomputer group, that computers could help people

Scoring Guidelines for Concept Maps

Maps were scored according to the following guidelines adapted from Peard (1983):

Appropriate examples used	1 mark
For each propositions that is:	
valid and significant	4 marks
valid but trivial	1 mark
For each crosslink that is:	
valid and significant	10 marks
valid but trivial	3 marks
Hierarchies	
Correct placement / relationship	1 mark
Incorrect links / ambiguous links	-1 mark

Appendix B

Student Handouts

This program is designed to review your unit on monohybrid crosses. By the end of this program you should be able to:

1) Define the following terms: gene, allele, monohybrid cross, Punnett square, dominant, recessive, homozygous, heterozygous, genotype, and phenotype.

2) Distinguish between:

   a) an allele and a gene
   b) homozygous and heterozygous
   c) recessive and dominant
   d) genotype and phenotype

3) Given the parent's genetic make-up, determine the probability of the appearance of a particular characteristic in their offspring.

4) Identify the relationship between meiosis, Punnett squares and genetics.

Before discussing gentetic terms you need to review meiosis. It is important that you understand how gametes are formed and why they have a reduced number of chromosomes. You have the option of a review of meiosis before taking the Meiosis Test. This is a short ten minute review. If you are fairly familiar and confident with the material you may go directly to the test. The test will check your understanding of meiosis (reduction division of cells). You should try to achieve at least 80% on the ten item test before going on to the Monohybrid Crosses lesson.

Meiosis

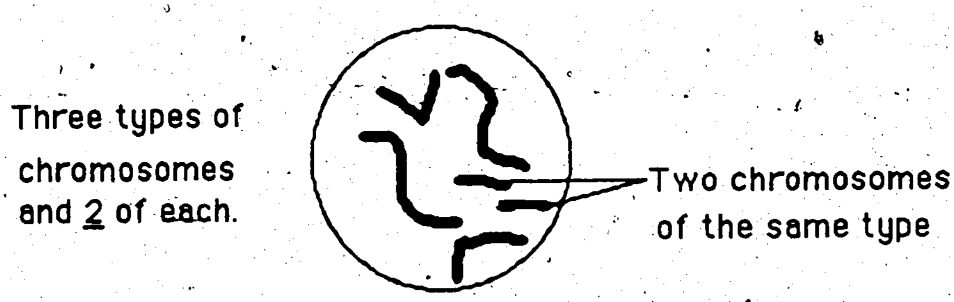
This is a very short review of meiosis. If the material presented here is too simple for you, you may go immediately to the test. Keep in mind however, that you will be expected to achieve at least 80% on that test.

DNA replication is an essential process in cell division. Chromosome replication results in replication of DNA because DNA molecules make up chromosomes.

When studying cellular division, it is important to understand the difference between somatic cells (body cells) and gametes (sex cells) and between diploid and haploid.

Somatic cells contain two of each type of chromosome. One set is inherited from the female and the other from the male. This double set of chromosomes is called the DIPLOID number and is represented by '2n', 'n' standing for the number of different types of chromosomes.

<u>Somatic Cell</u>

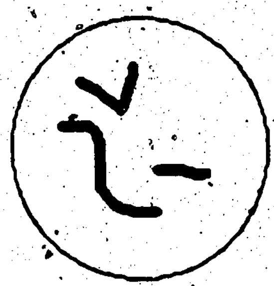


2n=6

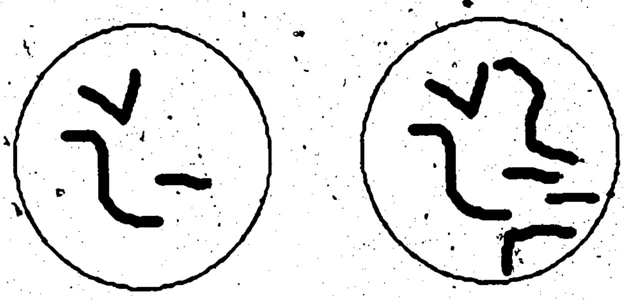
Haploid cells have only ONE of each type of chromosome. This is known as the monoploid number and is represented by 'n'.

<u>Gamete Cell</u>

Three types of chromosomes and only <u>one</u> of each.



Compare the 2 cells below and make sure you understand the differences.



n=3 haploid

2n=6 diploid

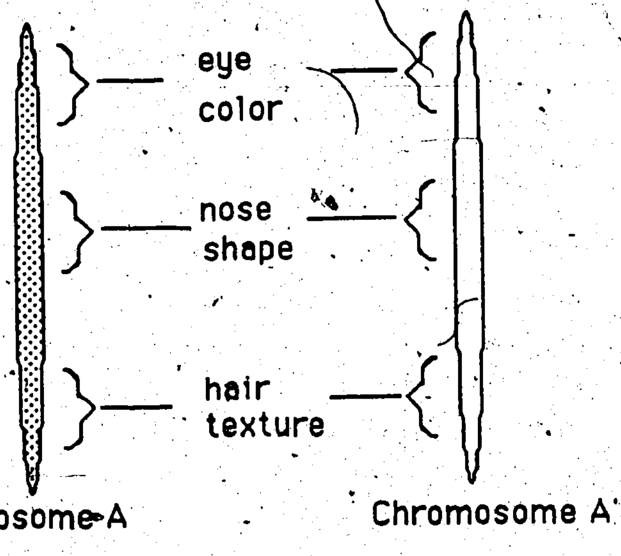
Meiosis is also known as REDUCTION DIVISION. This makes sense since the number of chromosomes (the units of DNA that carry the genetic information) in a cell is reduced in half after this type of cell division.

Meiosis occurs in all sexually reproducing organisms. The cells formed at the end of this cell division are called GAMETES or SEX CELLS.

When two gametes fuse together they form a zygote. For example in humans the gametes are called sperm and egg. When a sperm cell fuses together with an egg cell a zygote is formed. The zygote contains twice the number of chromosomes of the individual sex cells. If this reduction division in meiosis did not occur, the chromosome number would double. For example, in humans the diploid number (2n) is 46. If there was no reduction division then after one generation there would be 92 chromosomes in the cells of the offspring. In the second generation there would be 184 chromosomes in each cell. By the tenth generation there would already be 94,208 chromosomes per cell.

Homologous chromosomes are two chromosomes that contain the same gene sites. For example two chromosomes are homologous if they both contain the gene for eye color, hair texture, nose shape and so on. So a set of homologous chromosomes are responsible for the same TYPE of genetic information.

The section outlined for eye color exists on both chromosomes but the color (blue, brown etc.) may be different on chromosome A than the color information for chromosome A'.



Each gene site is responsible for a particular feature (eye color) but the actual trait expressed for the trait may be different on chromosome A (eg. blue eyes) than on chromosome A' (brown eyes).

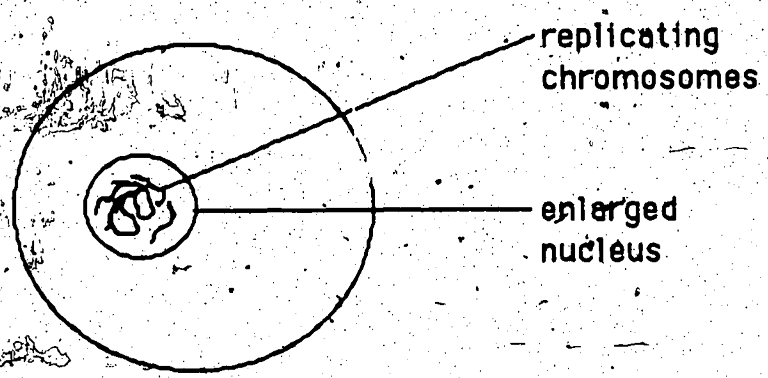
Meiosis then is the process that divides the cell chromosome number into half. Each of the resulting haploid cells has ONE of EACH type of chromosome. The process of meiosis can be broken down into several stages. You will now review these stages.

I. Interphase

- chromosomes replicate and shorten
- nucleus enlarges
- each chromosome completes duplication producing sister chromatids.

Two sister chromatids are exact copies of each other. At this stage each chromosome consists of two sister chromatids.

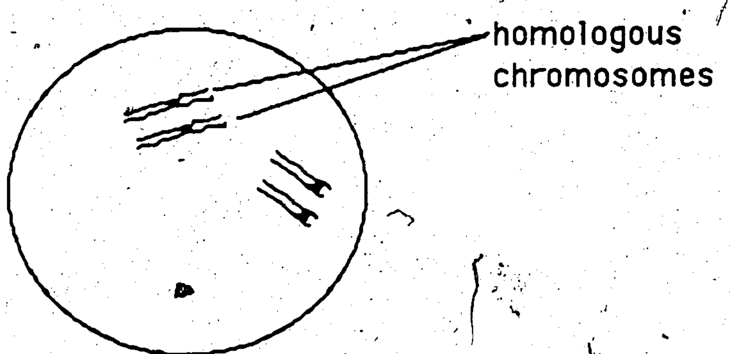
Interphase



II. Prophase I

- homologous chromosomes (each consisting of 2 chromatids) pair up with each other to produce a tetrad (4 chromatids).
- nuclear material and nuclear membrane breakdown.
- spindle fibers appear.

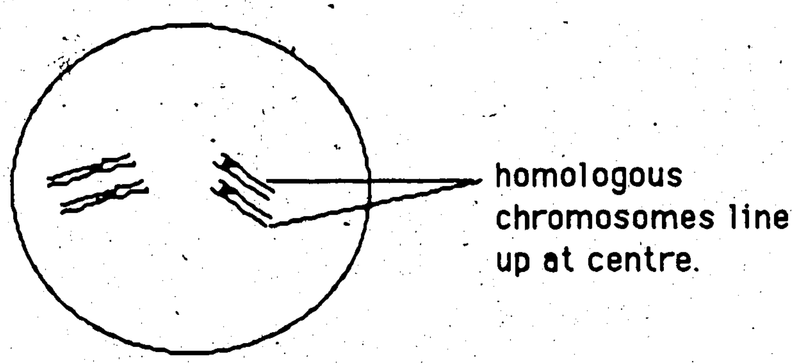
Prophase 1



III. Metaphase I

- chromosomes move to the center of the cell to form the equatorial plate.
- homologous chromosomes line up opposite each other on the equatorial plate.

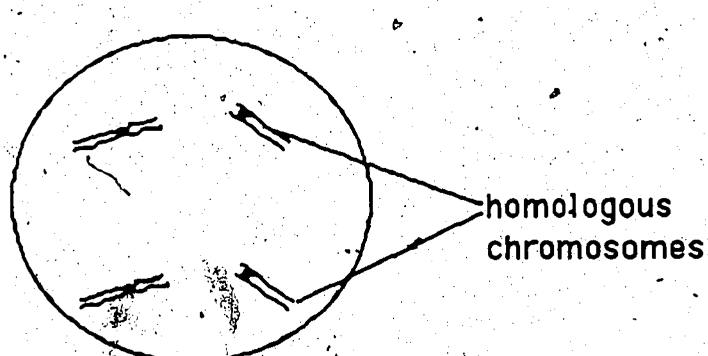
Metaphase 1



IV. Anaphase 1

- homologous chromosomes (each composed of 2 chromatids joined by a centromere) separate and move apart towards the poles.

Anaphase 1

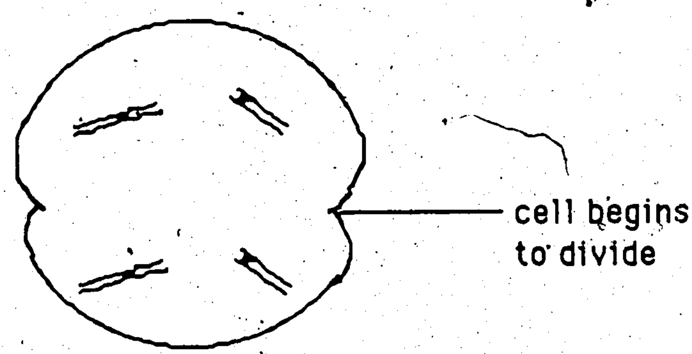


V. Telophase I

- one set of duplicated chromosomes accumulates at each pole.
- nucleus may or may not reform.
- division plates form, separating the cell into two cells.

[illegible] this stage the number of chromosomes is reduced to the haploid [illegible] from the diploid number (2n). That is, there is only one set of chromosomes per cell but each chromosome still consists of two chromatids. These chrpmatids will separate in the second phase of meiosis.

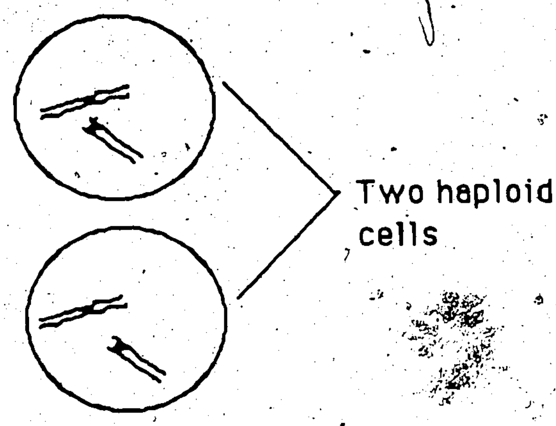
Telophase 1



VI. Prophase II

- spindle apparatus reforms
- there are now two haploid cells.

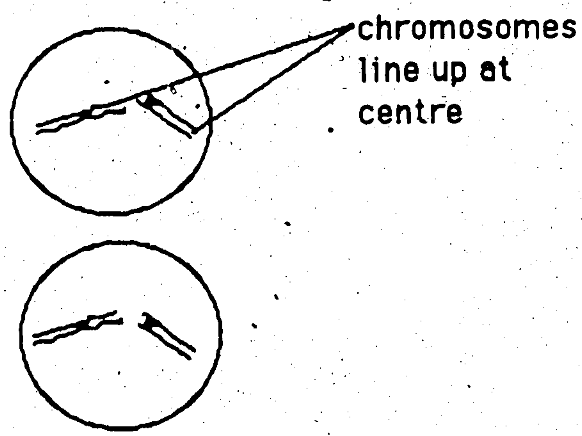
Prophase II



VII. Metaphase II

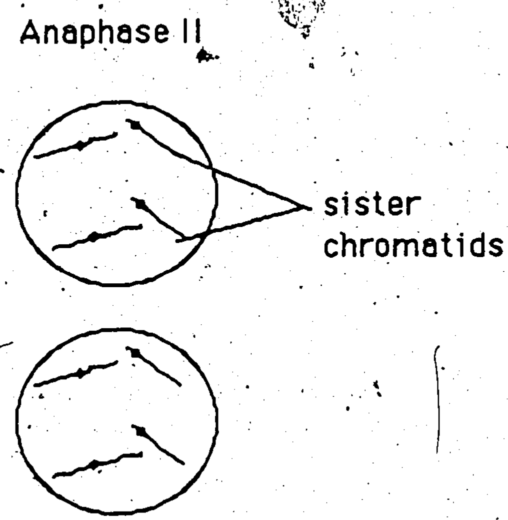
- duplicated chromosomes line up in the center of each cell to form equatorial plates.

Metaphase II



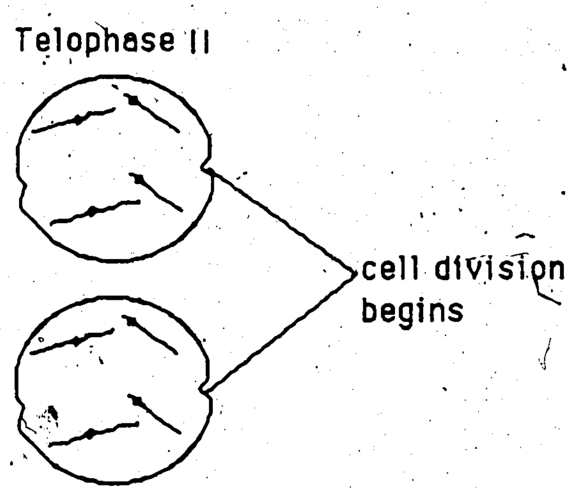
VIII. Anaphase II

- sister chromatids separate, each now being called a daughter chromosome



IX. Telophase II

- daughter chromosomes lengthen and nuclei reform in each cell.
- each cell forms a cleavage furrow that pinches and divides it in two.



The end result is four cells with the haploid (n) number of chromosomes

You should realize that meiosis is a continuous process. When you view this cell division under the microscope it is very difficult to distinguish all the stages.

Meiosis Test

This test consists of ten questions dealing with meiosis. You should have a fair understanding of the meiosis process and the differences between diploid and haploid cells. Write your answers on a separate sheet and then check your response with the answer key.

1) The main function of meiosis is to

A. double the chromosome number
B. counteract the doubling chromosome effect of fertilization
C. replace mitosis if it's not functioning
D. reduce the chromosome number by one quarter

2) Meiosis

A. is a general process for organism growth
B. occurs in all cells of the organism
C. involves two cell divisions
D. involves a single division of chromosomes

3) If the diploid chromosome number in an animal cell is twelve, each gamete contains

A. three chromosomes
B. six chromosomes
C. twenty-four chromosomes
D. sixteen chromosomes

4) When two gametes unite the result is a

A. a sperm cell
B. an egg cell
C. a zygote
D. a meiotic cell

5) Each diploid cell of the adult organism possesses

A. two complete sets of genes
B. one complete set of genes
C. one half the number of genes
D. four complete sets of genes

6) At the end of the first meiotic division, there are two cells, each with

A. n number of chromosomes
B. n pairs of chromosomes
C. 2n number of chromosomes
D. 2n pairs of chromosomes

7) What is the difference between a chromosome and a chromatid

A. a chromatid contains no genes
B. a chromosome contains no genes
C. two chromosomes make up a chromatid
D. two chromatids make up a chromosome

8) What is the difference between a gene and a chromosome?

A. a gene contains DNA that provides the information for many characteristics and a chromosome does not
B. a chromosome contains one gene
C. a gene contains many chromosomes
D. a gene contains DNA that provides the information for one characteristic and a chromosome contains many genes

9) In what stage of meiosis do chromatids move away from each other?

A. Interphase
B. Prophase
C. Metaphase
D. Anaphase

10) At the end of Telophase II there are

A. 2 haploid cells
B. 4 haploid cells
C. 2 diploid cells
D. 4 diploid cells

Answer Key for the Meiosis Test

1. B
2. C
3. B
4. C
5. A
6. A
7. D
8. D
9. D
10. B

Monohybrid Crosses

This lesson is on monohybrid crosses. If you are already familiar with the material you can ask for the test but it is to your advantage to go through the short tutorial lesson. By the end of the lesson you should be able to:

1) Define the following terms: gene, allele, monohybrid cross, Punnett square, dominant, recessive, homozygous, heterozygous, genotype and phenotype.

2) Distinguish between:
   a) an allele and a gene
   b) homozygous and heterozygous
   c) recessive and dominant
   d) genotype and phenotype

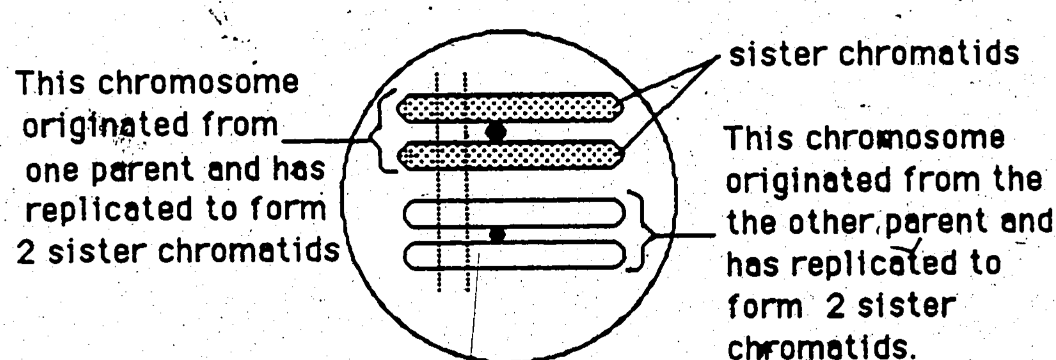
3) Given the parent's genetic make-up, determine the probability of the appearance of a particular characteristic in their offspring.

4) Identify the relationship between meiosis, Punnett squares and genetics.

The discovery of how cells divide into gametes helped to clarify the means of genetic transmission. The probability of a particular trait being inherited could be determined provided sufficient information about the parents was available. This lesson will remind you of some terms and will look at some examples of determining the probability of inheritance of genetic traits.

A gene can be defined as a sequence of DNA that carries information of a particular trait or characteristic. Genes are found on chromosomes. For example there is a gene that controls eye color. Genes that occupy the same site on homologous chromosomes and control the same trait are ALLELES. The gene for eye color has two different alleles. They are the alleles for blue and brown eyes. The following diagram should help you understand these terms.

This diagram represents a cell at Metaphase I

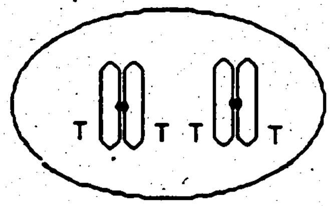


The section between the dotted lines represents a gene.

Gregor Mendel, an Austrian monk, examined the inheritance pattern of a number of characteristics of pea plants. Each characteristic was determined by a gene. Some of the characteristics that he looked at were as follows: plant height, flower color and seed shape. In his experiment, Mendel took pollen (male gamete) from a homozygous tall plant and pollinated the egg (female gamete) of a homozygous short plant. Homozygous means that both alleles controlling a characteristic are the same.

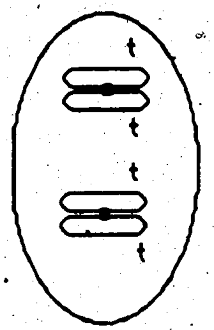
Eg) Both alleles determine the tall sequence.

Diploid Cell of Tall Plant



T= Tall allele

Diploid Cell of Short Plant



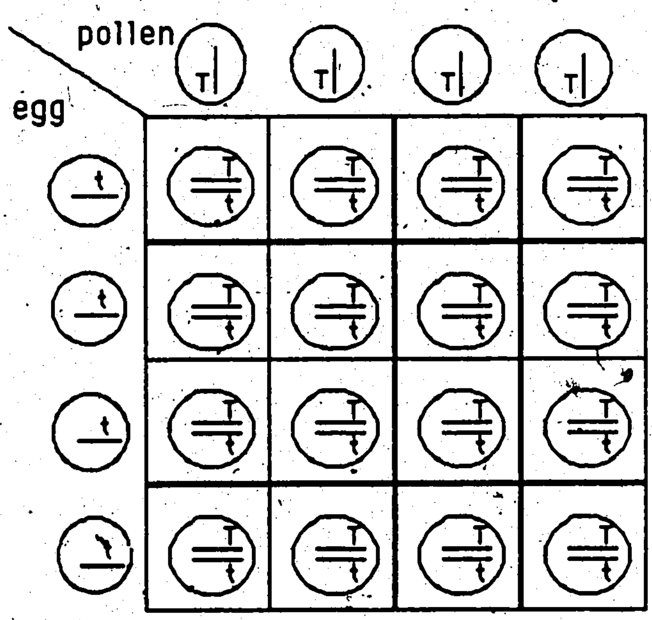
t=short allele

The tall plant has two chromosomes to carry the T alleles for the characteristic plant height. The same applies to the short plant except the allele is t not T.

Remember in meiosis these cells would divide twice each producing 4 gametes. The chromosomes carrying the gene for plant height are segregated into gametes. In this example gametes are egg or pollen cells. Now the rest is up to chance. Any one of the pollen cells can fuse with anyone of the egg cells to form a diploid zygote. The following grid or square shows all the possible combinations.

This diagram shows all the possible combinations of pollen and egg.

In this case all the eggs carry a t and all the pollen cells carry a T.



This square showed you that all the possible combinations of egg and pollen gave only one type of zygote. Since all the eggs carried the same allele and all the pollen cells carried the same allele, all zygotes are the same.

When the gametes, egg and pollen cells fuse together, they form a zygote that develops and grows into a plant. The organisms that arise from a mating (cross) are called offspring. In the square you just saw, all the resulting offspring will have the GENOTYPE (the hereditary make up of an organism) Tt. Offspring with two different alleles for the same characteristic are referred to as HETEROZYGOUS. Even though the offspring carry both alleles, the actual physical appearance (PHENOTYPE) is tall and not an inbetween height, as might be expected.

It appears that the T allele is dominant over the t allele. That is, a dominant allele expresses a physical characteristic, even when it is found in combination with another allele for the same characteristic. The t allele therefore is recessive since it can only express itself in the homozygous condition and not in the heterozygous state when the dominant allele is present.

Several terms have been presented. The next three questions will test your understanding of these concepts. Circle the correct answer directly on this sheet.

1. Which of the following genotypes is an example of a homozygous individual?

   A. Bb
   B. b
   C. bb
   D. bt

2. Which of the following genotypes is an example of a heterozygous individual?

   A. Yy
   B. YY
   C. YT
   D. y

3. A guinea pig homozygous for the trait long hair is mated with a guinea pig homozygous for the trait short hair. All five offspring had long hair. Which trait is dominant?

   A. hair length
   B. short hair
   C. long hair
   D. medium hair

Answers

1. C
2. A
3. C

It is necessary to know which symbols to use to express traits and how to apply these when working out a cross (mating). Although there are no universal rules, the following are the most commonly used.

RULES

1) Use the first letter of the word expressing the phenotype produced by the dominant allele to represent both alleles. For example, for the trait plant height, the letter 't' is used in both its capitalized and uncapitalized form because a tall plant is the product of the dominant allele.

2) The dominant allele is always capitalized. The dominant allele for tall plants is written as a capital 'T'.

3) The recessive allele uses the same letter as the dominant allele except that it is written in uncapitalized form. The recessive allele for short plants is written as an uncapitalized 't'.

4) For heterozygous genotypes, the capital letter representing the dominant allele is written first. eg) Tt and not tT.

The next two questions will check your understanding of the above rules. Circle the correct answer directly on this sheet.

1. In fruit flies, the allele for red eyes is dominant over the allele for white eyes. The allele for red eyes is represented by:

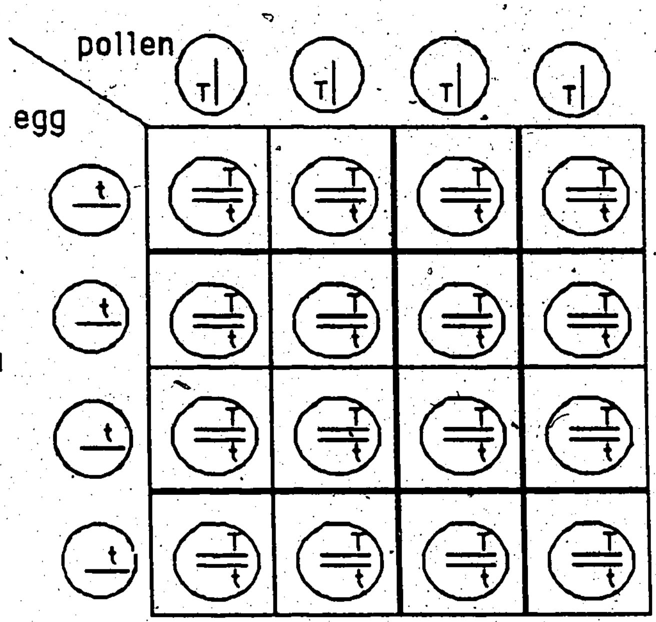
   A. R and the white allele by W
   B. R and the white allele by w
   C. r and the white allele by R
   D. R and the white allele by r

2. If red eyes is dominant and white eyes are recessive, what is the genotype for a heterozygous fruit fly?

   A. RR
   B. Rr
   C. RW
   D. Rw

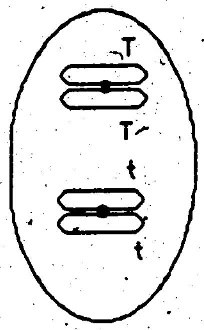
Answers

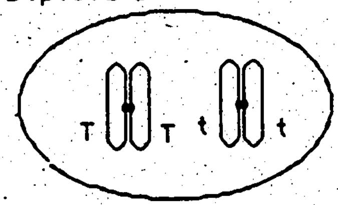
You are now ready to use a punnett square to solve genetic problems. This square that you saw earlier is very similar to a punnett square.



Steps For Using A Punnett Square

A PUNNETT SQUARE is a checker board diagram that will help you work out a cross (mating). In this lesson we are dealing with MONOHYBRID CROSSES. That is we are looking for the outcome of only ONE genetic trait in a particular mating. For example, what offspring might result from crossing two heterozygous (Tt) plants? Let's solve this problem step by step. First you already know that the letters we will be using are T and t.



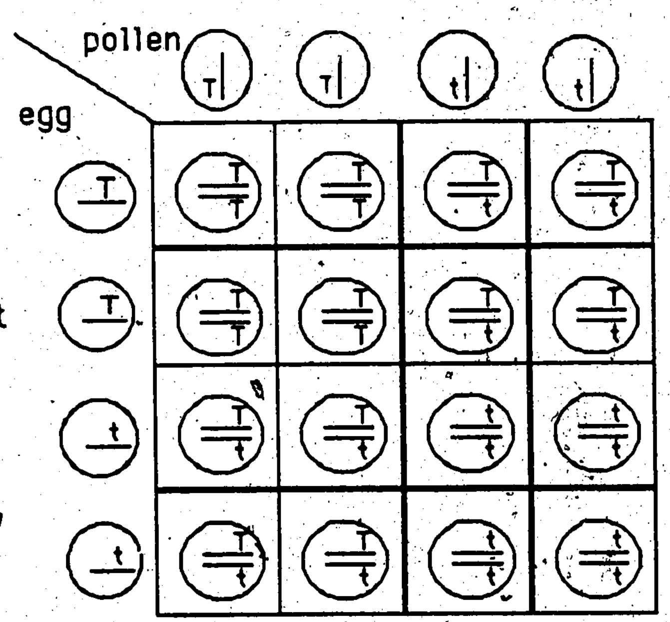


T= Tall allele
t=short allele

Determine the gametes of EACH parent. This is where your knowledge of meiosis is essential.

These are the gametes that will be produced.

To simplify things we can use just the letters to represent the alleles carried by the gametes.



Remember each letter represents an allele on a chromosome. We can simplify this even further.

egg \ pollen	T	T	t	t
T	TT	TT	Tt	Tt
T	TT	TT	Tt	Tt
t	Tt	Tt	tt	tt
t	Tt	Tt	tt	tt

We can reduce the square since 2 of the 4 (1/2) of the gametes carry a T and the other half carry the t allele.

female gamete \ male gamete	1/2 T	1/2 t
1/2 T		
1/2 t		

Half the male gametes carry a T allele the other half carry a t allele.

Half the female gametes carry a T allele and the other half carry a t allele.

female gamete \ male gamete	1/2 T	1/2 t
1/2 T		
1/2 t		

Now if the male T gamete and the female T gamete fuse together they would form a zygote with a TT genotype, Therefore a 1/4 (1/2 x 1/2) CHANCE that the offspring will be homozygous tall (TT).

female gamete \ male gamete	1/2 T	1/2 t
1/2 T	1/4 TT	
1/2 t		

Here is the completed punnett square.

female gamete \ male gamete	1/2 T	1/2 t
1/2 T	1/4 TT	1/4 Tt
1/2 t	1/4 Tt	1/4 tt

There are only two different phenotypes:
Tall (TT and Tt)
Short (tt)

female gamete \ male gamete	1/2 T	1/2 t
1/2 T	1/4 TT	1/4 Tt
1/2 t	1/4 Tt	1/4 tt

Remember these steps when solving monohybrid crosses.

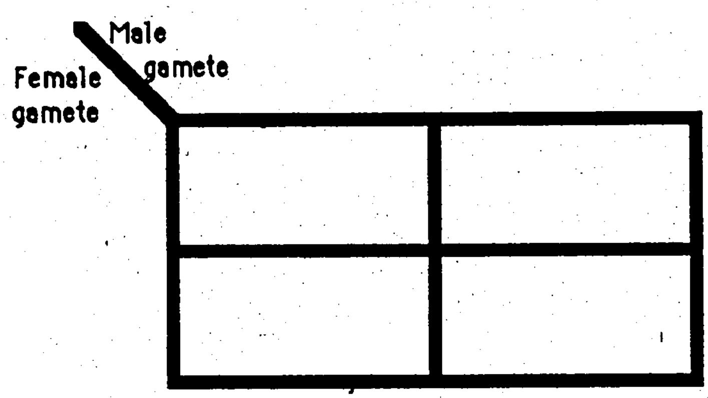
1) Determine the letters to be used.
2) Determine the gametes of each parent.
3) Each different gamete is represented by a letter. The gametes are on the top row for one sex and in the first column for the other sex.
4) Complete the squares by calculating the products of the letters.

Now you can try a problem. First you will be guided part way through then you will solve the Punnett square.

Problem: In humans the allele for brown eyes is dominant over the alleles for blue eyes. What are the chances of a heterozygous brown eyed male and a heterozygous brown eyed female having a child with blue eyes?

First we are told that brown is dominant so we can use the letter B for brown and b for blue. Next we know that they are both heterozygotes, therefore they each carry a brown and blue allele. The male will produce either B or b sperm and the female will produce either B or b eggs. Now think about how you would use the Punnett square to solve this problem.

Use the letters on the right to complete this Punnett square.



B B

b b

BB Bb

Bb bb

Answer

Male gamete / Female gamete	B	b
B	BB	Bb
b	Bb	bb

This concludes the lesson on monohybrid crosses. You should ask for the Monohybrid Crosses test. You should have some scrap paper available to work out the problems. Write your answers on a separate sheet of paper.

Appendix C

Monohybrid Crosses Test

Monohybrid Crosses Test

Write your answers on a separate sheet of paper. Remember to write your [illegible] on the answer sheet.

1) In garden peas, a green pod is the product of a dominant allele and a [illegible] pod [illegible] product of a recessive allele. Which letter best represents the dominant [illegible]

A. G
B. g
C. Y
D. y

2) When a pea plant with round peas was pollinated by a pea plant with wrinkled peas all 36 of the offspring plants had round peas. What is the dominant trait ?

A. pea shape
B. round
C. wrinkled
D. pea color

3) Red color is dominant over white color in flowers. What is the genotype for a heterozygous flower ?

A. Ww
B. WW
C. RR
D. Rr

4) The purpose of meiosis is to

A. increase the number of cells
B. decrease the number of cells
C. form four haploid gametes
D. form 4 diploid gametes

5) Genes are best defined as

A. structures which occur in mutations
B. structures which make up chromosomes
C. structures which contain the chromosome
D. structures which contain cells

6) If a guinea pig homozygous for long hair (dominant trait) is mated with a short hair guinea pig, what will the offspring phenotype be ?

A. medium hair length
B. long hair length
C. LL
D. Ll

7) A certain couple with a child that has a hereditary disease have been told by their medical geneticist that any other child they bear will have a 1 in 4 chance of being affected with the same disease. This means that if they have:

A. 4 more children, only the last one will be abnormal
B. 3 more children, all are likely to be abnormal
C. 1 more child, it has a 25% chance of being abnormal
D. 1 more child, it has a 75% of being abnormal.

8) In humans, the normal pigmentation of the skin is due to a dominant gene N, and albinism (no skin, hair or eye color) is due to a recessive gene n. A normal woman married an albino man. Their first child was an albino. What was the genotype of the mother?

A. n
B. NN
C. Nn
D. nn

9) For a child to inherit a recessive genetic disease he/she must inherit the harmful gene from

A. his/her mother
B. his/her father
C. each of his/her parents
D. mutation

10) In guinea pigs the allele for a rough coat is dominant over the allele for a smooth coat. A rough coat female (who's mother had a smooth coat) is mated with a smooth coated male. What percentage of offspring will have smooth coats ?

A. 25%
B. 50%
C. 75%
D. 100%

Key

1. A
2. B
3. D
4. C
5. B
6. B
7. C
8. C
9. C
10. B

Appendix D

Student Questionnaire

Student Questionnaire

This scale has been prepared so that you can indicate how you feel about the materials and the method of presentation used in this class today. Please circle the letters on the left indicating how you feel about each statement. (SA strongly agree, A agree, U undecided, D disagree, SD strongly disagree).

SA A U D SD	1. I prefer learning in the traditional classroom.
SA A U D SD	2. This program helped to clarify some of the concepts in genetics that confused me.
SA A U D SD	3. Teachers can not be replaced by machines.
SA A U D SD	4. I understood this material before the review.
SA A U D SD	5. I would rather learn this material from a person.
SA A U D SD	6. I like to have control over my learning.
SA A U D SD	7. More topics should be taught by computer.
SA A U D SD	8. I need more time than my classmates to understand genetics.
SA A U D SD	9. I would prefer doing this type of review on the computer.
SA A U D SD	10. Understanding the process of meiosis is important when learning about genetics.
SA A U D SD	11. I find genetics to be a difficult subject.
SA A U D SD	12. Computers can help people learn.
SA A U D SD	13. There is a relationship between meiosis and genetics.
SA A U D SD	14. This material was easy to understand.
SA A U D SD	15. People should be allowed to learn at their own speed.
SA A U D SD	16. I would prefer doing this type of review from a set of handouts
SA A U D SD	17. There is a relationship between meiosis and Punnett Squares.

Please answer the following questions.

1) Did you enjoy working with this program? (Yes or no)_____ Why or why not? What did you like or dislike - be specific.

2) In what way or ways if any, did you feel this program helped you learn genetics?

3) Do you feel this program pinpointed any difficulties in genetics of which you were unaware? (Yes or no)____ If you answer yes, be specific in describing such difficulties.

4) Have you had any computer experience?(Yes or no)____ If you answer yes, describe how often you have used the computer and for what purpose.

Student Comments - Open Ended Questions

1) Did you enjoy working with this program? (Yes or no) _____ Why or why not? What did you like or dislike - be specific.

Responses from Microcomputer Group

A yes response was obtained from 29 of these students. Their comments were as follows:

It was a good review. It's more efficient than studying from books and less work too.

It was more interesting (and entertaining) then worksheets etc. You tend not to let your mind wonder off as much as usual.

Because there is something about sitting in front of a computer and you reading instead of someone reading it to you, it's simplified.

It was a change from my regular study or classwork.

You can work at your own speed. Easy to understand.

It helped me refresh my memory of this particular unit. I liked it also because it gave me a quiz at the end to let me know how much I really knew about what I just read.

I enjoyed working on the computer, although I found the concept map unimportant.

The diagrams with the text helped with the understanding of the material.

It was nice to just sit down and just have to push one button to go through a lot of review, sometimes it can get frustrating when you have to constantly flip through papers to review.

I enjoyed the change and the ability to work at my own speed thus enabling me to more clearly understand the material at hand.

You have the opportunity to change your answers and you don't feel as much pressure, time wise. etc.

I liked the way it was presented.

It gave me a different perspective on ways that certain subjects can be taught in the school system.

Because it was faster and easier.

Liked the speed at which you can take information in compared to teaching by people.

Because I got to do it on a computer and it was fun and interesting.

I enjoyed being able to work at my own pace with a one on one strategy and being able to correct my own mistakes.

Its a new way to review. It would be nice to be able to ask questions about what you got wrong.

Different.

Because I don't have to write it out. I liked the diagrams.

It was easier to understand. I liked working with computers.

I liked the program because the learning rate was basic and the review was simple. The test was easy. Disliked not being able to clarify a point - can't ask a computer.

I think the program was good idea because it gave me the chance to review and learn at my own pace.

I liked the fact that I was more in control of what I was doing. I also liked it because it was new and different from having worksheets. It kept my attention more than a worksheet.

It was interesting working on the program.

It was okay, but I would like to be able to ask questions, such as about meiosis.

It was a very clear and a good review. Some concepts were unclear such as phases of meiosis graphics section.

I don't usually enjoy computers but this was kind of neat. If only you could go back and redo those tests I would learn more.

The three students who responded no gave the following comments:

It's too logical. A teacher can explain things with more sense for me.

I enjoyed working with the program but find working with computers difficult. I have trouble if I can't learn something by myself through taking notes or other methods.

I much prefer having all the information in front of me and easily available rather than chopped up frame by frame. I find computers interesting but hard to read off of and concentrate on for studying.

Responses from Handouts Group

One student was undecided. A yes response was obtained from 26 of these students. Their comments were as follows:

It was a good, condensed review of genetics.

I liked this because the material was easy to understand and very helpful.

Some points clearer. Good review.

I enjoyed working with the program because it was a good chance to review and to attain a better comprehension of this unit.

I find genetics very interesting. No matter how I learn it I think I would still enjoy it.

It was a really good review for genetics considering finals are coming.

I think it is much easier to learn by doing the work.

Fun being part of an experiment.

It is a lot easier to understand this review. The Biology 20 text book is written in another language.

More fun keeps interest for longer.

But I need more time to understand it.

It referred me back to meiosis and monohybrid crosses. It was an excellent way of reviewing certain concepts that I'd forgotten.

I liked the idea of being able to keep the review sheets.

It was very easy to understand.

I liked it because it made it easier to understand.

Because it will help me with my upcoming exams

I enjoyed working at my own speed, and not being pushed along.

It helped clarify stuff.

It helped me study for my final.

The material was easy to understand.

It was a good review of genetics. I didn't like to draw the concept maps though, because I would have liked to pick my own concepts to draw.

I found it fun and it was a change from the usual biology class we have.

Breaks the boredom of everyday class.

The three students who responded no gave the following comments:

It was too long, too much writing and reading. Also I didn't get to play around with the computer!

Rather do my own review.

Enjoy isn't the word - saw something different.

2) In what way or ways if any, did you feel this program helped you learn genetics?

Responses from Microcomputer Group

It helped me remember what I had already learned.

It clarified and gave immediate praise or correction for short quizzes.

I found this very thorough. I wish more subjects had reviews or this type of program.

It gave some good examples.

I think it helped me remember what I had already learned but I did not think it taught me anything new.

It was mainly a general review for me.

The information the program provided was good and easy to understand.

The graphics. The program did explain clearly.

It didn't help me learn but it helped me review because I had already learnt it but just forgotten it.

It helped me understand most of the definitions that I didn't know before.

It helped because I read the information and then was tested and could see what I did wrong.

It helped by giving me an easy direct outline of what I had to learn. The tests helped. I didn't feel so pressured.

It did review things but I prefer reviewing worksheets.

Showed me graphics of each phase from interphase to telophase II.

Clarified many points.

It helped me review.

It had some good diagrams.

I had the time to read it and didn't get pushed, like I would in the classroom.

The diagrams were helpful, easy to understand, cleared a lot of areas up.

I could learn on my own speed. Made me more independent.

It helped me to review and to show me my mistakes. I did not do so well on the reviewing so I really know I have to sit down and study.

Liked the challenge of doing the test on the computer, as you could not go back to the review to cheat and the computer gave you your score, or the option to change answers, right away.

I learned a little more on meiosis and Punnett squares. It brought a better explanation without a lot of reading and worksheets to do.

By reviewing what I didn't know.

I still got mixed up with some of the definitions but everything else went okay.

It tested you on what is important, quality not quantity, and told you what you did wrong.

I already knew all of the material, this just refreshed my memory.

Responses from Handouts Group

It helped me understand (quickly) the basics of meiosis.

I feel if I read over the material I will do very well in my final exam.

Just made some concepts clearer.

It gave me a brief yet structured overview of the unit and I was able to comprehend the unit easily.

It helped me understand the differences between similar terms.

It went into detail about everything concerning genetics that we learned.

Reviewed. Made me feel that I need to review quite a lot.

By reviewing.

More review.

It didn't

I already knew this but it helped me understand it better.

Helped in way of understanding - good review but not to start off with.

Helped me to review the topic.

It was very basic so I did not miss any thing.

I understand and remembered some terms I had forgotten.

I understand it better.

The language was specific and easy to comprehend.

It made clear for me on a lot of definitions, phase, etc.

The way it was outlined was clear and understandable.

The way it was written.

Took the time to go over it and made sure I understood before I moved onto another area.

It helped in the sense of reviewing a course subject for a final exam. It brought back certain topics that were important in the subject course.

I can realize more about what is what because of parents.

Reviewed.

I could understand it.

Did not help me learn but remember what I learned.

3) **Do you feel this program pinpointed any difficulties in genetics of which you were unaware? (Yes or no) _____ If you answer yes, be specific in describing such difficulties.**

Responses from Microcomputer Group

A total of 15 students responded no to this question.

A yes response was obtained from 13 students. Their comments were as follows:

I must study the definitions in genetics.

I had difficulty with the relationship of terms. I'm still a little foggy on genes/chromosomes and their relationship

I have not put a lot of time into genetics, in fact I have not started studying genetics and I now realize just how much there is to learn.

Alleles.

The difference between meiosis and mitosis, the stages which occur during Prophase, Anaphase etc.

I didn't quite know what the meaning of allele was, or the difference between meiosis I and II.

The genetic combination in chromosomes. I had forgotten information involving this.

I could understand more because I can read at my own speed and it gave me the time I needed.

But the way it taught was too simplistic.

It showed me that I don't know the exact way that meiosis worked and that I was getting the stages mixed up.

It showed me what was inside of what.

In the areas of meiosis.

After completing the program, I found it easier to complete the map.

Responses from Handouts Group

A total of 15 students responded no to this question. Two students made further comments.

It just maintained the same knowledge that was taught before the review.

Things I had problems with before were cleared up.

A yes response was obtained from 13 students. Their comments were as follows:

I got mixed up between definitions and this can really help.

Definitions. How things worked.

Understanding meiosis.

I can not really explain.

Meiosis.

Chromosomes and chromatids.

Made things much clearer.

I can do Punnett squares easily but I get confused by the vocabulary. This helped.

The Punnett square.

Definitions.