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Full Length Research Paper

A computer mediated simulation module for teaching cell division in secondary school biology

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This paper describes the design and development of a valid, reliable and flexible instrument, a Computer-Mediated Simulation (CMS) module for teaching cell division topic in secondary school biology. The design was based on the generic instructional approach of Plan, Do, See and Improve (PDSI). Each step has an outcome that feeds the subsequent step or results in modification of the prior step. The design and development of a CMS module is aimed at bringing out the dynamics of the process of cell division to facilitate students understanding of the topic better. The process of cell division specifically involved the aspects of meiosis and mitosis. The module was also developed to fill, in some way, the special need for media and technology in biology teaching at secondary school level in Kenya and perhaps elsewhere. Evaluation of the CMS results of the actual implementation in test schools provide improvement highlights of the strengths of the module geared towards shifting the point set presently to a more desirable outcome.

Key words: Computer mediated simulation, cell division, mitosis, meiosis.

INTRODUCTION

The topic 'cell division' is a form three topic under the concept reproduction and introduces students to sexual and asexual reproduction and genetics. Cell division is a continuous process but a series of stages are assigned marking the significant features at a given time. The stages involved are: (i) interphase, (ii) prophase, (iii) metaphase, (iv) anaphase, and (v) telophase (KIE, 1992).

The dynamics and chromosomal orientation during the process of cell division are pertinent to the understanding of the concept by the students of biology. Yet the process does not come out vividly in conventional instructional methods and in biology textbooks. Traditionally, cell division has been taught via traditional lecture and laboratory methods that involve use of squashed young onion root tip. However, a current trend in science is to integrate technology into the classroom in a variety of ways (Wekesa, 2003; Kiboss et al., 2004). One such area is Computer-Based Simulation (CMS), which has been applied in the teaching and learning of various courses and subjects with promising results (Allesi and Trollip, 1991; Njoo and Dejong, 1993; Kiboss, 1997; Wanjala, 2005; Wekesa, 2003).

A computer simulation improves the teachers' repertoire by enhancing and expanding the educational environment particularly in areas considered difficult or dangerous (Wekesa, 2003). Several benefits attributed to CMS have been reported. These include: the ability to shift learning to more hands-on and visual imagery interaction that is often lacking in traditional teacher based classroom. It natures confidence, initiative and enhances cognition, psychomotor and effective behaviour. It provides immediate feedback and it is self-paced. The ability to employ animated colour graphic enhanced features of the computer to demonstrate concepts is the most valuable component of CMS because it may enhance students' conception. The animated colour graphic enhanced CMS may be especially beneficial for teaching cell division through a

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multi-sensory approach because of the visual dynamic nature of the concept (Willet, 2004). Learning in such an environment may therefore be effective in that it can involve students in a complex study process that allows them to examine a model in a computer simulation in a very explorative and interactive way. Therefore, this study was set up to design and develop a CMS simulation intervention and to investigate its effectiveness for teaching the cell division in school biology.

Objectives

This study aimed at designing a teaching innovation (the CMS module), which was designed and developed from the point of view of the prevailing educational problem. Should the CMS be adopted, it could be applied in other areas of science to improve the teaching and learning of science in general and biology in particular.

Design and development of the CMS module

The Plan, Do, See and Improve (PDSI) approach contained research elements. These were employed as explained hereunder:

Plan

Baseline studies on performance of science and mathematics indicate that the status of science teaching is poor due to lack of enough and appropriate facilities in Kenyan schools (SMASSE, 2000). In biology, cell theory is one of the topics ranked near the top of the ladder of difficulty by pupils and teachers. It was envisaged that traditional lecture-based pedagogical practice might not be the best approach to support deep understanding of cell theory among students. In this case, it was decided that an alternative approach to cell theory be sort. Fortunately, the explosion of computer technology in recent decades offers an opportunity to explore a very different, perhaps fuller and more engaging experience to students. One such area is the Computer Based Instruction (CBI). It was therefore concluded that a Computer Mediated Simulation (CMS) teaching format could be a viable course format alternative as to bring to students the dynamics of the process of cell division.

Do

The next step in the PDSI approach was to determine how to develop a CMS module. Experts in Education communication and information technology departments at the author's institution were consulted. Three individuals agreed to consult on the module. The experts were to assist in the choice of pedagogical approaches that the courseware would adopt, determine the ideal mode of delivery of the courseware and set the plan of action for development of the CMS module.

Exploiting computer attributes, colour graphic simulations on cell division was done, marking the module distinguishable from the ordinary textbook. It was thought that the incorporation of graphic simulations would play a key role in enhancing student learning. The mode of courseware delivery was to be CD-ROM based and designed using Visual Basic software. The rationale for this software choice included: (i) portability, (ii) machine-independence, (ii) the use of general and advanced controls that allow the creation of complex forms and programs, and (iv) possibility to run an individual form instead of running the whole system at a go. Also it allows the use of automatic completion lists that guide the user when writing the code. This makes it easy to compile, execute, package and deploy the CMS program.

The instructional material used in the development of the module was from a form 3 biology course dealing with the concept of cell theory. The course content was based on the KIE approved syllabus for science education, teacher's guide, pupils' textbooks, and other relevant materials. The CMS lesson contained instruction on five topics, namely: (i) interphase, (ii) prophase, (iii) metaphase, and (v) telephase.

The CMS materials were organised in a format that rendered learning of complex factual information on the cell division easier and interesting. The materials were presented in the form of short notes and animated colour graphics that allow key concepts to be learnt as a coherent whole than in isolation from one another.

See

The CMS module underwent several reviews during its development. This involved two computer experts and four high school teachers that assessed the general format, sequencing of events, language level and grammar, subject content and pedagogical issues. Their recommendations and suggestions led to some appropriate modifications made before the CMS was tried using a small group of learners and finally implemented in a real classroom setting.

Improve

At the pilot stage, the learners were allowed to go through the CMS module lesson with the least help. Their feelings, difficulties, and experiences were closely monitored. At the end of the session, an informal interview was undertaken to get their views regarding the content and the general format of the CMS module. They were also administered with three dependent measures: BAT, BCEQ and SAQ. The problems and/or errors detected were rectified. The observation notes on the learners' psychological reactions as they went through the CMS lesson and interview conducted showed some minor difficulties, which were rectified.

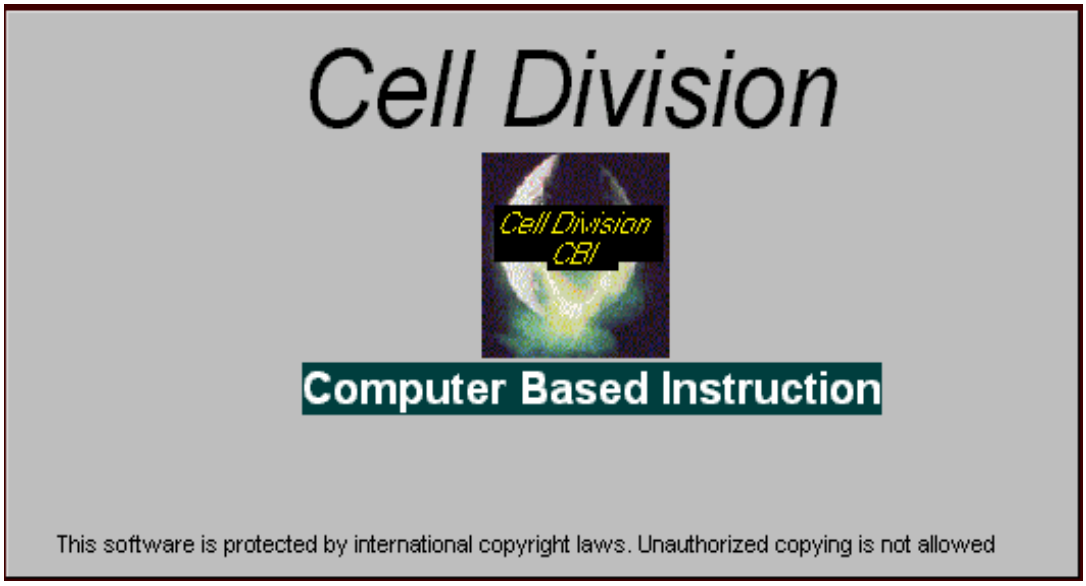

Figure 1. CBI logo.

Figure 2. Welcome page.

Theoretical framework

The design of the CMS module was guided by the dual-coding theory of the cognitive paradigm. According to this theory, information in memory is represented by both images and verbal codes. Park and Hopkins (1993) argue that there is a 'referential connection' that links verbal and non-verbal cues into a complete associative network to potentially allow such operations as imaging to words and naming to pictures. Therefore, something is more likely to be remembered if coded both verbally and visually because representatives of one form reinforces the other (Tennyson and Rash, 1988). This led the researcher to design the conceptual model in Figures 1 to 22 to guide the study.

In this model, it is assumed that the interactive

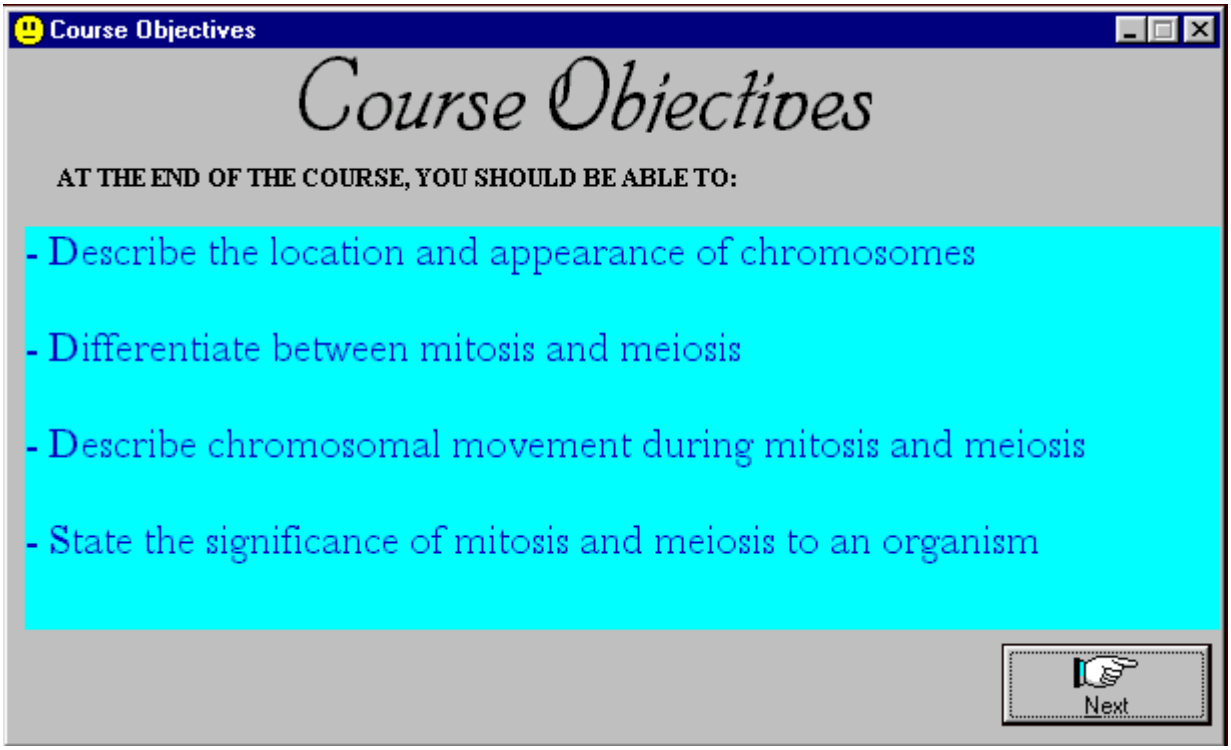

Figure 3. Course objectives.

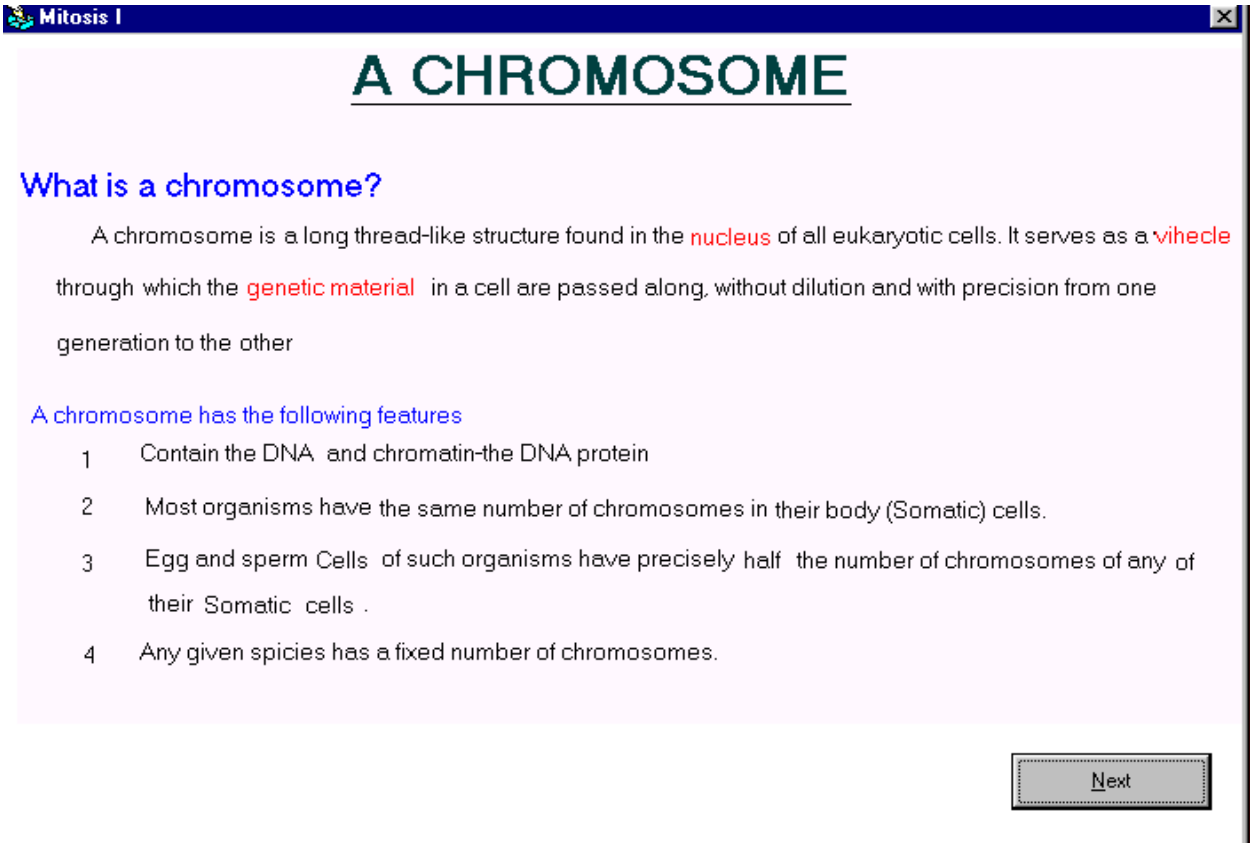

Figure 4. Definition of chromosome.

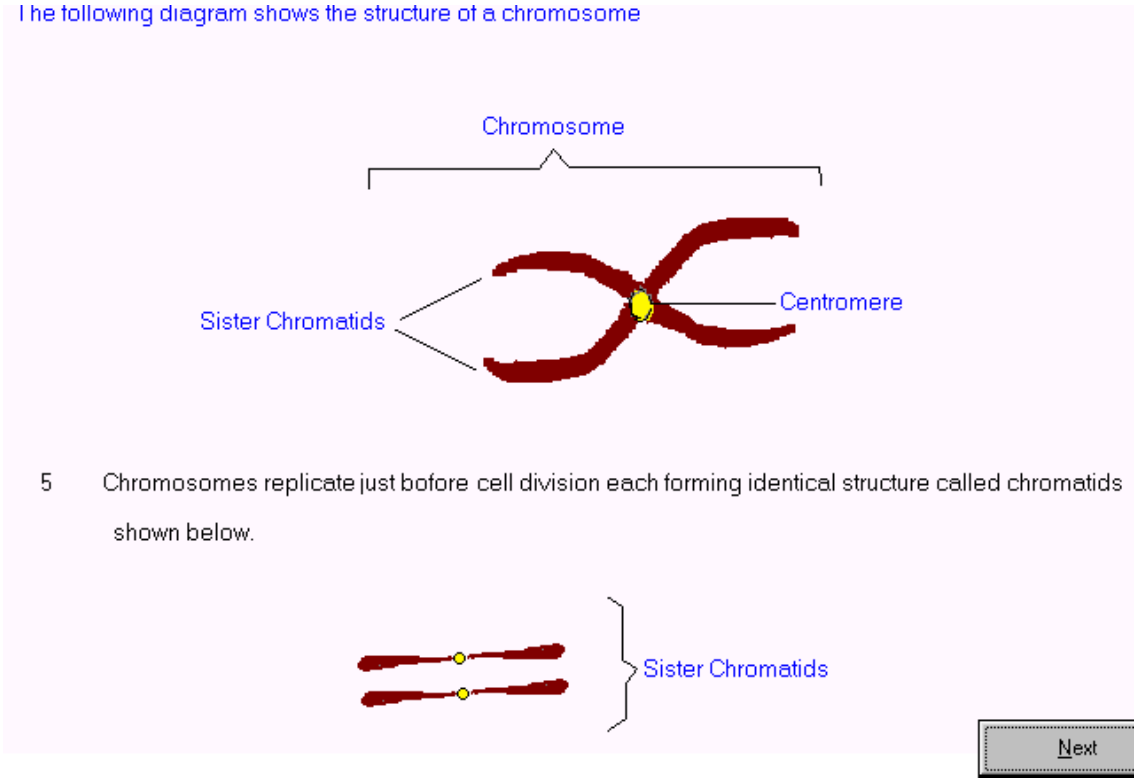

Figure 5. Formation of a chromosome.

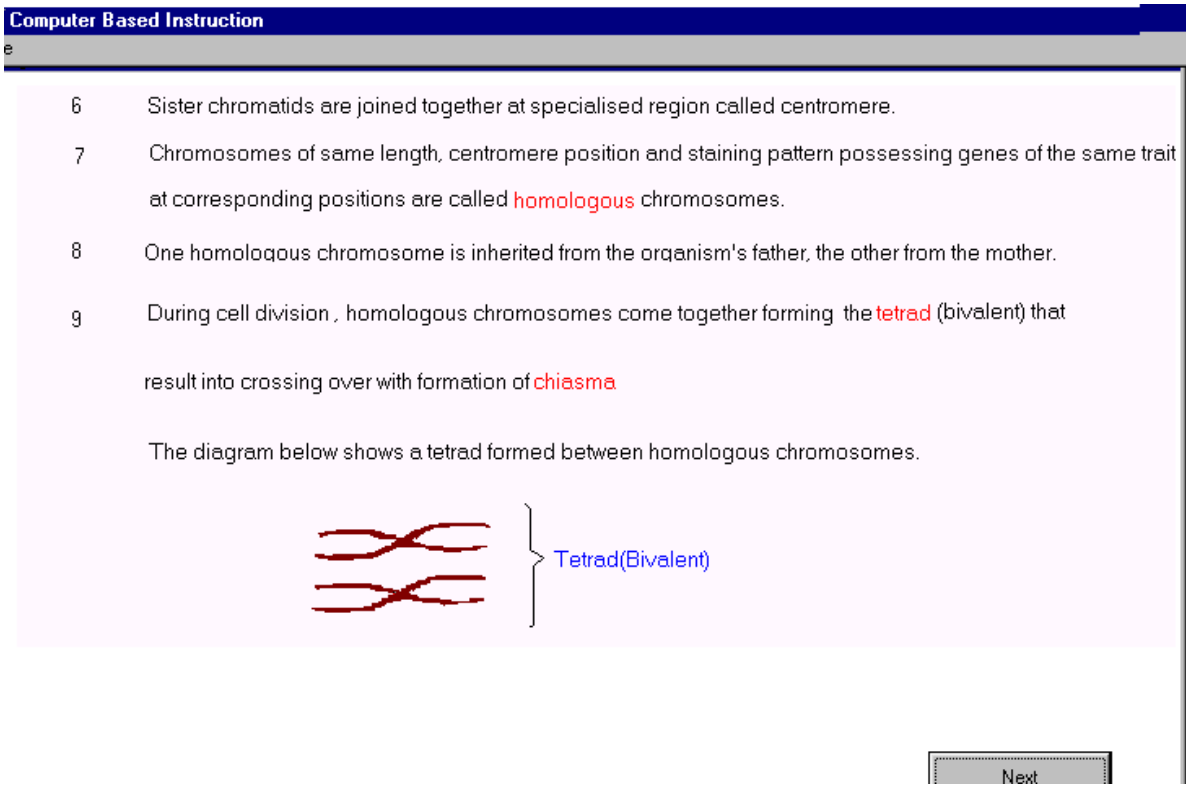

Figure 6. Structure of a chromosome.

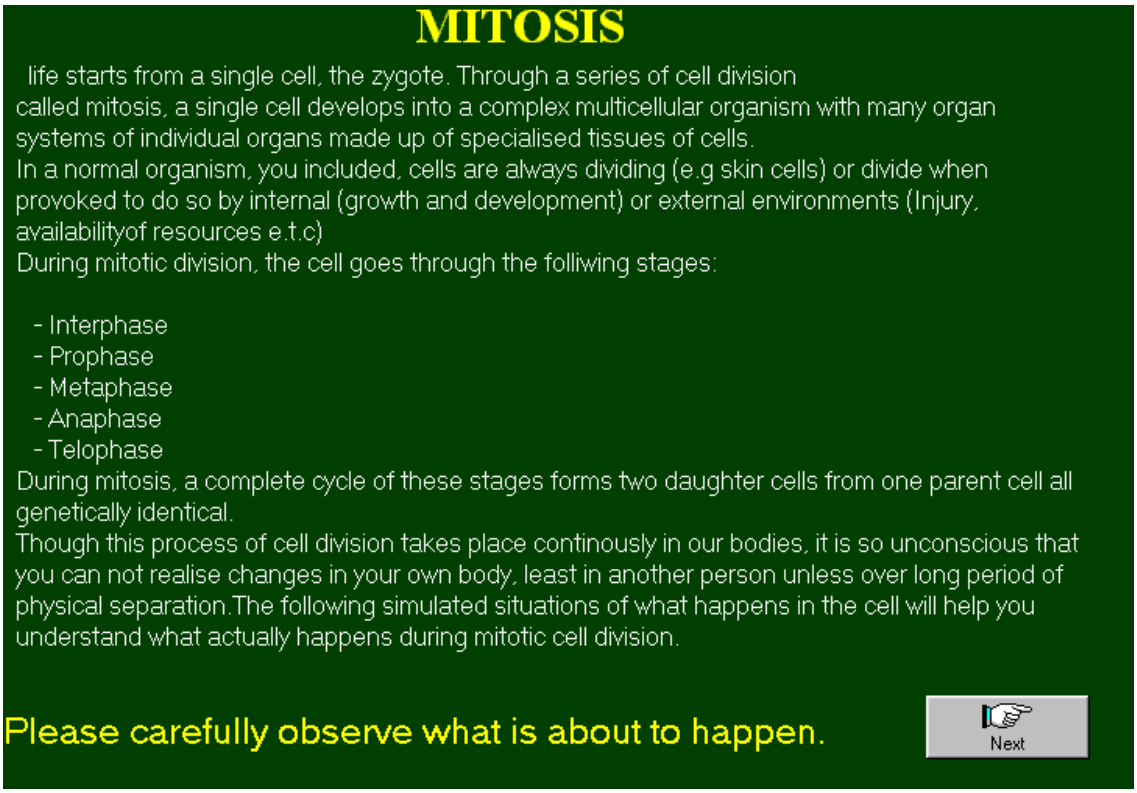

Figure 7. Tetrad formation.

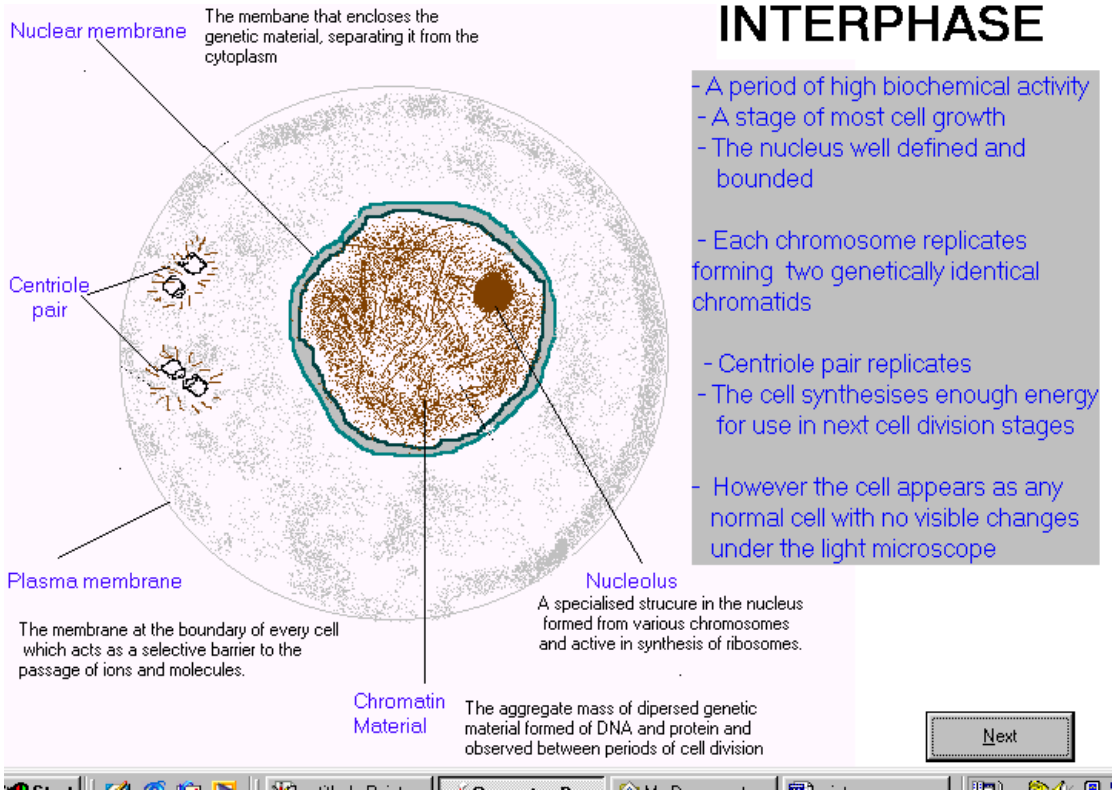

Figure 8. Mitotic division.

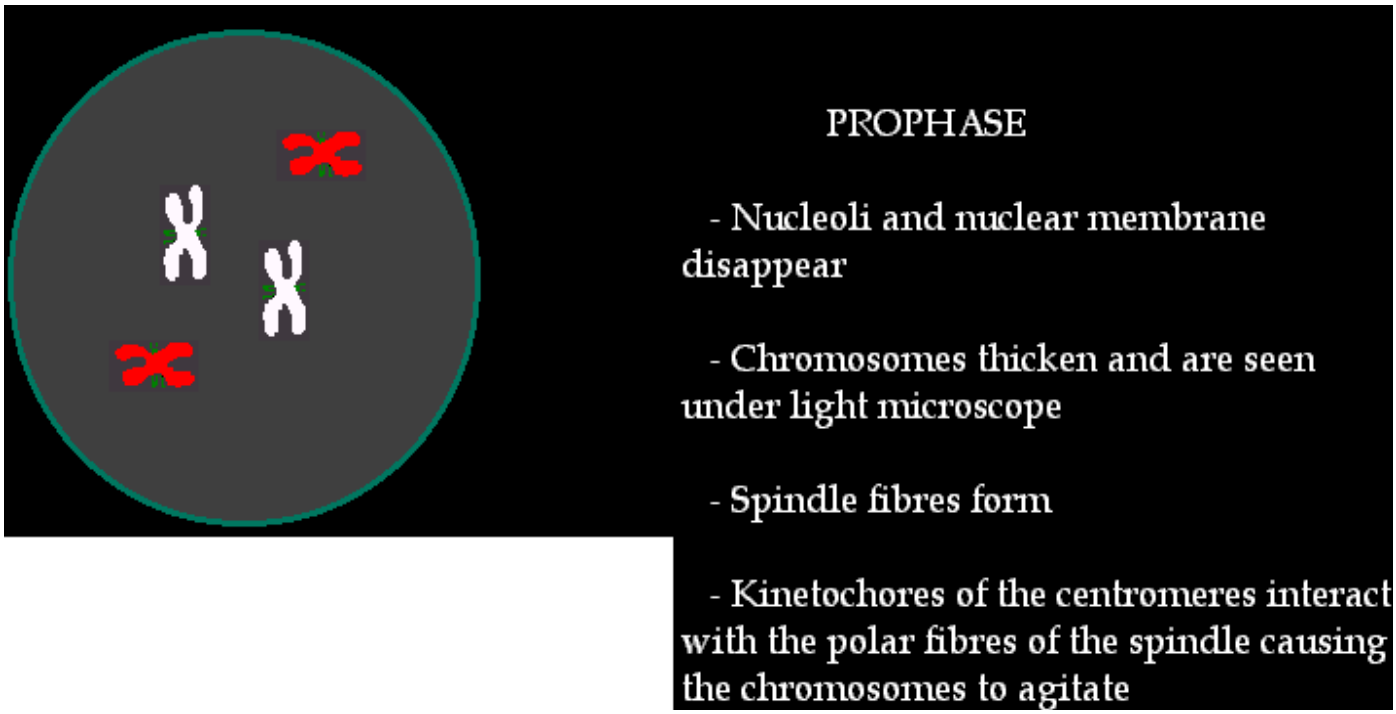

Figure 9. Interphase.

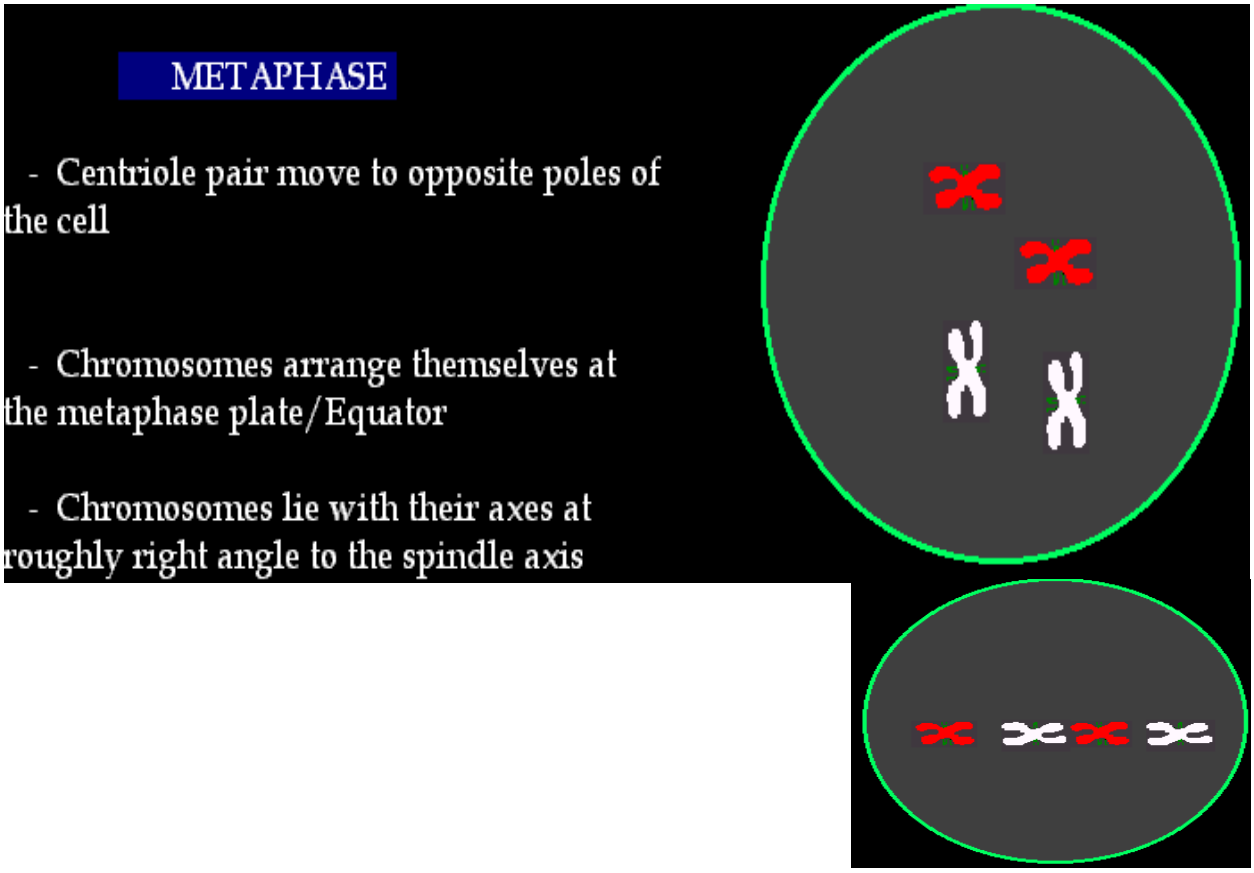

Figure 10. Prophase.

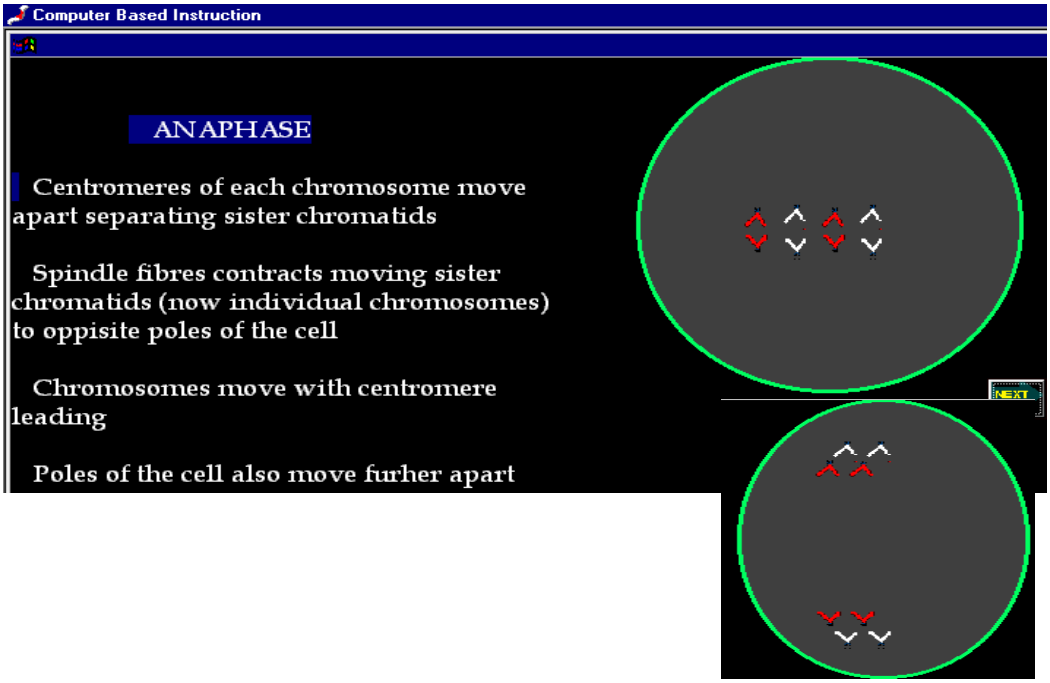

Figure 11. Metaphase.

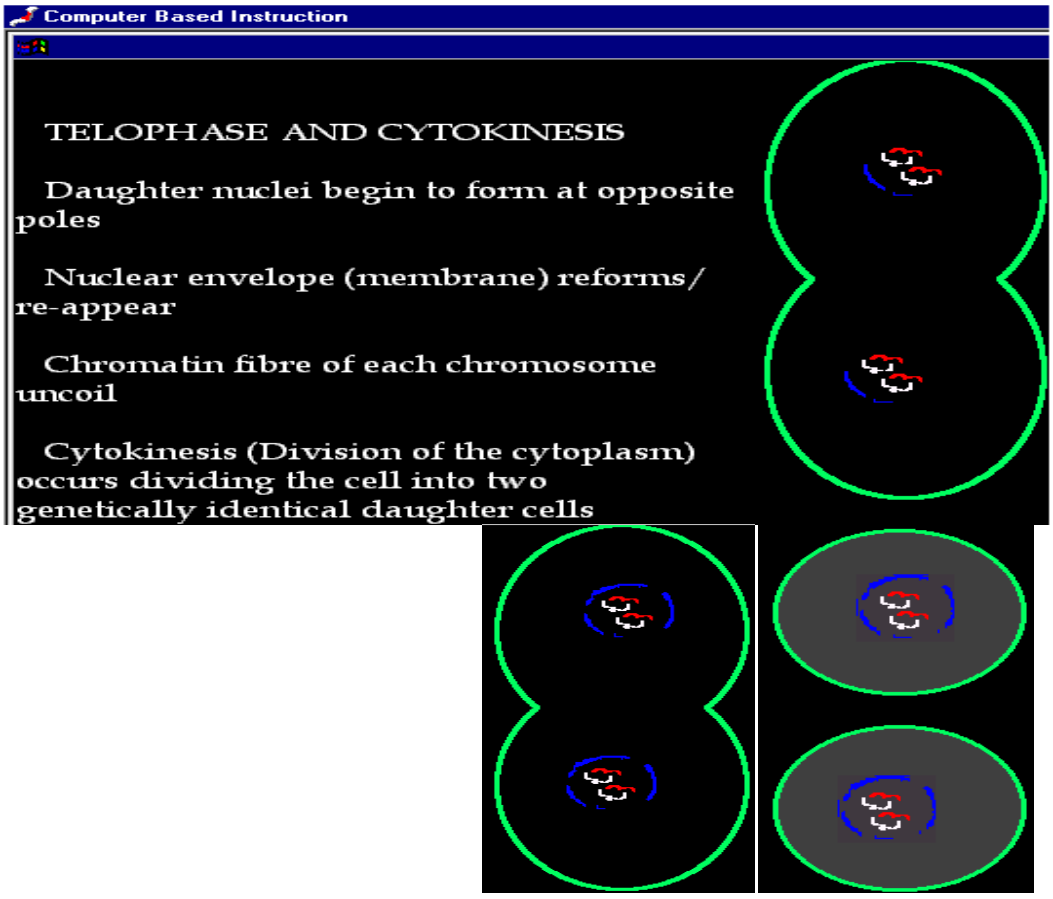

Figure 12. Anaphase.

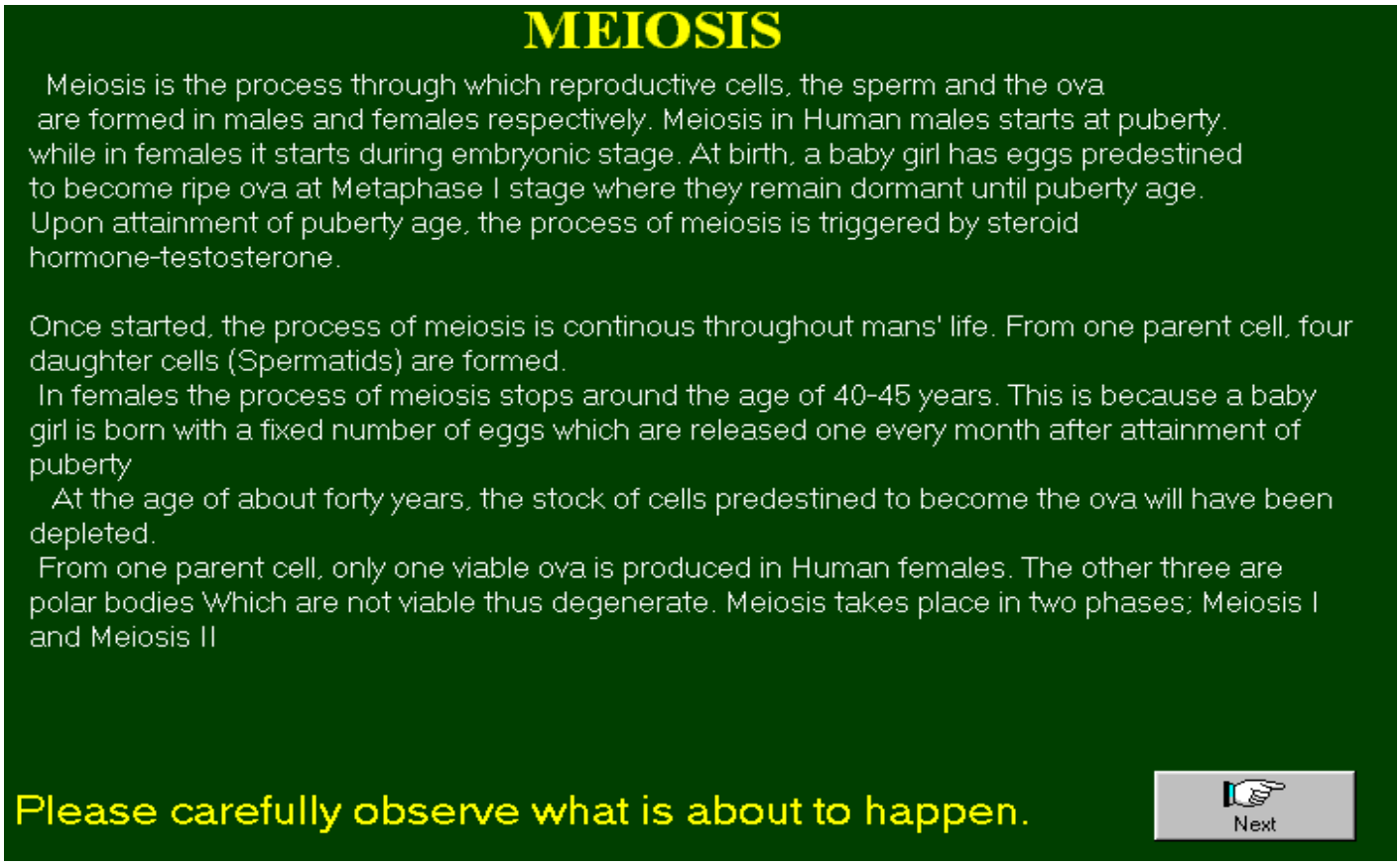

Figure 13. Telophase and Cytokinesis.

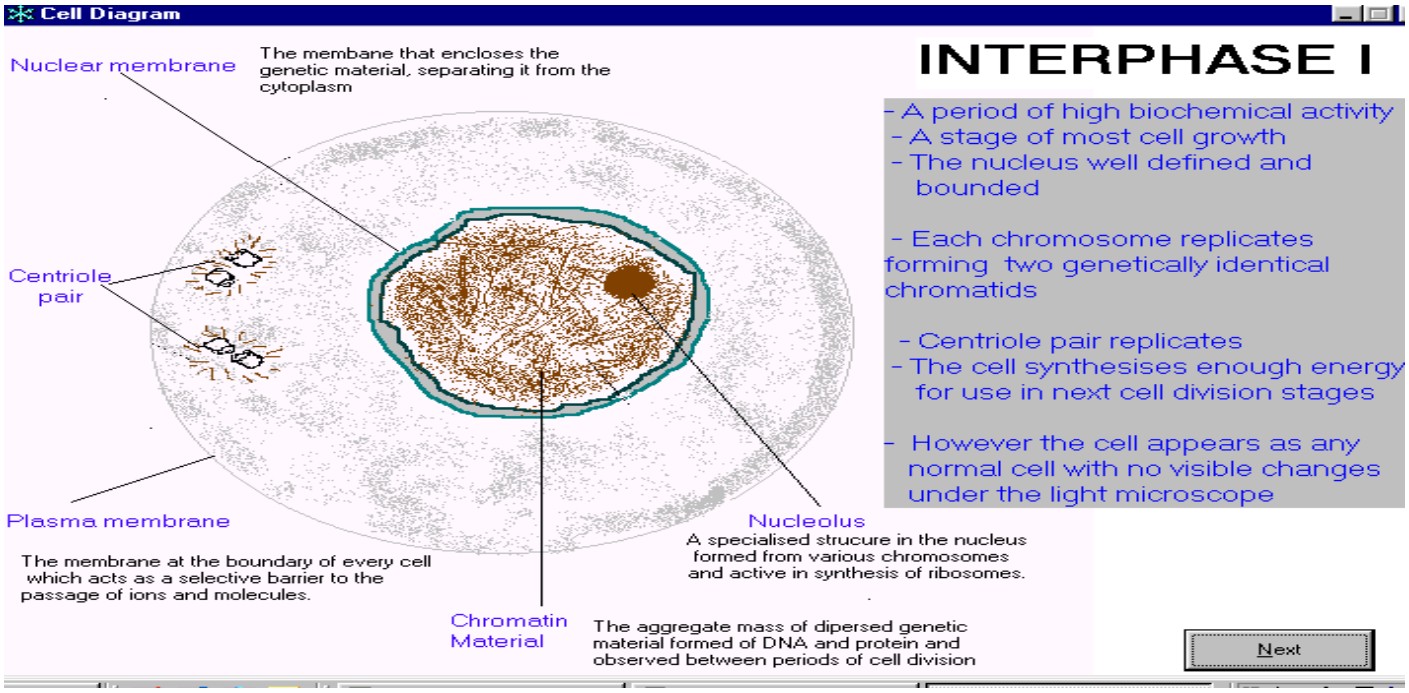

Figure 14. Meiotic division.

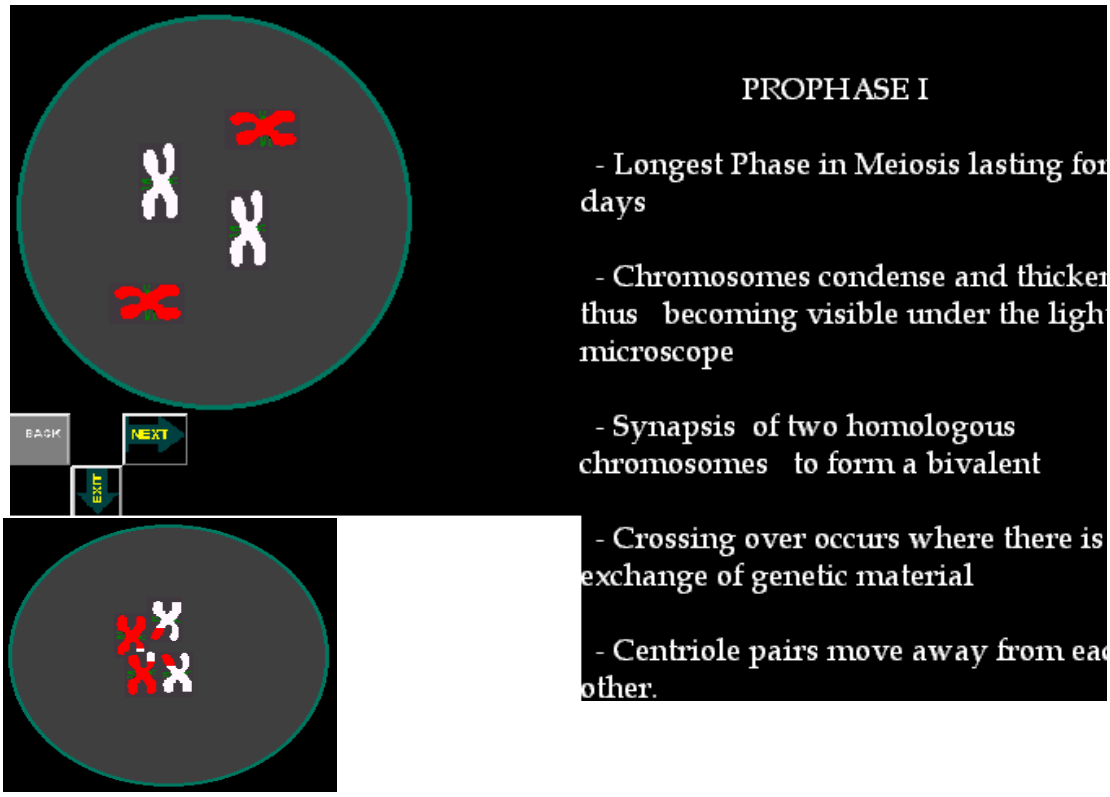

Figure 15. Interphase 1.

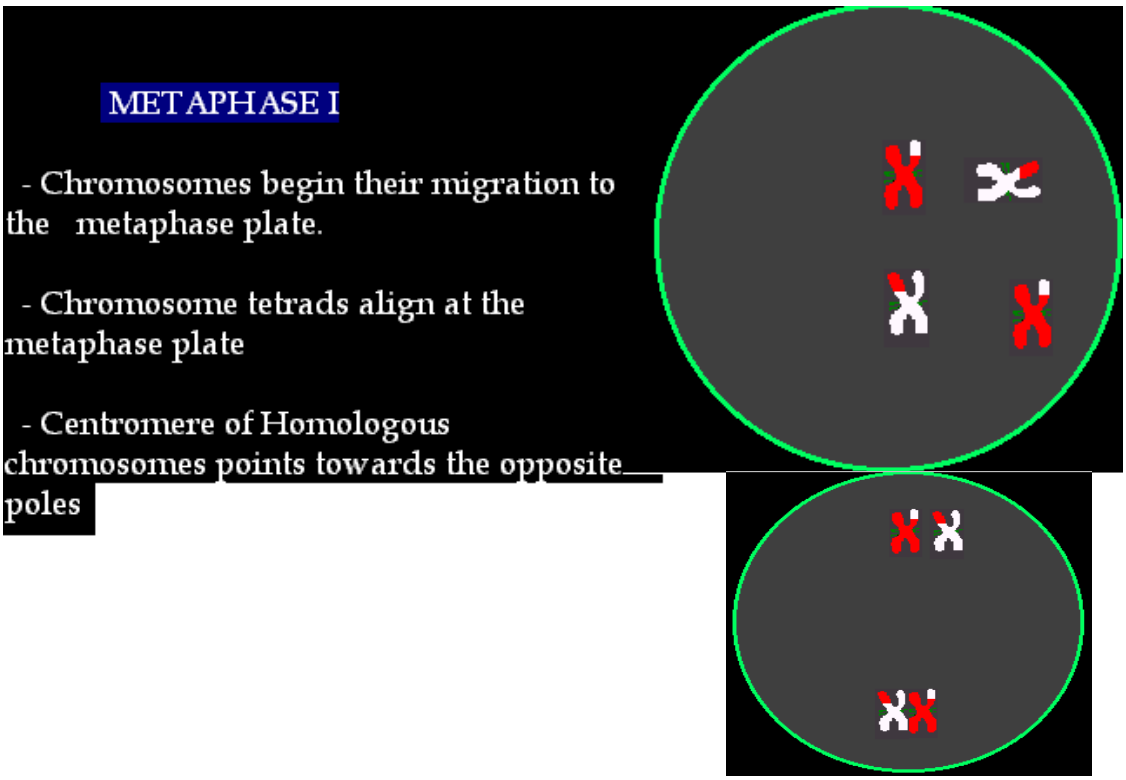

Figure 16. Prophase 1.

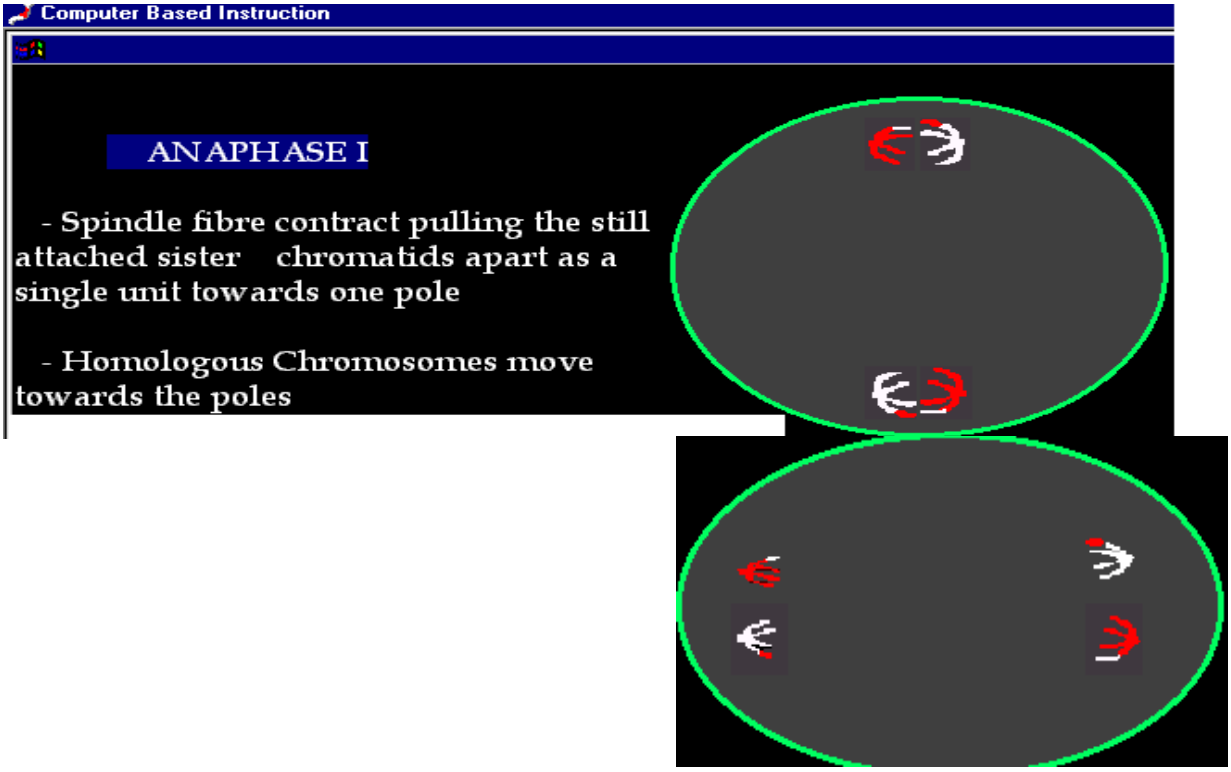

Figure 17. Metaphase 1.

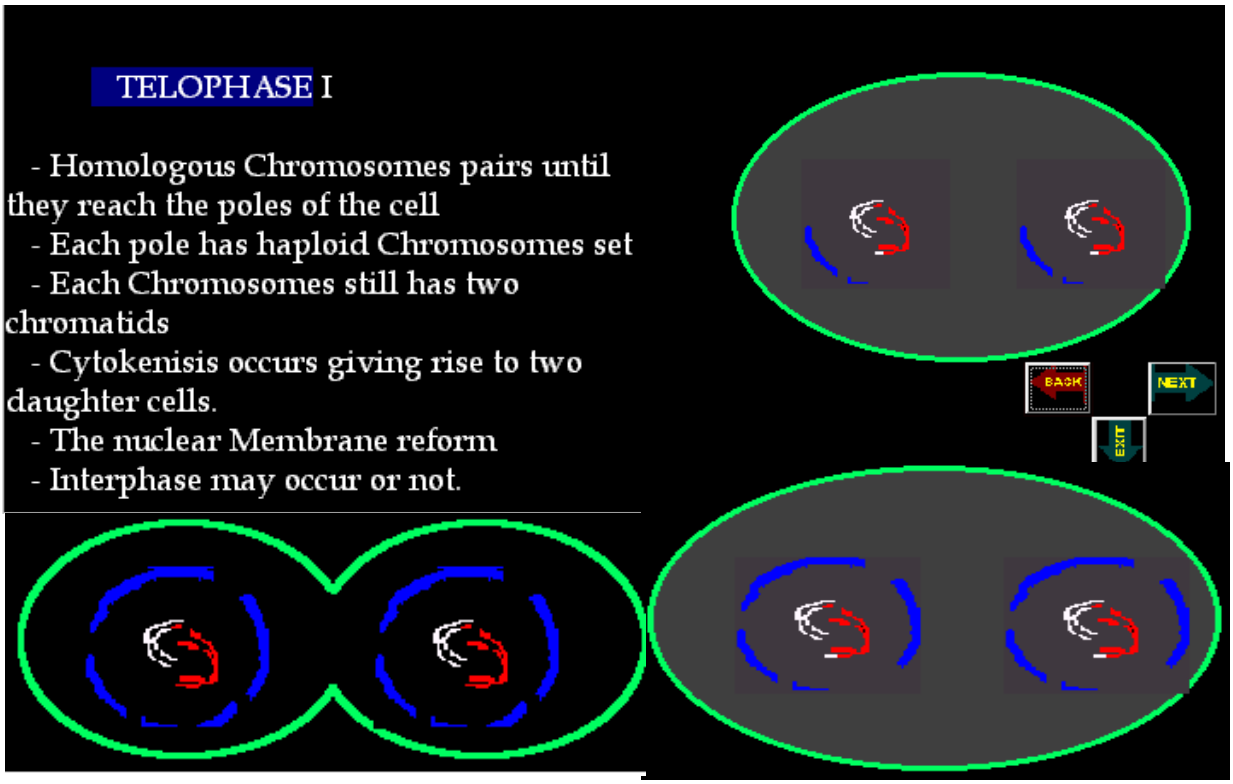

Figure 18. Anaphase 1.

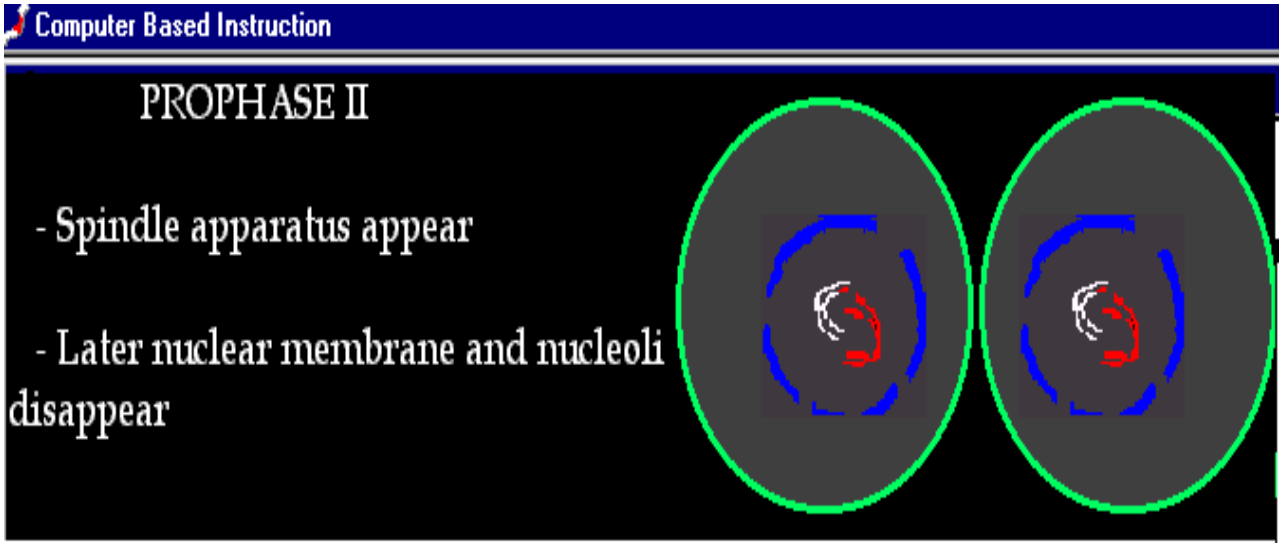

Figure 19. Telophase 1.

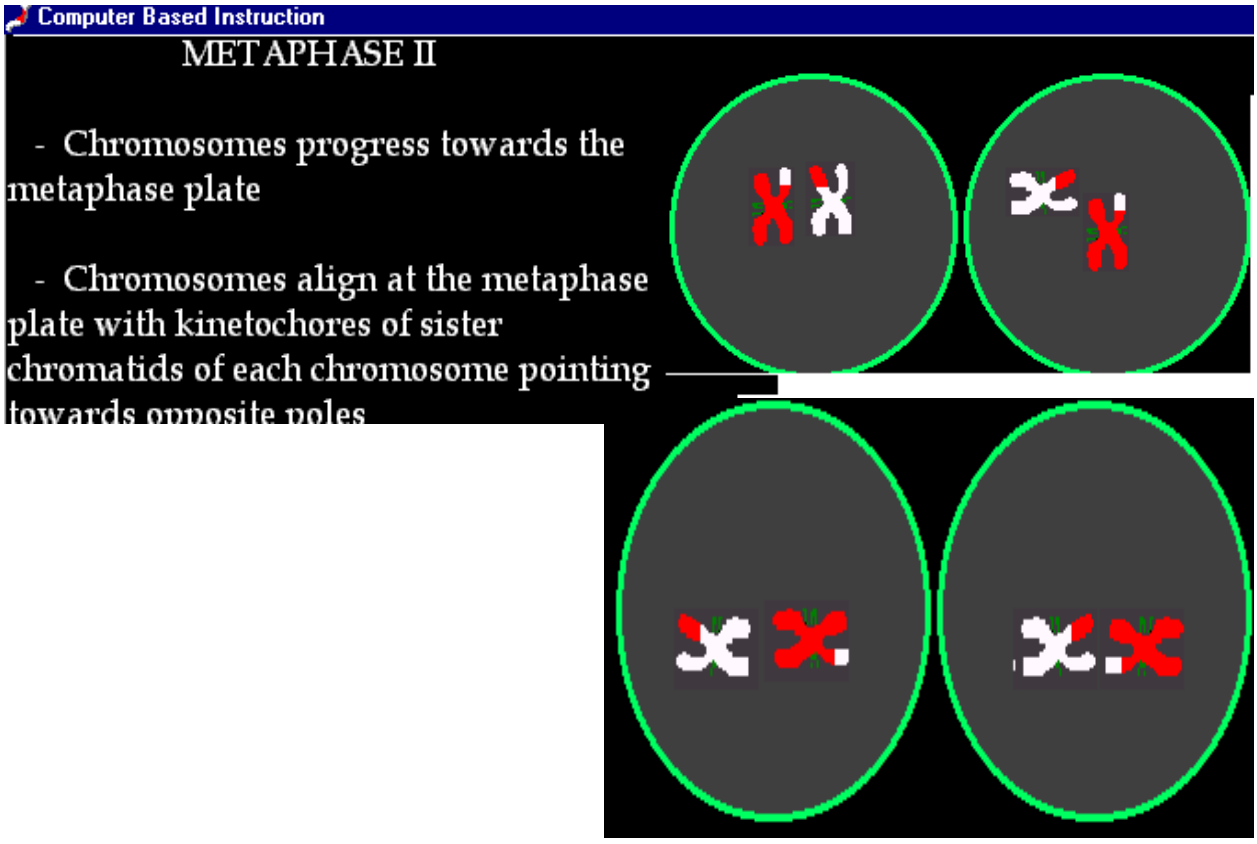

Figure 20. Prophase II.

attributes of the computer combine verbal codes with graphical illustrations and animation to give the learner not only a wider range of learning activities and tasks within the concept of cell division but also provide them with the options to interact more overtly with the instructional material and hence engender more active

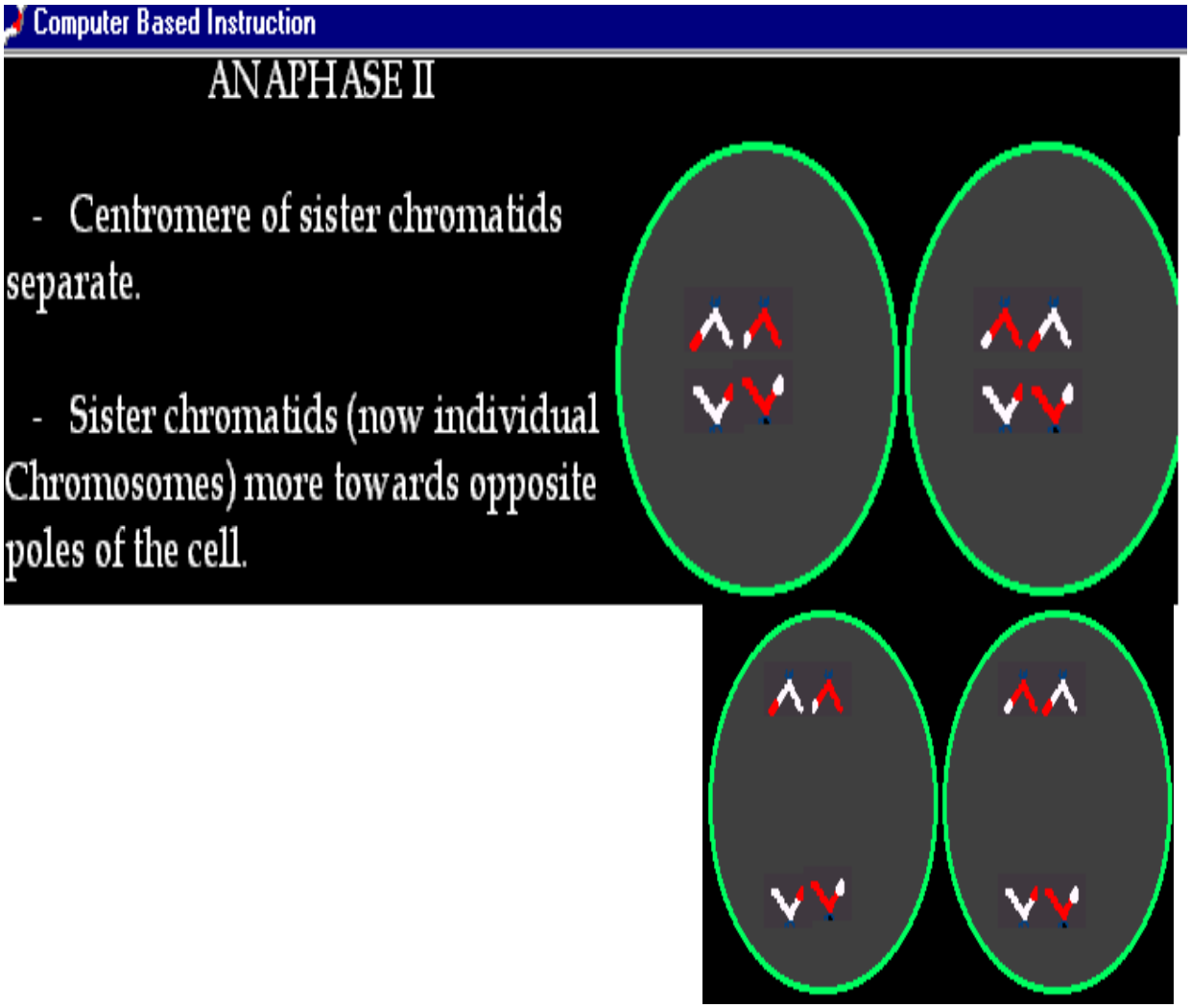

Figure 21. Metaphase II.

processing of information (Gavora and Hannafin, 1995; Kiboss, 1997).

The design of the CMS learning environment was based on two major assumptions that persist in achieving the above goals not available in the regular instructional method. Firstly, appropriate instructional methods that would bring out the dynamic nature of the process of cell division are not available. Secondly, improvement in cognition occurs when students experience and interact with the learning materials unlike in regular instruction where students are passive. As such, the CMS simulation may serve effectively as a facilitator to the learner's cognitive processing and positive attitudinal change towards cell division topic in school biology.

Constructs of the module

The CMS module sought to bring to the student the dynamics of the process of cell division. This was considered important in enhancing students' conception that the process of cell division does not occur in discrete stages and it is not static as depicted in textbooks. This was achieved by simulating the process of cell division by use of animated colour graphic images through a multi-sensory approach. In this regard, the learner accessed the content presented by logging into the computer which first presented the objectives expected to be achieved by the end of the topic. The learner could then proceed to introduction where definition and description of a chromosome is presented by clicking the neat button. This process is repeated after every section of the processes involved in the meiosis and mitosis stages. A detailed presentation of the CMS as presented on computer is outlined in Figures 1 to 22.

THE RESEARCH DESIGN

The study utilised the Solomon-Three Group design

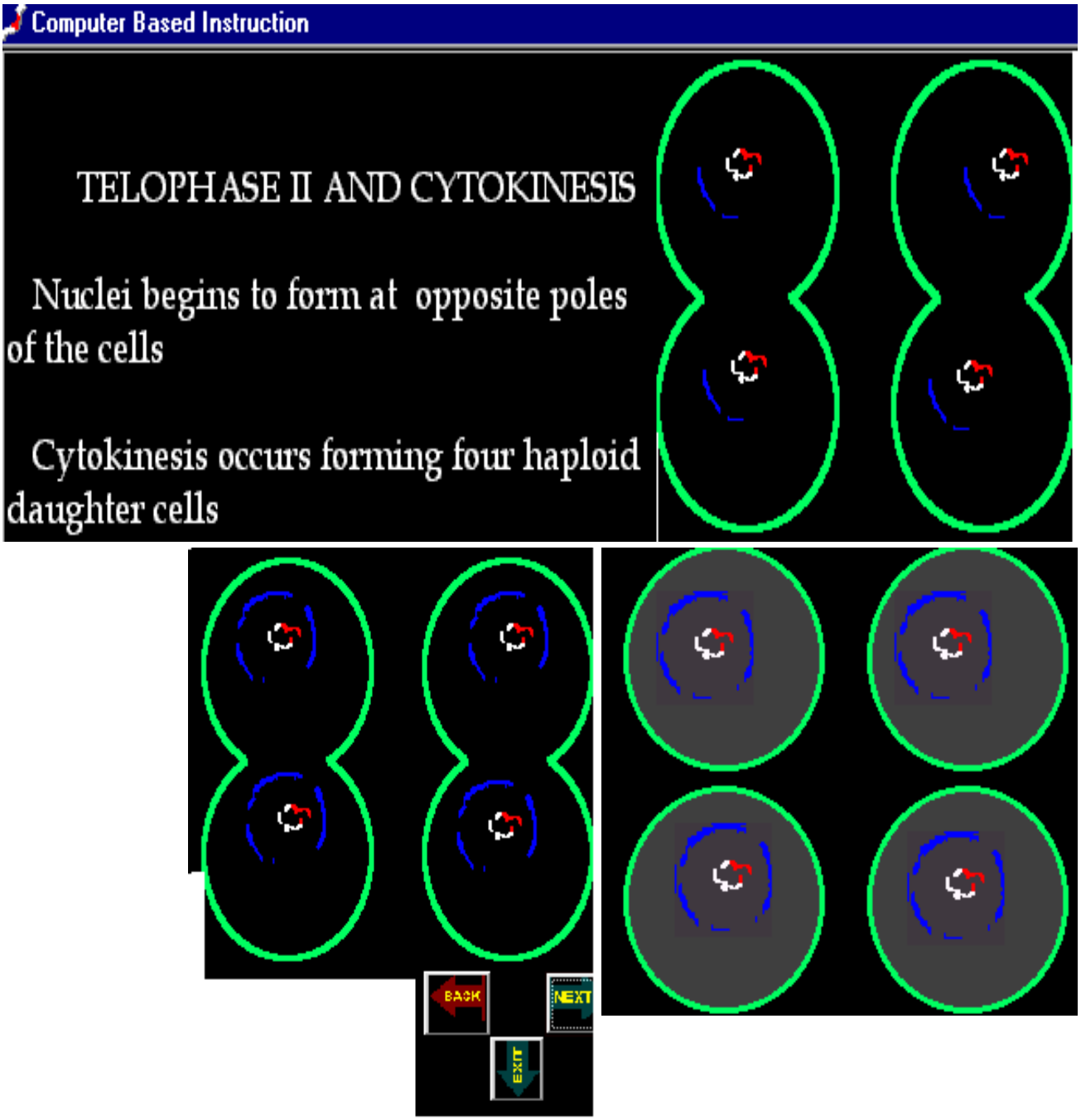

Figure 22. Anaphase and Cytokinesis II.

(Table 1), which is considered sufficiently rigorous and appropriate for experimental and quasi-experimental studies (Ogunniyi, 1992). Solomon-Three Group design involves a random assignment of subjects to three groups with two groups taking the pre-test and one not taking it. One pre-tested group and the other that is denied the pre-test are usually exposed to the treatment (Koul, 1984; Ogunniyi, 1992). However, this study adopted the quasi-experimental approach because the subjects were already constituted and it was not possible to randomly select them individually. This was because school authorities do not allow random assignment of individual subjects once they are already constituted.

Nevertheless, this research design can provide adequate control of the extraneous variables that would have otherwise affected the internal and external validity of the study. According to Koul (1984), the reactive effects of experimentation are more easily controlled

Table 1. The Randomised Solomon Three-Group Design.

Randomly assigned	Dependent variable (T_1)	Independent variable	Dependent variable (T_2)
Experimental group (E)	$T_1E\ 0_1$	Teaching using CBI module	$T_2E\ 0_2$
Control group I (C_1)	$T_1C_1\ 0_3$	Teaching using conventional methods	$T_2C_1\ 0_4$
Control group II (C_2)	No pre-test	Teaching using CBI module	$T_2C_2\ 0_5$

Source: Koul (1984). Key: T_1 - Pre-test; T_2 - Post test; 0_{1-5} - Observations of dependent variables.

Table 2. A comparison of the subjects' pre-test and post-test mean scores obtained by the subjects on the BAT.

Scale	Group			
	Overall	E (n = 30)	C_1 (n=32)	C_2 (n = 40)
Pre-test	3.42	3.43[a]	3.40[a]	-
S.D	1.75	1.76	1.74	-
Post-test	25.65	28.03[b]	19.88	29.03[b]
S.D	5.72	6.45	3.98	6.73
Mean gain	22.23	24.60	16.48	-

[a,b] denotes similar mean scores.

through this design because the subjects are less aware of the fact that they are being subjected to the experimental treatment than when the subjects are randomly drawn individually and put into experimental sessions. Contamination was taken care of by having the treatment and control groups being situated in different schools. Also, statistical regression was taken care of by having another group of subjects (C_2) not taking the pre-test. In this study, one group served as the experimental group (E) and two others as control groups. However, the C_2 became a control group only because the pre-test was withheld.

Sample size

This study involved three mixed secondary schools situated along Nakuru-Nyahururu and Nakuru-Mau-Narok roads. The schools were purposively sampled on the basis of easy accessibility and the availability of IBM compatible computers. A total of 102 form three students (59 males and 43 females) were randomly selected from three intact classes that served as the experimental group (E) and the control group 1 (C_1) and control group II (C_2). In the study, two groups (E and C_1) were pretested but all were post tested after treatment.

Instruments

In this study, the variables of interest are the students' learning outcomes in biology course on cell theory that were used to determine the validity and reliability of the CMS module. The first is students' academic achievement that was assessed using the Biology Achievement Test (BAT), which was developed for the purpose of this study. BAT, consisting of a 30-item paper and pencil instrument (that is, 20 multiple-choice and 10 completion questions) was reviewed by six experts knowledgeable in science education. After it was piloted, a reliability coefficient of 0.81 was obtained using K-21 formula.

The second dealt with the affective realm referred to as students' attitude towards the biology course on cell division. One paper-and-pencil checklist instrument measured the students' affective learning outcomes namely the Students' Attitude Questionnaire (SAQ). Six experts vetted the items and scales before they were tried on a group of students (N=20) from Njoro area. SAQ instrument consisted of 20 Likert-type scales. The piloting of these instrument yielded reliability coefficient of 0.78 using the K-21 formula. This value is higher than the suggested suitable level of 0.70 (Fraenkel and Warren, 1998).

RESULTS AND DISCUSSION

The effect of the CMS on students' learning outcomes on the concept of cell division was determined by the ANOVA tests using the SPSS computer software.

Effects of CMS on students' academic achievement as measured by BAT

The results presented in Table 2 shows the distribution of both the pre-test and post-test mean scores obtained by the subjects on the BAT.

A close examination of the results in Table 2 indicates

Table 3. Comparison of the pre-test and post-test mean scores obtained by the subjects on the SAQ.

Scale	Group			
	Overall	E	C_1	C_2
Pre-test	62.18	61.57[a]	62.78[a]	-
S.D	4.21	4.61	3.81	-
Post-test	70.53	73.40[b]	64.98	73.22[b]
S.D	5.32	5.12	3.85	6.99
Mean gain	8.35	11.85	2.20	-

[a,b] denote similar mean scores.

a significant gain in terms of academic achievement in favour of the treatment group. For instance, the mean score obtained by the subjects in the E group (M=28.03) and C_2 (M=29.03) on the BAT are similar, and significantly higher than that of C_1 (M=19.88) that did not receive the CMS treatment.

A further analysis using the Turkey's-Honest Significant Difference (THSD) for multiple range test revealed a mean difference of 8.16 between E group and C_1 group, and that of 9.77 obtained between C_1 and C_2 were statistically significant at $P<0.05$. However, no statistically significant difference was established between the mean scores of treatment groups E and C_2 as it was only 0.99.

These findings support earlier studies, which concluded that the use of CMS programmes involving the students more actively in the learning process result in higher achievement (Kiboss, 1997; 2000; Wekesa, 2003; Wenglinsky, 1998).

Effects of CMS module on students' attitude towards cell division

The results shown in Table 3 suggest that the CMS module positively influenced the students' attitude towards the topic of cell division in school biology.

On the overall, there was a mean score gain of 8.35 on students' attitude. However, the groups E and C1 scored differently on the post-test and the results reveal a markedly higher gain of 11.85 in favour of the treatment group as opposed to the 2.20 obtained by the control group. Moreover, the mean score gain of the CMS group was much higher than the overall mean gain of 8.35.

These results are in agreement with earlier findings showing that the use of CMS significantly affect the affective realm of students towards the scientific concepts that are considered hard and difficult for students to learn and teachers to teach (Kiboss, 1997, 2002; Wekesa, 2003).

Limitation of the CMS module

The CMS module was designed to run on IBM compatible computers only and will therefore not run on DOS prompt.

Conclusion

The main goal of this study was to design and develop a valid CMS module for the teaching of cell division topic in school biology in Kenya. In this paper, an attempt was made to use quantitative findings on three dependent measures to determine the validity and reliability of the CMS module.

On the whole, and considering the significant learning gains, there is evidence to suggest that the CMS module was effective in positively influencing the students' understanding of the cell division topic in school biology. This study also demonstrated that CMS have potential for favourable effects on the students' achievement, perception of the classroom environment and attitude towards cell division.

As such, the problem of the concept of cell division being a difficult topic for students to learn and teachers to teach may be resolved by the use of a CMS module that emphasize interactive student learning.

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