

Full Length Research Paper

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

Wekesa D. W.^{1*}, Wekesa E. W.² and Amadalo M. M.¹

¹Department of Science and Mathematics Education, Masinde Muliro University of Science and Technology, Kenya.

²Lubinu Boys High School, Mumias, Kenya.

Accepted 12 April, 2013

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

*Corresponding author. E-mail: duncanwasike@yahoo.com.

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.

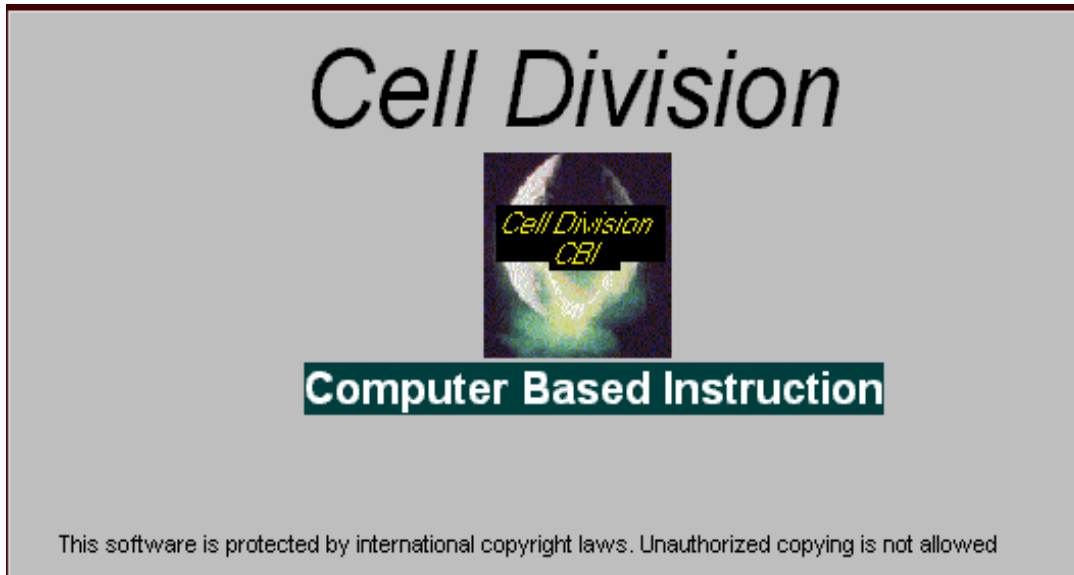


Figure 1. CBI logo.



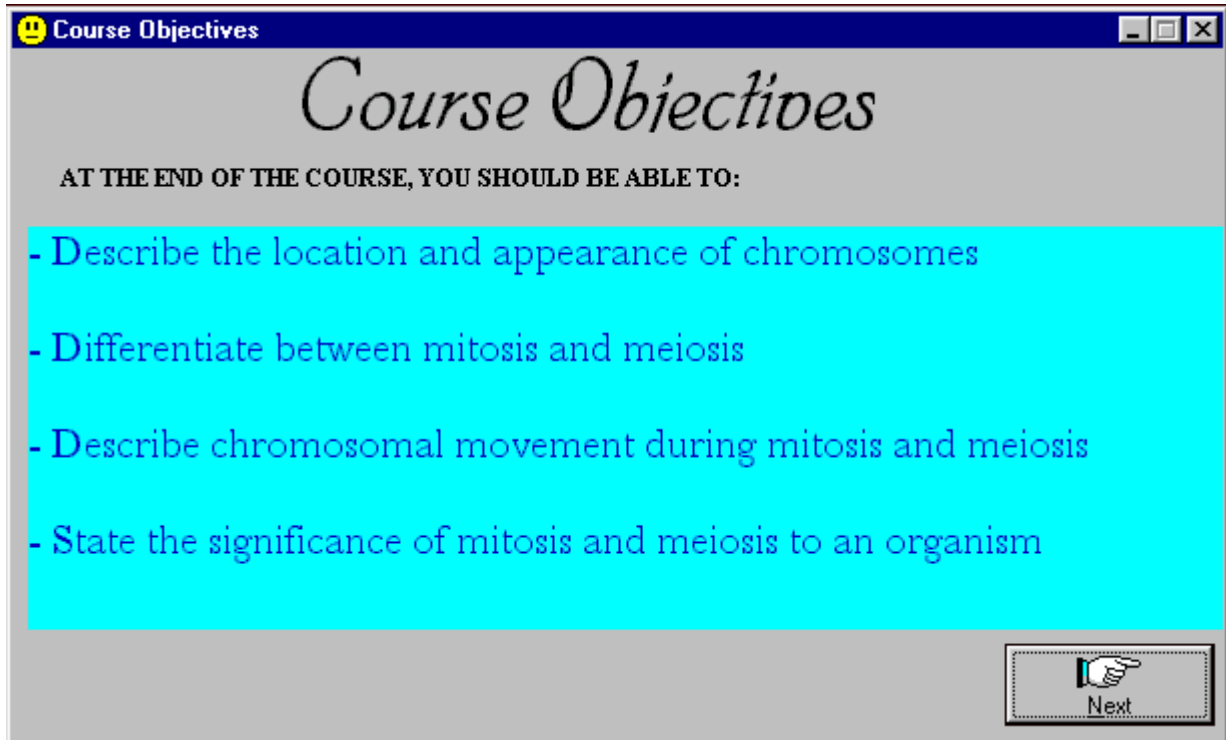
Figure 2. Welcome page.

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



Course Objectives

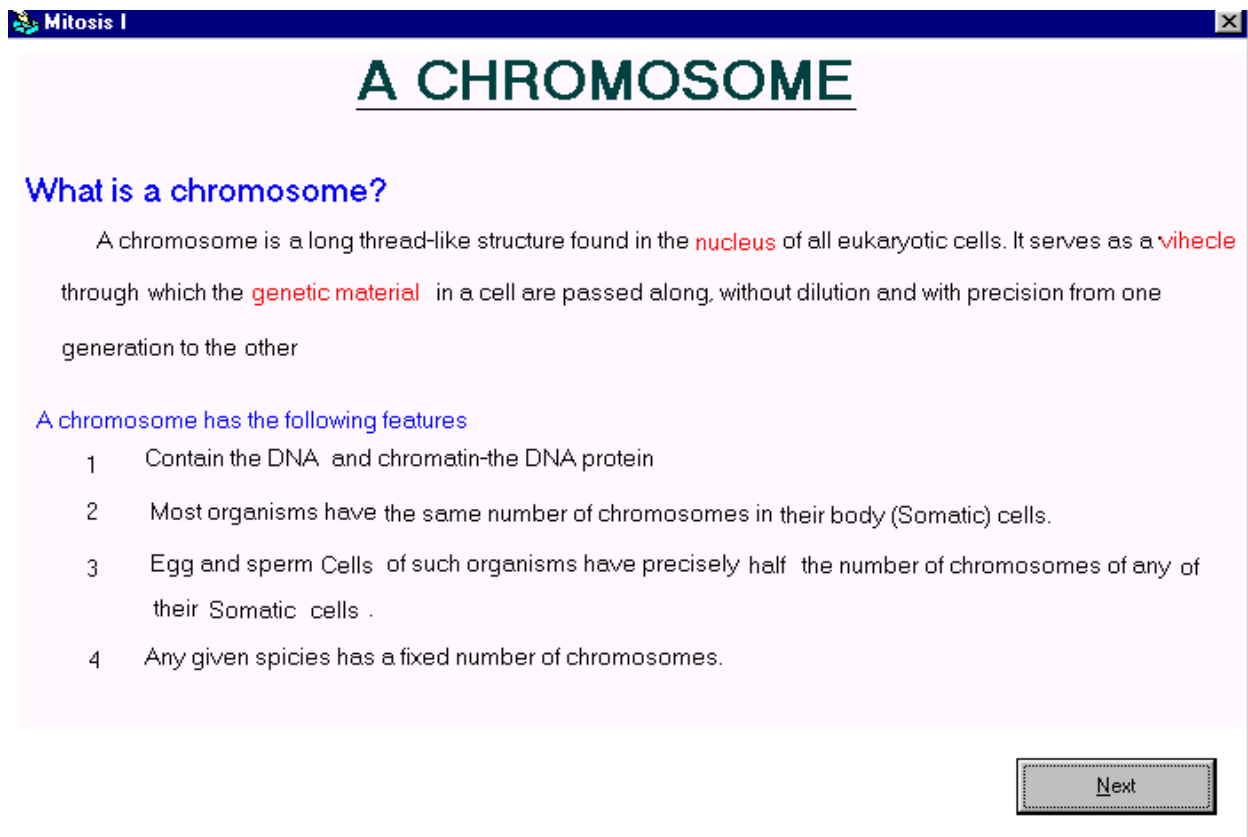
Course Objectives

AT THE END OF THE COURSE, YOU SHOULD BE ABLE TO:

- Describe the location and appearance of chromosomes
- Differentiate between mitosis and meiosis
- Describe chromosomal movement during mitosis and meiosis
- State the significance of mitosis and meiosis to an organism

Next

Figure 3. Course objectives.



Mitosis I

A CHROMOSOME

What is a chromosome?

A chromosome is a long thread-like structure found in the **nucleus** of all eukaryotic cells. It serves as a **vehicle** through which the **genetic material** in a cell are passed along, without dilution and with precision from one generation to the other

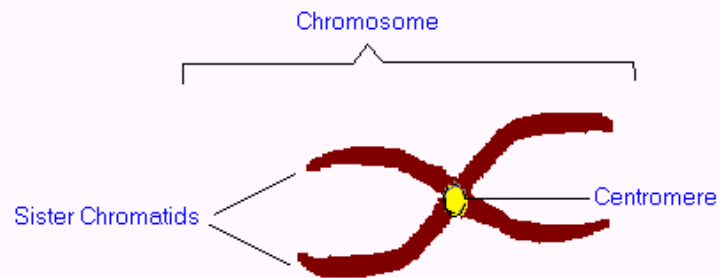
A chromosome has the following features

- 1 Contain the DNA and chromatin-the DNA protein
- 2 Most organisms have the same number of chromosomes in their body (Somatic) cells.
- 3 Egg and sperm Cells of such organisms have precisely half the number of chromosomes of any of their Somatic cells .
- 4 Any given species has a fixed number of chromosomes.

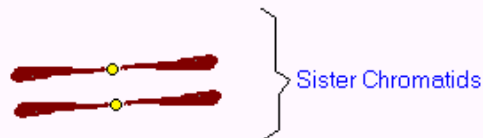
Next

Figure 4. Definition of chromosome.

The following diagram shows the structure of a chromosome



- 5 Chromosomes replicate just before cell division each forming identical structure called chromatids shown below.



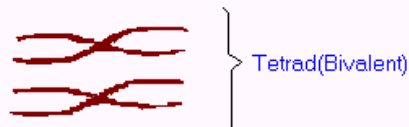
Next

Figure 5. Formation of a chromosome.

Computer Based Instruction

- 6 Sister chromatids are joined together at specialised region called centromere.
- 7 Chromosomes of same length, centromere position and staining pattern possessing genes of the same trait at corresponding positions are called **homologous** chromosomes.
- 8 One homologous chromosome is inherited from the organism's father, the other from the mother.
- 9 During cell division, homologous chromosomes come together forming the **tetrad** (bivalent) that result into crossing over with formation of **chiasma**

The diagram below shows a tetrad formed between homologous chromosomes.



Next

Figure 6. Structure of a chromosome.

MITOSIS

life starts from a single cell, the zygote. Through a series of cell division called mitosis, a single cell develops into a complex multicellular organism with many organ systems of individual organs made up of specialised tissues of cells.

In a normal organism, you included, cells are always dividing (e.g skin cells) or divide when provoked to do so by internal (growth and development) or external environments (Injury, availability of resources e.t.c)

During mitotic division, the cell goes through the following stages:

- Interphase
- Prophase
- Metaphase
- Anaphase
- Telophase

During mitosis, a complete cycle of these stages forms two daughter cells from one parent cell all genetically identical.

Though this process of cell division takes place continuously in our bodies, it is so unconscious that you can not realise changes in your own body, least in another person unless over long period of physical separation. The following simulated situations of what happens in the cell will help you understand what actually happens during mitotic cell division.

Please carefully observe what is about to happen.

Next

Figure 7. Tetrad formation.

Nuclear membrane
The membrane that encloses the genetic material, separating it from the cytoplasm

Centriole pair

Plasma membrane
The membrane at the boundary of every cell which acts as a selective barrier to the passage of ions and molecules.

Nucleolus
A specialised structure in the nucleus formed from various chromosomes and active in synthesis of ribosomes.

Chromatin Material
The aggregate mass of dispersed genetic material formed of DNA and protein and observed between periods of cell division

INTERPHASE

- A period of high biochemical activity
- A stage of most cell growth
- The nucleus well defined and bounded

- Each chromosome replicates forming two genetically identical chromatids
- Centriole pair replicates
- The cell synthesises enough energy for use in next cell division stages

- However the cell appears as any normal cell with no visible changes under the light microscope

Next

Figure 8. Mitotic division.

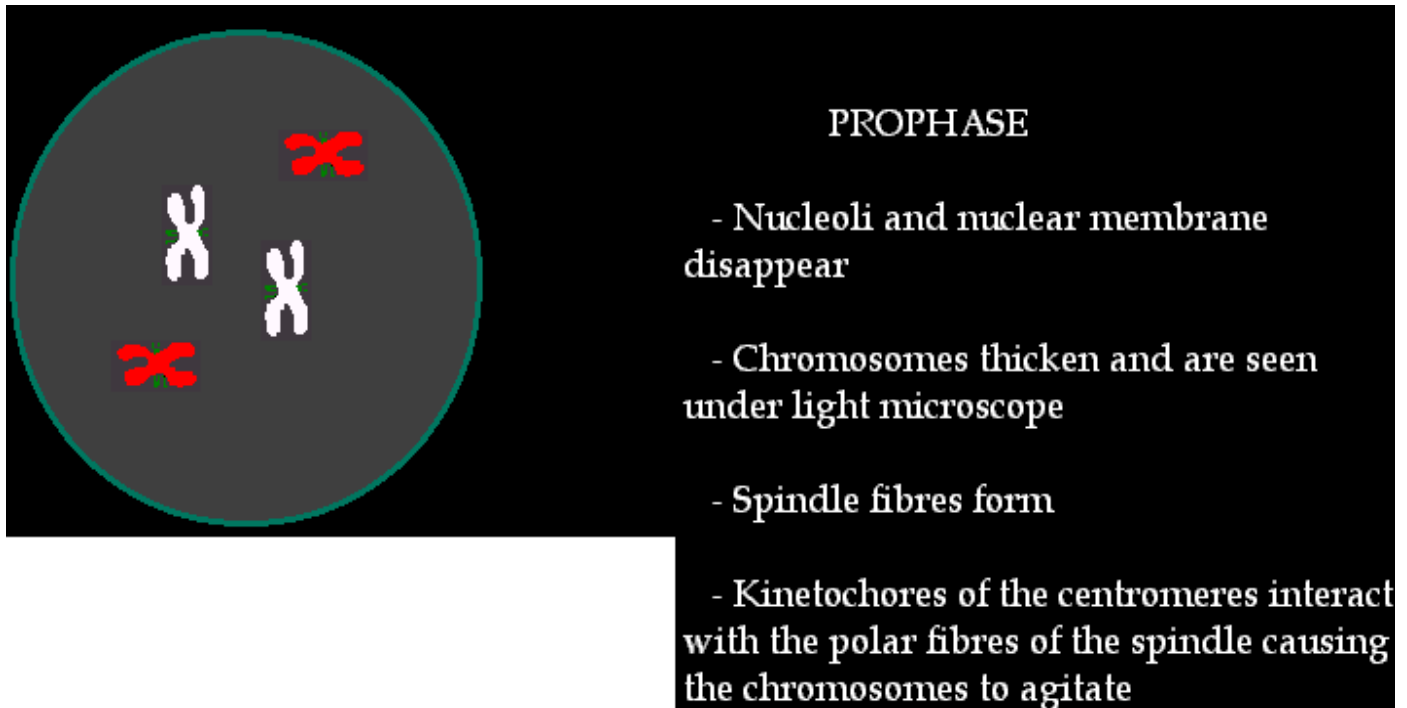


Figure 9. Interphase.

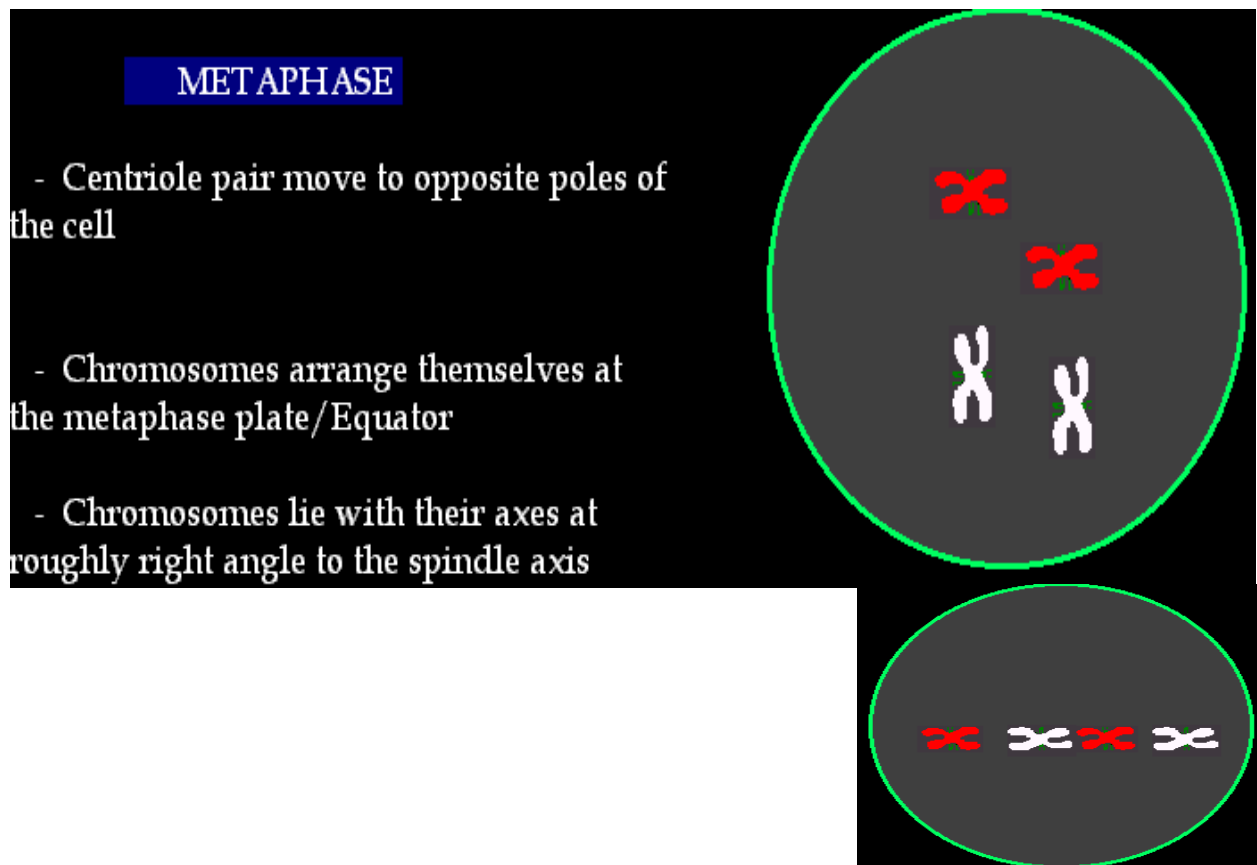


Figure 10. Prophase.

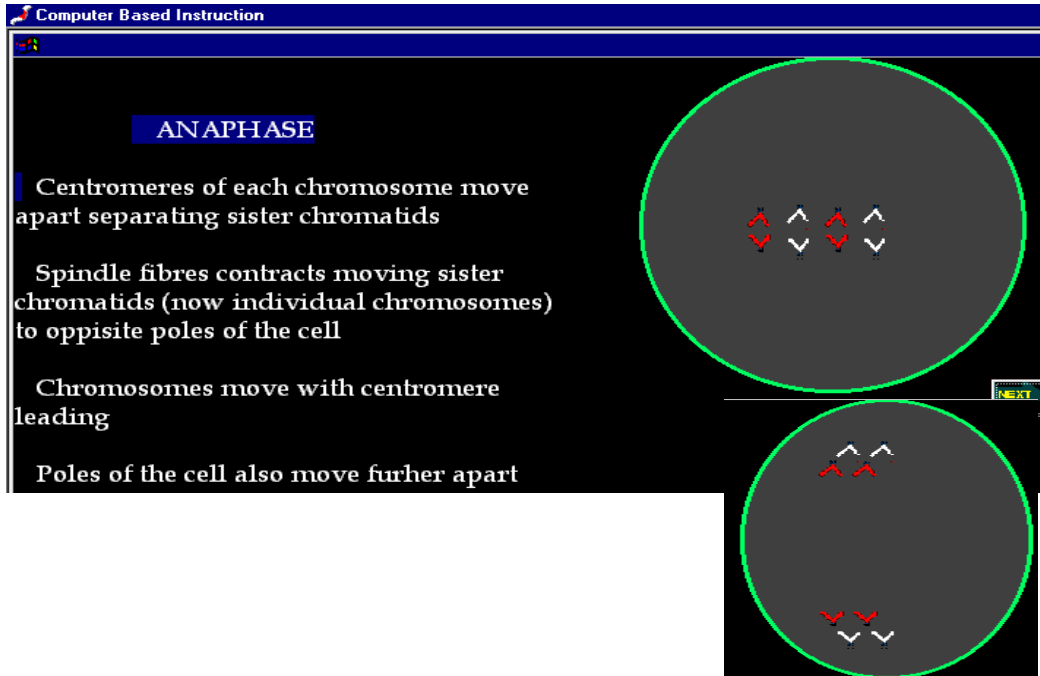


Figure 11. Metaphase.

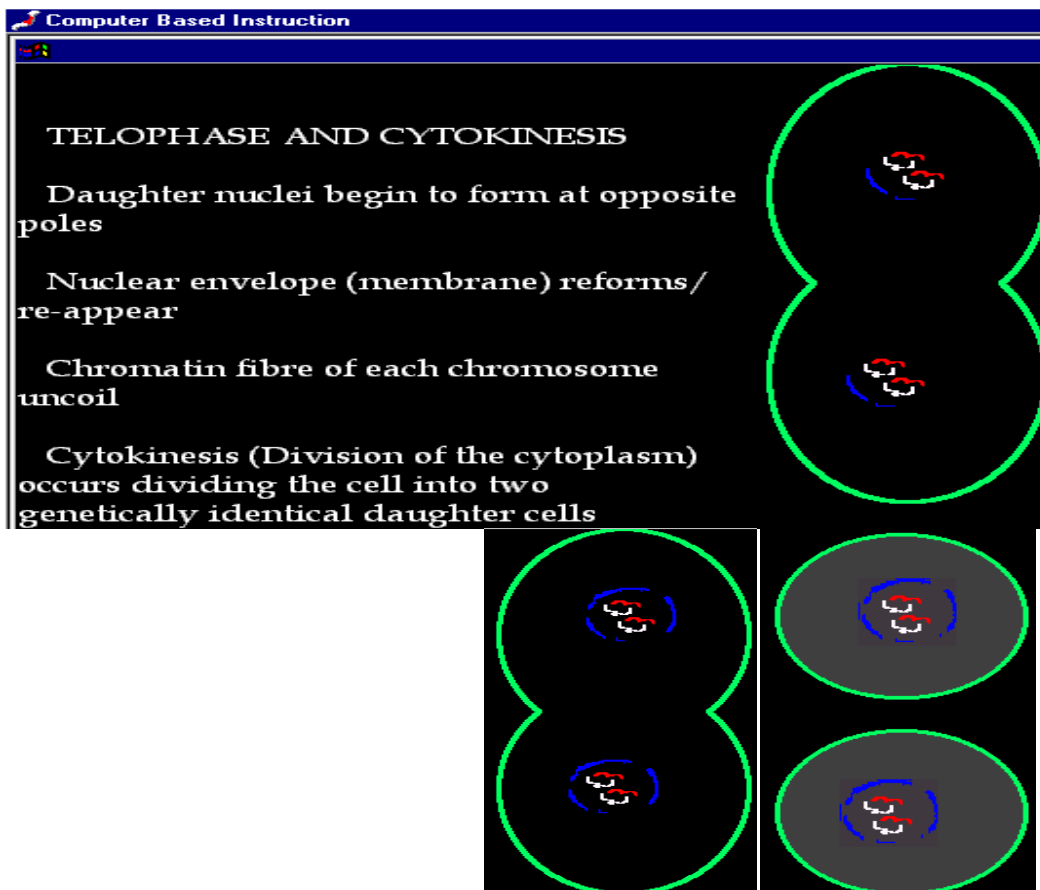


Figure 12. Anaphase.

MEIOSIS

Meiosis is the process through which reproductive cells, the sperm and the ova are formed in males and females respectively. Meiosis in Human males starts at puberty, while in females it starts during embryonic stage. At birth, a baby girl has eggs predestined to become ripe ova at Metaphase I stage where they remain dormant until puberty age. Upon attainment of puberty age, the process of meiosis is triggered by steroid hormone-testosterone.

Once started, the process of meiosis is continuous throughout mans' life. From one parent cell, four daughter cells (Spermatids) are formed.

In females the process of meiosis stops around the age of 40-45 years. This is because a baby girl is born with a fixed number of eggs which are released one every month after attainment of puberty

At the age of about forty years, the stock of cells predestined to become the ova will have been depleted.

From one parent cell, only one viable ova is produced in Human females. The other three are polar bodies which are not viable thus degenerate. Meiosis takes place in two phases; Meiosis I and Meiosis II

Please carefully observe what is about to happen.



Figure 13. Telophase and Cytokinesis.

✳ Cell Diagram
⌵ ⌵ ⌵

Nuclear membrane The membrane that encloses the genetic material, separating it from the cytoplasm

Centriole pair

Plasma membrane The membrane at the boundary of every cell which acts as a selective barrier to the passage of ions and molecules.

Nucleolus A specialised structure in the nucleus formed from various chromosomes and active in synthesis of ribosomes.

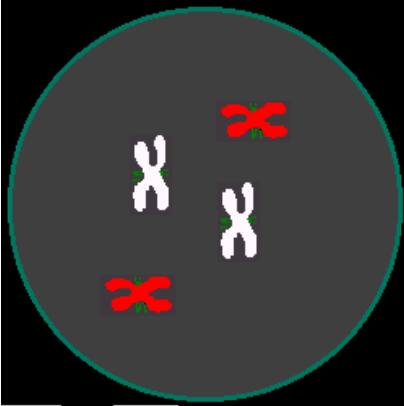
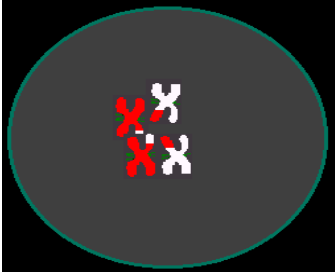
Chromatin Material The aggregate mass of dispersed genetic material formed of DNA and protein and observed between periods of cell division

INTERPHASE I

- A period of high biochemical activity
- A stage of most cell growth
- The nucleus well defined and bounded
- Each chromosome replicates forming two genetically identical chromatids
- Centriole pair replicates
- The cell synthesises enough energy for use in next cell division stages
- However the cell appears as any normal cell with no visible changes under the light microscope

Next

Figure 14. Meiotic division.

PROPHASE I

- Longest Phase in Meiosis lasting for days
- Chromosomes condense and thicken thus becoming visible under the light microscope
- Synapsis of two homologous chromosomes to form a bivalent
- Crossing over occurs where there is exchange of genetic material
- Centriole pairs move away from each other.

BACK
NEXT
EXIT

Figure 15. Interphase 1.

METAPHASE I

- Chromosomes begin their migration to the metaphase plate.
- Chromosome tetrads align at the metaphase plate
- Centromere of Homologous chromosomes points towards the opposite poles

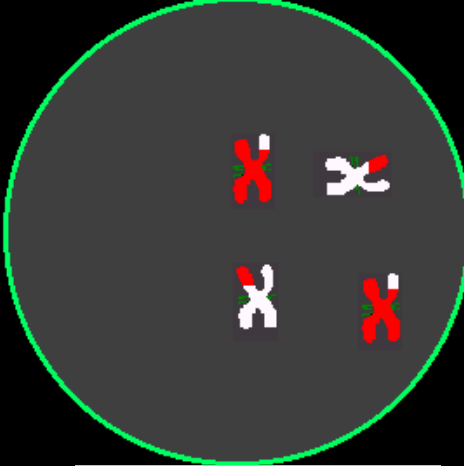
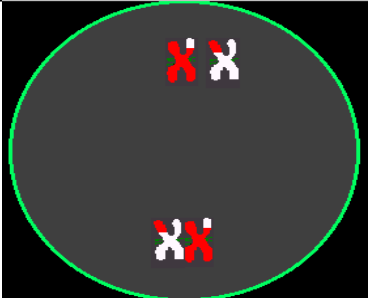



Figure 16. Prophase 1.



Figure 17. Metaphase 1.

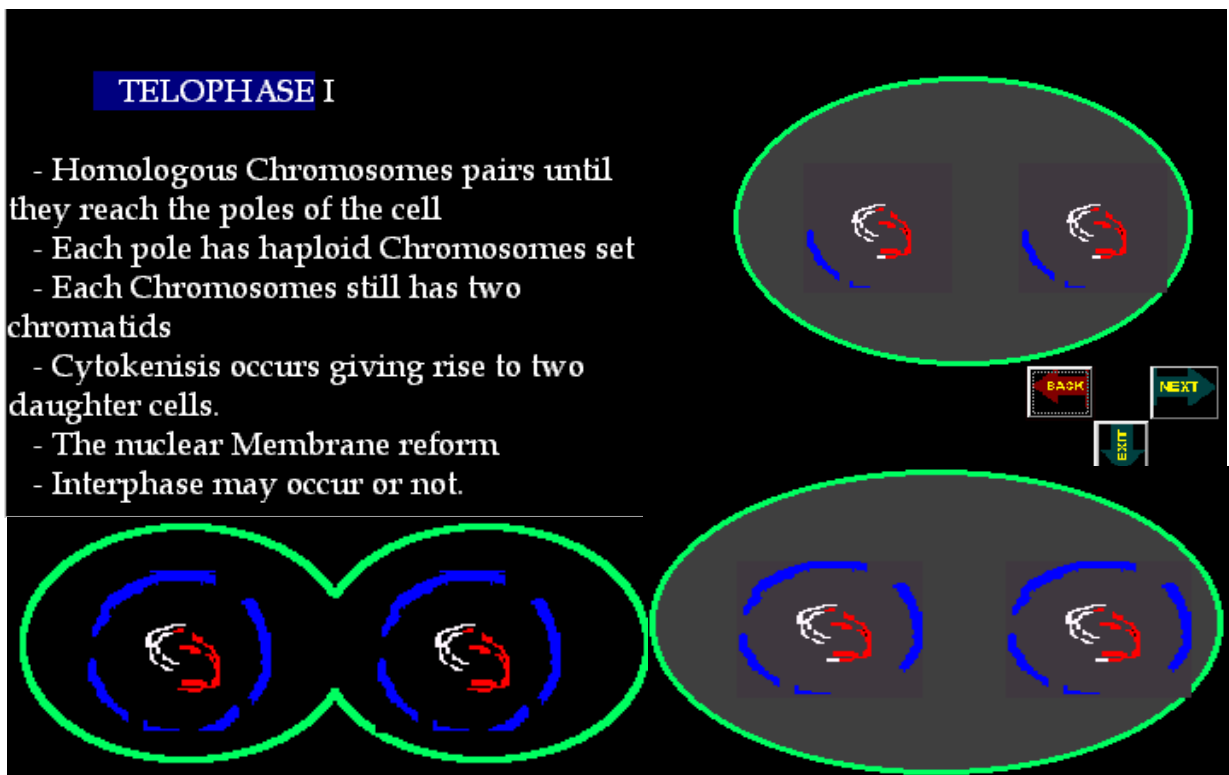


Figure 18. Anaphase 1.

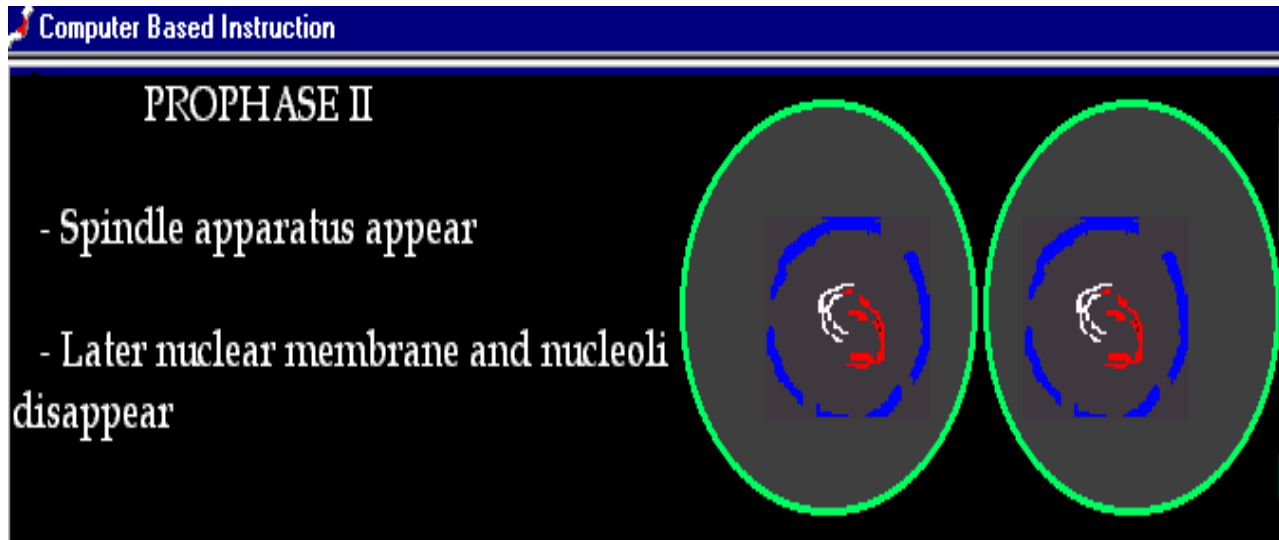


Figure 19. Telophase 1.

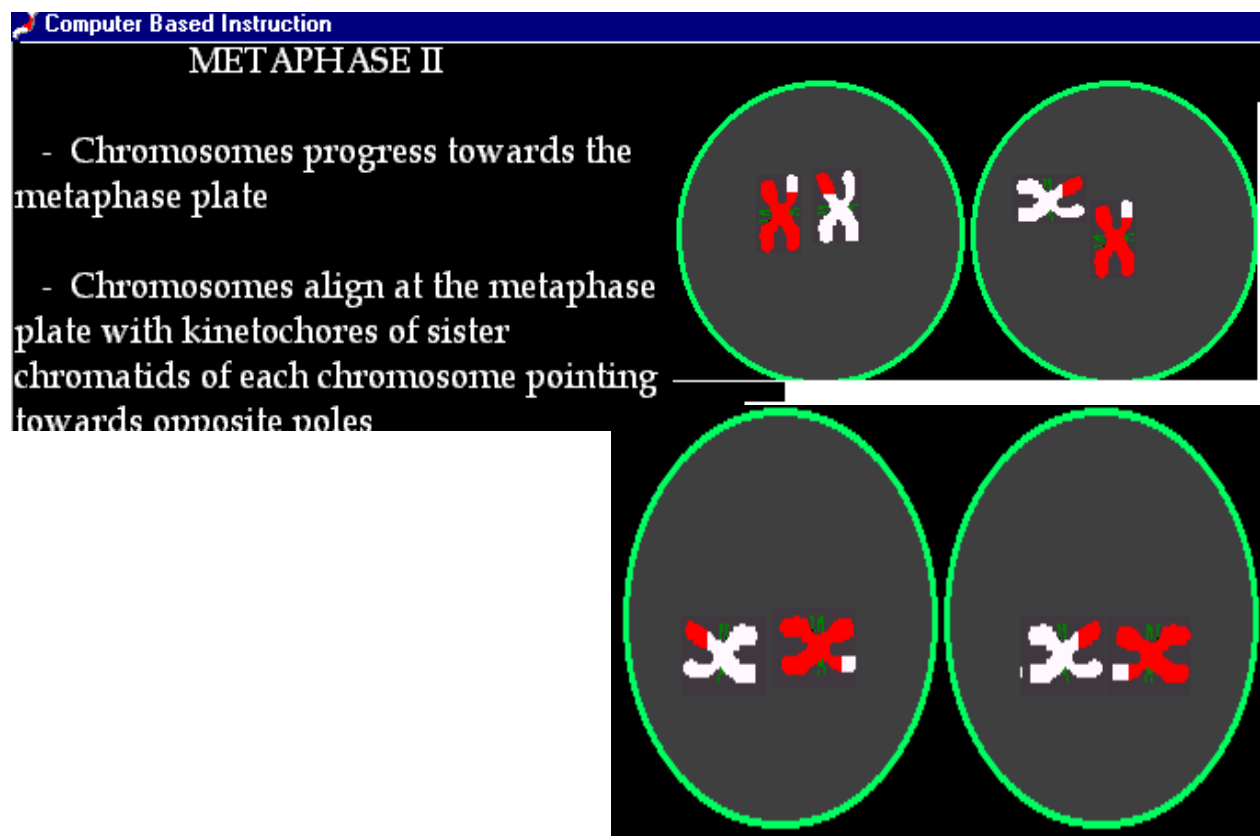


Figure 20. Prophase II.

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

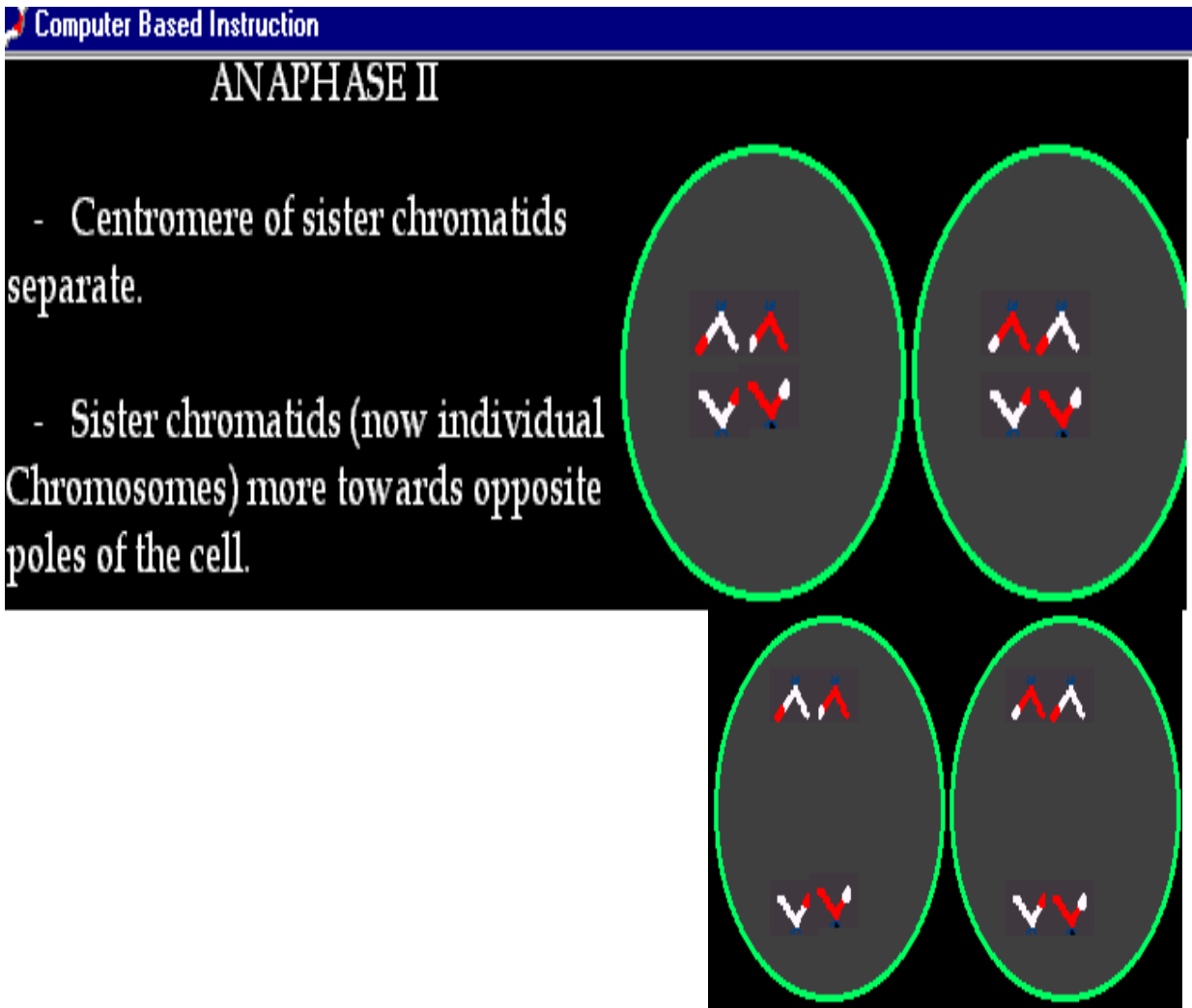


Figure 21. Metaphase II.

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

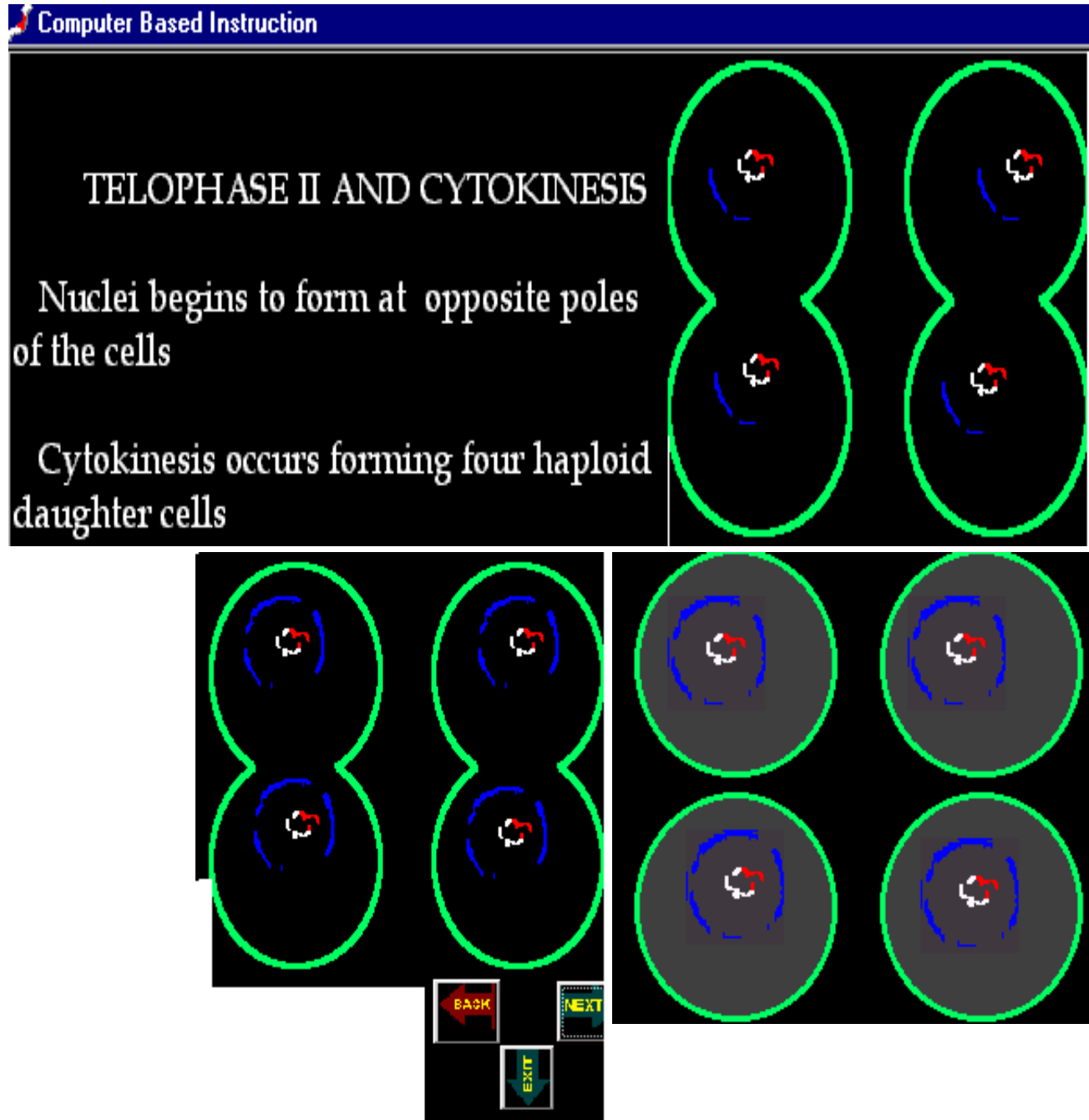


Figure 22. Anaphase and Cytokinesis II.

(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 ₁ E 0 ₁	Teaching using CBI module	T ₂ E 0 ₂
Control group I (C ₁)	T ₁ C ₁ 0 ₃	Teaching using conventional methods	T ₂ C ₁ 0 ₄
Control group II (C ₂)	No pre-test	Teaching using CBI module	T ₂ C ₂ 0 ₅

Source: Koul (1984). Key: T₁ - Pre-test; T₂ - Post test; 0₁₋₅ - 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 (C₂) not taking the pre-test. In this study, one group served as the experimental group (E) and two others as control groups. However, the C₂ 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 (C₁) and control group II (C₂). In the study, two groups (E and C₁) 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 C₂ (M=29.03) on the BAT are similar, and significantly higher than that of C₁ (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 C₁ group, and that of 9.77 obtained between C₁ and C₂ were statistically significant at P<0.05. However, no statistically significant difference was established between the mean scores of treatment groups E and C₂ 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.

REFERENCES

- Allesi SM, Trollip SR (1991). Computer Based Instruction: Methods and Development, 2nd ed., Prentice-Hall, Englewood Cliffs, NJ.
- Fraenkel JR, Warren NE (1998). How to design and evaluate research in Education, 2nd Edition McGraw-hill, New York.
- Gavora MJ, Hannafin MJ (1995). Perspectives on the design of human computer instructions: Issues and implications. *Instructional Sci.*, 22: 445-447.
- Kenya Institute of Education (1992). Secondary education Syllabus vol. Seven. Kenya Institute of Education, Nairobi: Kenya Literature Bureau.
- Kiboss JK (1997). Relative Effects of Computer Based Instruction in Physics on Students' Attitude, Motivation and understanding about Measurement and Perception of classroom environment. Doctoral thesis presented at University of Western Cape: Bellville.
- Kiboss JK (2000). Teacher/pupil perspective of computer

- augmented physics lessons on measurement in Kenyan secondary school. *J. Info. Technol. Teacher Edu.*, 9(3): 119-213.
- Kiboss JK (2002). Impact of a Computer-Based Physics Instruction Program on Pupils' Understanding of Measurement Concepts and Methods associated with School Science. *J. Sci. Edu. Technol.*, 11: 2.
- Kiboss JK, Ndirangu M, Wekesa EW (2004). Effectiveness of a Computer-Mediated Simulation Program in School Biology on Pupils' Learning Outcome in Cell Theory. *J. Sci. Technol.*, 1: 2.
- Koul L (1984). *Methodology of Educational Research*. New Delhi: Vikas Publishing House Limited.
- Njoo M, De Jong T (1993). *Learning Process of Students working with a Computer Simulation in Mechanical Engineering*. Eindhoven University of Technology. Netherlands.
- Ogunniyi BM (1992). *Understanding Research in Social Science*. Ibadan: University Press Plc.
- Park OC, Hopkins R (1993). Instructional Conditions for Using Dynamic Visual Displays: A review. *Instructional Sci.*, 21: 427-449.
- Strengthening Science and Mathematics in Secondary School Education (SMASSE) (1999). findings of baseline survey. Butere/Mumias District.
- Tennyson RD, Rash M (1988). Linking cognitive learning theory to instructional prescription. *Instructional Sci.*, 17: 369-385.
- Wekesa E (2003). *Effects of a Computer-Based Instruction Module on Students' Achievement, Perception of the Classroom Environment and Attitude Towards School Biology in Nakuru District*. Kenya, Master's Thesis, Egerton University, Kenya.
- Wenglinsky H (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Princeton, NJ: ETS Policy Information Center-Research Division.
- Willet GM (2004). Development of a prototype computer-based instruction module: Foundational neuroscience for physical therapy students. *The Internet J. Allied Health Sci. Pract.*, 2: 2.