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DEVELOPMENT AND IMPACT OF THE USAGE OF ANIMATION IN TEACHING MOLECULAR AND CELLULAR BIOLOGY STUDENT LEARNING

Snezana Stavreva Veselinovska
Faculty of Educational Sciences, Goce Delcev University – Stip, Republic of Macedonia
snezana.veselinovska@ugd.edu.mk
Anastasija Stavreva
Institute of Biology, Faculty of Natural Sciences and Mathematics – Skopje, Republic of Macedonia
anastasija_65@yahoo.com

Abstract: Although microscopy has long been used as a valuable teaching tool, the use of computer animation in teaching has recently expanded. Animation can have advantages over microscopy, including simplification, unlimited resolution and magnification, ability to highlight certain symbols within a complex background, control of motion, shape, or color changes, and the step- wise fading in and out of symbols. To address the different learning styles of students, and be- cause students can access animation from off-faculty computers, the use of digital animation in teaching molecular and cell biology has become increasingly popular. Sample processes from molecular cell biology that are more clearly presented in animation than in static illustrations are identified. The value of animation is evaluated on whether the process being taught involves motion, cellular location, or sequential order of numerous events. Finally, future teaching tools for all fields of biology will increasingly benefit from an expansion of animation to the use of simulation. One purpose of this review is to encourage the widespread use of animations in biology teaching by discussing the nature of digital animation.

Over the last decade, the unifying approach of many biology courses has evolved from an emphasis on the whole organism to a concentration on the molecular and cellular basis of life. This change reflects the recent shift in biology research toward an approach that addresses questions of function, structure, development, and evolution at the molecular and cellular levels. To reflect these discoveries, students in freshman-level general biology courses are taught that organisms are made of cells, that eukaryotic cells are compartmentalized into organelles while prokaryotic cells are not, and that cellular life is maintained by molecular and cellular processes. Naturally, the complexity of these processes and their interrelation is often difficult for the novice student to understand.

Keywords: computer animation, teaching, molecular and cellular biology, cell, organelles, mitosis, meiosis, student achievement.

1. INTRODUCTION

The acceptance of innovation and improvement of competencies must be the foundation of the professional development of teachers, particularly in the areas of effective instruction and management in the classroom, for the development of the desired pupils' competencies for a life in the contemporary environment, as well as in the goal of getting to an effective teaching and contemporary forms of learning in practice. Biology teaching must reflect the exciting nature of the subject and its surroundings. Student work in biology lessons should be practical and visual in nature wherever possible. In actual fact, teachers often use only lecture method (with-out visual aids or demonstrations) in biology lesson in general, (Stavreva V. S, 2014).

Motion distinguishes animation from static; still images and provides a smooth transitional representation that captures the critical interrelationships along the path of specific process. Motion leads to longer-term memory; an effect not observed with static images (Goldstein et al., 1982).This result is most dramatic for individuals who have difficulty grasping spatial relationships (Blake, 1977). Although research has clearly shown that students learn more from animations than from static images, this is maximized by lesson plans that include lecture and other learning inputs (Rieber, 1990). Learning is best achieved when an animation is coupled with a lecture, because this combination provides a reference from which students can appreciate the knowledge presented in the animation (Paivio, 1979, 1991). The lecture cues students while they are studying the animation. Multimedia tools provide another level of sophistication.

Computer animations are often used in biology courses to help students visualize complicated biological processes and concepts. Animations can facilitate understanding of complex spatial and temporal relationships that are difficult to depict in static images. Education research supports the claim that animations can lead to increased student learning and identifies features that make animations effective. Given the wide variety of high quality animations freely available to educators on the web, the challenge is finding creative and effective ways to tap into their potential for learning. We generally present animations didactically, as self-evident resources rather than leveraging them to support student-centered active learning. Here, we review the use of animations in undergraduate biology education, and make recommendations on how they can be used more effectively to support student learning. Through methods such as scaffolding student analysis of animations, increasing their understanding of visual literacy, and using multiple representations students can begin to use animations as a tool to support their own learning, rather than simply a source of content.

Animations can be too quick or too complex; the brain cannot process information as quick as the animation is moving, or the animation may be too involved and too much information is presented to be processed in the timeframe of the animation (Falvo 2008; Tversky et al. 2002). A major disadvantage is simply the logistics of the instructional technique. If the technology necessary to present the animations malfunctions or become unavailable for any reason, the lesson can be a complete waste of time.

2. ANIMATIONS IN EDUCATION

Animations are now a common learning tool in classrooms throughout the world. As the availability of computers and accompanying presentation programs such as Microsoft PowerPoint become more widespread, so too are techniques to incorporate this technology as an instruction- al advantage. The so-called "traditional" means of teaching such as lecture, worksheet, and text- book lessons are being supplemented with, and in some instances replaced by, virtual lectures, web-based learning, and project-based, student-created movies or computer presentations where students may assimilate and apply the information they have received. Newer textbooks are web-based, with accompanying services such as instructional videos by instructors, laboratory demonstrations, simulations, and a vast array of instructional animations (Sanger et al. 2001).

From an educational perspective, visualization aids student understanding of complex processes because it assists in the conversion of an abstract concept into a specific visual object that can be mentally manipulated. Further research has shown that by using well-designed visual tools, students can digest large amounts of information in a relatively short time and construct their own personal visualization of a process (Kraidy, 2002; Linn et al., 1996). Student learning research has shown that visual perception is the most developed sense in humans and is an important way by which we learn (Sekular and Blake, 1985). Vision allows us to collect and process information from our environment and to make decisions or form concepts from that information.

Instructional animations are valued for their ability to display temporal changes, as well as depiction of changes in position and form (Stith 2004). Also, there is less need for interpretation or inference with animations compared to a picture with arrows or other symbols (McLean et al. 2005). Animations are dynamic and engaging to the majority of learners as attention is better maintained by movement and colors, and animations are generally considered aesthetically pleasing. Learning styles are also served well through animations. Visual learners are ex- posed to transitional images, auditory learners may rely on the accompanying narrations, and even kinesthetic learners may benefit from a more complex, interactive animation that can be manipulated to explore the possible effects.

The information is presented in a consistent manner, as all learners are presented with the same information in an identical format and reading comprehension is not an obstacle to learning. Potential disadvantages of using animations to instruct do exist. The educator must be careful in the development of the animation, or selecting the most appropriate animation.

Further research has shown that by using well-designed visual tools, students can digest large amounts of information in a relatively short time and construct their own personal visualization of a process (Kraidy, 2002; Linn et al.,1996).Graphical representations are visualizations that augment the information presented in text by providing a focus for the learner (Mayer, 1989). They are most effective when they support content for which the learner has little prior knowledge (Mayer and Gallini, 1990).

Slide shows that use a presentation package such as Microsoft Power Point can provide a step-by-step graphic representation of a process. Individual molecules can beaded, and specific interactions can be highlighted. The advantage of this tool is that the instructor or learner can move forward and backward one step at a time during the learning process and emphasize key transitions. Yet, the final slide is still a complex display that takes concentrated study to grasp.

The goal of the Virtual Cell animation is to create high-quality animations of selected molecular and cellular processes that support student learning. They are also used as references to create interactive 3D simulations of these processes for immersive, role based learning.

Example: Through the Virtual Cell **– http://vcell.ndsu.nodak.edu/animations/mitosis/first.htm**

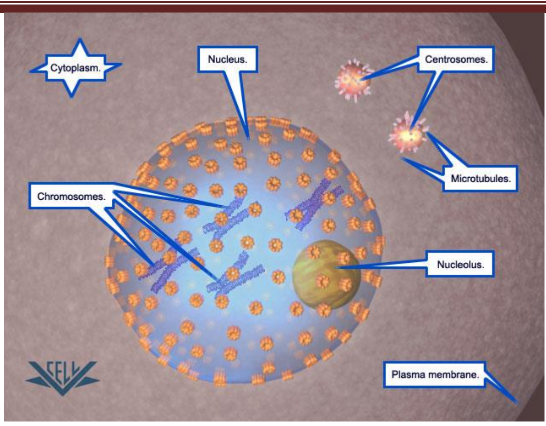


Figure 1. The first stage of mitosis is called prophase. During this stage the DNA condenses into chromosomes.

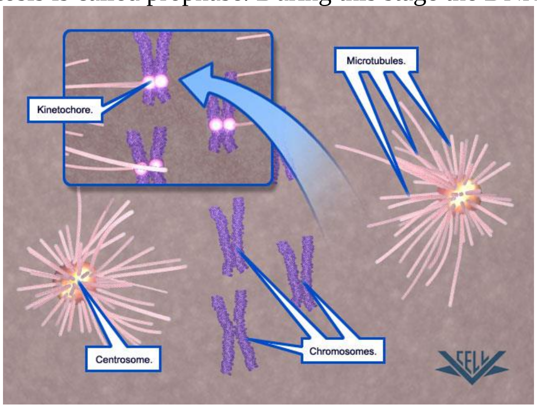


Figure 2. The next stage is called prometaphase. During this stage the nuclear membrane breaks down and microtubules attach to the chromosomes.

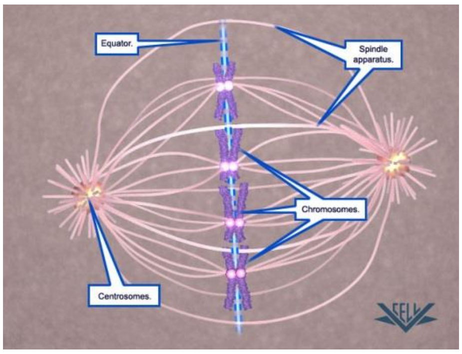


Figure 3. Next comes metaphase where the chromosomes align at the middle of the cell.

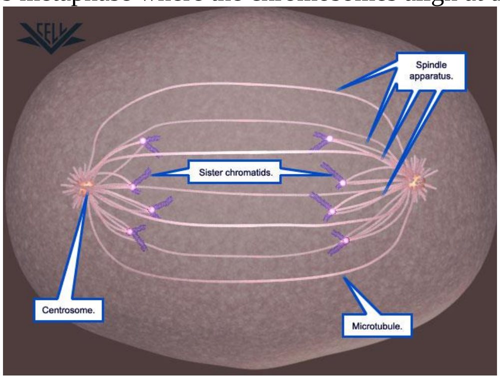


Figure 4. After the chromosomes are aligned, anaphas**e** begins. During this stage the microtubules or spindle fibers, pull the chromosomes apart and move them to the opposite ends of the cell

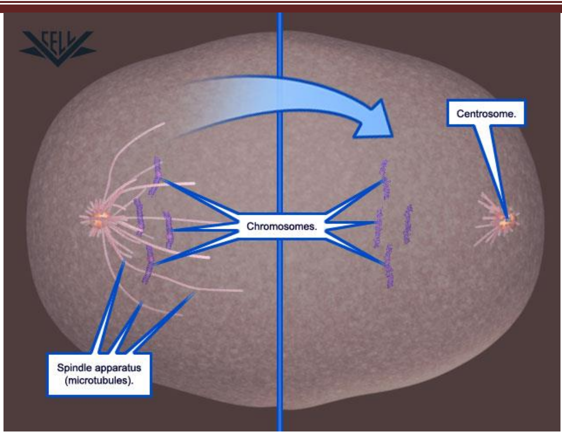


Figure 5. Next comes telophase**.** Here the spindle fibers are broken up.

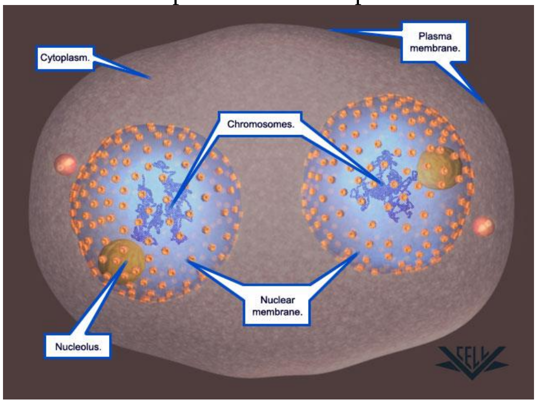


Figure 6. During telophase the chromosomes also uncoil and two new nuclear membranes form around them. This is the end of mitosis**.**

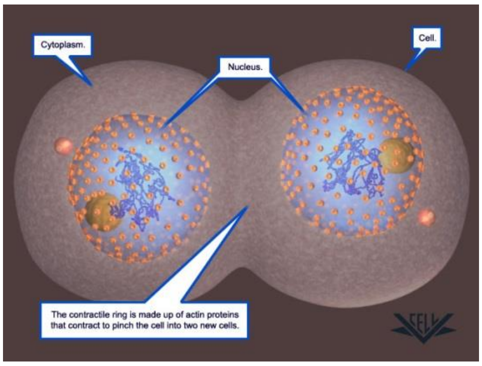


Figure 7. Following mitosis**,** a contractile ring splits the cell into nearly equal halves during cytokinesis.

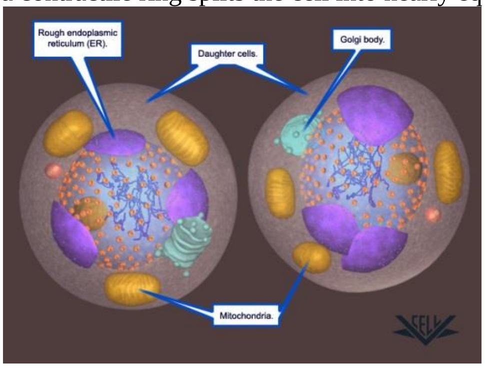


Figure 8. The organelles in the cell are also divided between the two new cells. Following cytokinesis, the two new cells are ready to perform their biological functions

3. EXPERIMENTAL DESIGN

Animations are typically used by a teacher as a lecture supplement in the classroom or by students as individual learning tools. Both of these learning approaches are supported by research demonstrating that animations significantly improved student learning.

Of primary interest were the following hypotheses:

1) Does using web animation in processing content from natural sciences improve the quality of learning, encourage reflective learning skills and influence the retention of the acquired knowledge among students? A comparison is made between groups A, B and C and the group D in order to test the hypothesis.
2) We were interested in determining whether there was an effect on student learning relative to the number of times a student was exposed to the animation. This was tested by comparing the performance of group A versus the other three groups (two versus one or zero animation activities), and comparing groups B and C with group D (one versus zero animation activities).
3) We considered whether, relative to our standard educational experience, adding animation to the lecture improved student retention (group B versus group D).
4) Students often are first exposed to a topic in class and then study the material outside of class. We were finally interested in determining whether exposure to an animation in class prior to individually studying the animation improved student learning (group A versus group C).

Students were divided into four experimental groups. First of all four groups were taught using the traditional lecture method on the process of dividing germ cells with the reductive division - meiosis. Then, each group presented their process of meiosis using other tools for learning and teaching.

3.1. TRADITIONAL LECTURE METHOD (Cytokinesis from Mitosis)

Cells divide and reproduce in two ways: mitosis and meiosis. Mitosis is a process of cell division that results in two genetically identical daughter cells developing from a single parent cell. Meiosis, on the other hand, is the division of a germ cell involving two fissions of the nucleus and giving rise to four gametes, or sex cells, each possessing half the number of chromosomes of the original cell.

Mitosis is used by single celled organisms to reproduce; it is also used for the organic growth of tissues, fibers, and membranes. Meiosis is found in sexual reproduction of organisms. The male and female sex cells (i.e., egg and sperm) are the end result of meiosis; they combine to create new, genetically different offspring.

Comparison chart

Meiosis versus Mitosis comparison chart

	Meiosis	**Mitosis**
Type of Reproduction	Sexual	Asexual
Occurs in	Humans, animals, plants, fungi.	All organisms.
Genetically	Different	Identical
Crossing Over	Yes, mixing of chromosomes can occur.	No, crossing over cannot occur.
Definition	A type of cellular reproduction in which the number of chromosomes are reduced by half through the separation of homologous chromosomes, producing two haploid cells.	A process of asexual reproduction in which the cell divides in two producing a replica, with an equal number of chromosomes in each resulting diploid cell.
Pairing of Homologs	Yes	No
Function	Genetic diversity through sexual reproduction.	Cellular reproduction and general growth and repair of the body.
Number of Divisions	2	1
Number of Daughter Cells produced	4 haploid cells	2 diploid cells

Meiosis versus Mitosis comparison chart

	Meiosis	Mitosis
Chromosome Number	Reduced by half.	Remains the same.
Steps	(Meiosis 1) Prophase I, Metaphase I, Anaphase I, Telophase I; (Meiosis 2) Prophase II, Metaphase II, Anaphase II and Telophase II.	Prophase, Metaphase, Anaphase, Telophase.
Karyokinesis	Occurs in Interphase I.	Occurs in Interphase.
Cytokinesis	Occurs in Telophase I and in Telophase II.	Occurs in Telophase.
Centromeres Split	The centromeres do not separate during anaphase I, but during anaphase II.	The centromeres split during anaphase.
Creates	Sex cells only: female egg cells or male sperm cells.	Makes everything other than sex cells.

Both Mitosis and Cytokinesis are a part of cell division. Basically, Mitosis is a process by which the duplicated genome in a cell is separated into halves that are identical in nature. Cytokinesis is the process where the cytoplasm of the cell divides to form two ‘daughter’ cells. There are other subtle differences between the two. Let us explore these in detail. The process of Mitosis occurs in three phases-namely Interphase, Karyokinesis and Cytokinesis. Karyokinesis occurs in 4 different phases. Once Karyokinesis is completed, Cytokinesis takes place. Cytokinesis occurs through two simple processes, one in animals and other eukaryotic cells and one in plant cells. During Cytokinesis, the cytoplasm of a cell is divided into two. The result is the formation of two ‘daughter cells’, each having a nucleus. Apart from the nuclei, Cytokinesis also results in the passing of cellular organelles equally between the two daughter cells. Since some of the molecules bind to the chromosomes, each daughter cell receives an equal share of the cytoplasmic components. In some instances, however, the cells may go on dividing the nucleus, without reaching the stage of Cytokinesis. In such a case, it leads to the formation of a multinucleate cell such as in those of striated muscles. The important thing to note is that even after the completion of Mitosis, there are two nuclei which are still enclosed in the same cell. Only under Cytokinesis does this cell physically divide into two.

The reasons behind Mitosis can be tracked quite easily. It is based on the need for a cell to grow and regenerate. Mitosis lies behind the propagation and continuation of all living forms. However, the process is slightly different between animals and plants. Cytokinesis on the other hand occurs so that the chromosome number is maintained between the generations. Since Mitosis is a part that divides the nucleus of a cell, Cytokinesis without Mitosis would create two cells, one with a nucleus and the other without one.

Since the two processes may often take place in conjunction with each other, they may be known collectively as the mitotic phase. However, there are a number of cells where the Mitosis and Cytokinesis processes occur differently. In such cases, it may result in the formation of single cells that have multiple nuclei. This is commonly found among moulds and fungi. In animals, it may occur in certain stages of the development of the fruit fly. It is important to note that this is one of the most important parts in the development of a cell. Any errors in Mitosis may either kill a cell or lead to cancer.

Mitosis - Meiosis

Meiosis and Mitosis describe cell division in eukaryotic cells when the chromosome separates. In mitosis chromosomes separates and form into two identical sets of daughter nuclei, and it is followed by cytokinesis (division of cytoplasm). Basically, in mitosis the mother cell divides into two daughter cells which are genetically identical to each other and to the parent cell.

The individual study materials were either 1) Cell division - meiosis text or figures from the book used in the Biology, or 2) the animation described above (Figure 3). The students listened to the animations through and were allowed to study the materials for up to 25 min. Stu- dents were allowed to study the text material for 25 min. Following the last activity of the test, each student completed a multiple-choice test consisting of four questions that addressed the major aspects of protein translation that were emphasized in the lecture and supported by the animation, overheads, and text material. The students completed the same test prior to the manners of presentation. In addition, during the pretreatment and post-test, students completed a confidence rating for each of their four answers. The pretest and post-test performance and confidence level data, measured as sum totals, were analyzed using single factor analysis of variance. The p value to test the mean difference between each pair of test groups was also cal collated following rejection of the null hypothesis that all test means were equal. Finally, prior to all treatments, the students completed survey to determine the number of science courses they had taken and whether they had completed an introductory college-level biology course.

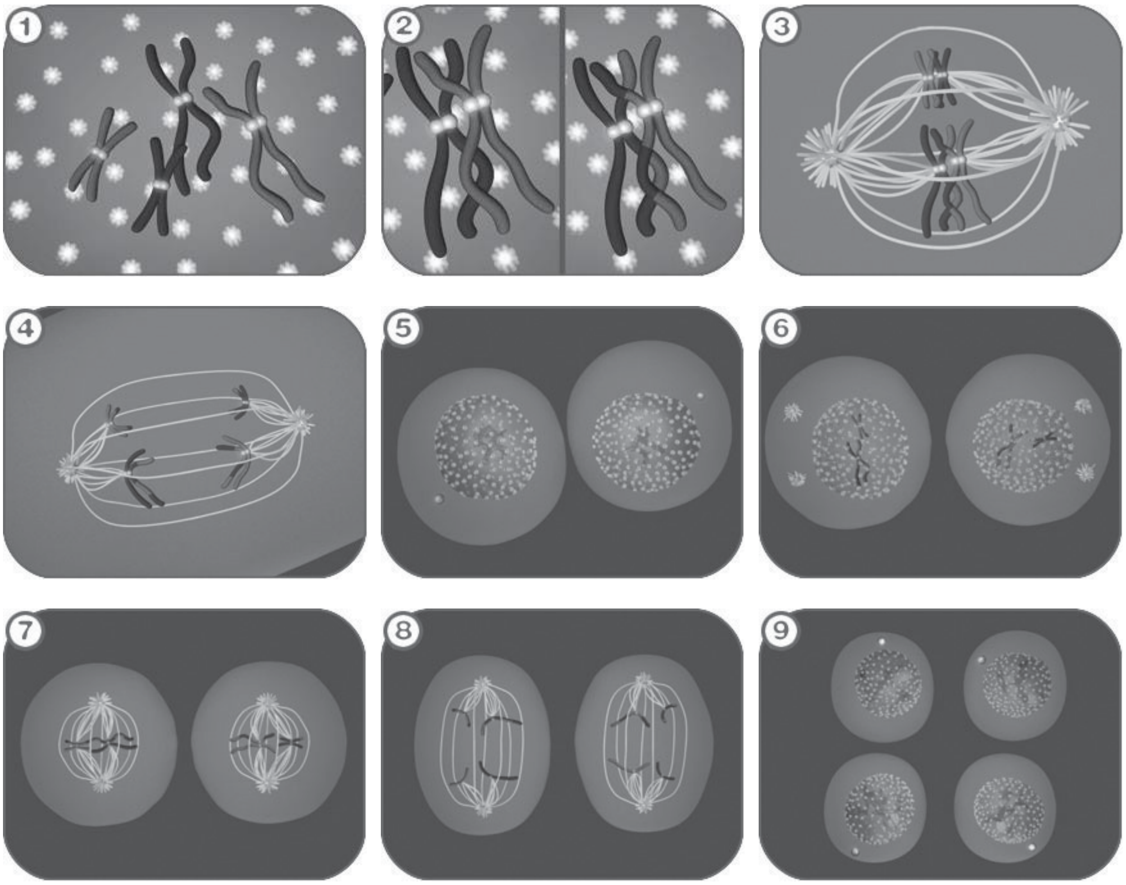
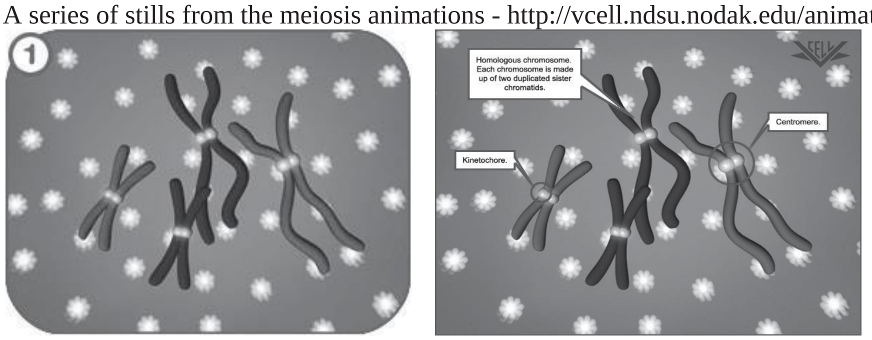
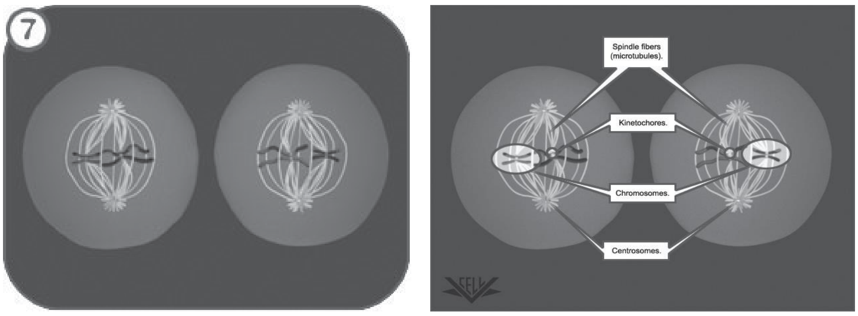


Figure 9. A series of stills from the meiosis animations - http://vcell.ndsu.nodak.edu/animations/



A.



B.

Figure 10. First Look animation stills (left) and annotated enlarged versions (right) of the animation stills. The stills are captured from the animations and illustrate major events in the process. A) **Meiosis** begins with **Meiosis I.** The first stage in Meiosis I is **prophase I.** During this stage the DNA condenses into

chromosomes. B) This is followed by **metaphase II**. Here the spindle fibers attach to the chromosomes and again align them at the middle of the new cells.

Test:
1.Meiosis results in
haploid daughter cells
4 haploid daughter cells
2 diploid daughter cells
4 diploid daughter cells

3. Which of the following cells undergo meiosis?
Sperm cells
liver cells
unicellular organisms
all of these
2.The picture depicts what phase of meiosis propase 1
prophase 2
anaphase 1
anaphase 2

4. What is the key difference between anaphase I in meiosis and mithosis?

The number-of-courses data were analyzed as a single-factor analysis of variance, while achi-square homogeneity test was used to determine group effects regarding the proportion of students who completed an introductory biology course. With a limited number of students available for our experiment, we could create only a limited number of treatment groups, which in turn allowed us to consider only select hypotheses relative to the value of animations in stu- dent learning. In each case, the null hypothesis was that there was no difference in effects of the manners of presentation of teaching material, whereas the alternative hypothesis was that man- ners of presentation effects existed. We chose individual student study of course materials prior to a lecture followed by a lecture enhanced with overheads that consisted of figures from the textbook as our baseline educational experience (group D; Table 1). Three other Table 1. The four treatments used to determine the significance of animations as a tool to improve student learning manners of presentation were included relative to our research objectives(Table 2).

Table 2. The four manners of presentation with group sizes in parentheses) used to determine the significance of animations as a tool to improve student learning

Group	Manners of presentation
A (n = 15)	Lecture enhanced with animation followed by individual study of animation
B (n = 15)	Individual study of text material followed by lecture augmented with animation C
(n = 17)	Lecture enhanced with overheads followed by individual study of animation
	D (n =14) Individual study of text material followed by lecture enhanced with overheads

Experimental Results
The statistical analysis of the results of the surveyed students who were divided into 4 groups showed the following conclusions:

A Chi-square test of homogeneity was performed on the proportion of students within each group that had completed an introductory biology course.

Table 3. *Mean student post-test performance and group contrasts for the four lecture/individual study manners of presentation*

Group	Mean	Versus A	Versus B	Versus C	Versus D
A	2.93	-	0.389	0.287	0.002
B	2.57	0.218	-	0.492	0.079
C	2.45	0.047	0.412	-	0.345
D	2.02	0.063	0.476	0.832	-

The mean is the post-test mean. Maximum score is 4. The difference between the post- test and pretest means is presented in parentheses. The manners of presentation group contrast p value for the post-test means are presented above the diagonal, and the manners of presentation group contrast p value for the difference between the posttest and pretest means is presented below the diagonal. Significant ($p \leq 0.05$) contrasts. By contrast, a significant group effect was noted for both the post-test mean ($p \leq 0.05$) and the difference between the post-test and pretest means ($p = 0.017$). To determine which manners of presentation were most significant and to allow us to address the specific hypotheses we were testing, the value associated with each pair wise contrast was calculated (Table 2). Group A, in which students heard a lecture enhanced with the animation followed by an individual study of the animation, performed significantly better than any other group. The performance of groups B and C (which contained a single animation activity) was not significantly different from that of group D, manners of presentation that did not have an animation component.
Collectively, these results allowed us to conclude the following relative to hypotheses 1 and 2: first, these results strongly suggest that the animation was a significant component in improving student retention of content material, but this effect was noted only when the students experienced two animation activities. This demonstrates that the best practice for using animations in learning would involve its incorporation both during the lecture and as an individual study aid. The other hypotheses considered the effect of animations relative to a standard educational experience in which a student studies course materials from the text prior to class and then listens to a lecture that is supported by overheads containing graphics found in the textbook. We first considered the effect of simply adding the animation to the lecture (hypothesis 3). That the performance of groups B and D did not differ demonstrates that simply adding the animation to the lecture did not produce a positive (or negative) effect on student learning. Students often do not study prior to class; rather, they listen to a lecture and then follow that up with individual study. Given this learning scenario, we were next interested in determining the effect of introducing a topic in class with animation versus overheads when students subsequently studied the topic using the animation (hypothesis 4). By comparing the performance of groups A and C, we determined that introducing a topic with animation leads to significantly improved student retention.

CONCLUSION

Student learning research has shown that visual perception is the most developed sense in humans and is an important way by which we learn. Vision allows us to collect and process information from our environment and to make decisions or form concepts from that information. From an educational perspective, visualization aids student understanding of complex processes because it assists in the conversion of an abstract concept into a specific visual object that can be mentally manipulated. Computer animation, in particular, is a new educational tool that fosters long-term learning by calling attention to objects during the early steps of instruction. Stavreva V.S, et all, 2011 that using animations to communicate ideas and processes that change over time reduces the abstractions associated with the temporal transitions of the process. As such, animations are valuable aids in supporting the visual aspects of long-term memory.

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