Effect of Animations in Constructing and Reconstructing Students' Knowledge of Cell Division (Mitosis)

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The main objective of this study was to explore whether the use of computer animations can contribute to students' understanding of concepts on cell division and encouraging them to play an active and critical role in their own learning. Undergraduate biology students of first year were divided into two groups - one control group and another experimental group. The control group students were taught cell division in the traditional lecture while the students of experimental group were taught by using computer animations. The results of pre- and post-tests showed that students' understanding of cell division improved substantially in experimental group. The findings also suggest that computer animations can serve as a vehicle for students to generate mental images.

Keywords: Computer animation, Achievement, Construction, Mitosis, Cell division

Introduction

Every child construct his/her knowledge on existing knowledge and understanding and therefore, it is likely that, teaching can be difficult for certain topics in biology, particularly those concerned with more complex areas such as cell division, DNA replication, excretion, photosynthesis and evolution in biology (Oztap, Ozay, & Oztap, 2003; Yip, 1998). Pupils and teachers consistently place cell division near the top of these 'ladders' of difficulty. It is well reported that cell division processes are poorly understood at all ages and levels of students (Lewis & Wood-Robinson, 2000; Smith, 1991). Researchers and teachers continue to try to find ways of teaching cell division so as to minimize misconceptions. Some improvements, such as diagrams and modeling would contribute to reducing misconceptions and learning difficulties among students (Oztap et al., 2003).

In recent years there has been a growing trend to use highly illustrated materials for instruction rather than relying on largely text-based presentations of information. Multiple technical resources (commonly referred to as multimedia) are currently used by many instructors to communicate difficult topics and concepts to their students in meaningful ways. With the newer technologies of instructions, this increasing reliance on pictures as a central part of instruction is not limited to static illustrations but also includes animations (Lowe, 2003; Rieber, 1994). Various sources have shown that animations are more effective than static sequential images (Nicholls & Merkel, 1996; Pollock, Chandler, & Sweller, 2002). Clearly, that are by nature dynamic should benefit by being represented in a dynamic way (Tversky, Morrisony, & Betrancourt, 2002). Visual representations are especially critical in the communication of science concepts (Cook, 2006; Mathewson, 1999). They provide a means for making visible phenomena that are too small, large, fast, or slow to see with the unaided eye. Similarly, visual representations illustrate invisible or abstract phenomena that cannot be observed or experienced directly (Buckley, 2000). In science education today, presentations that combine visual and verbal information are widely used for displaying instructional material. An extensive literature exists on the value of animations in teaching in many different disciplines, but studies in biology are few. This study aimed to investigate the effect of animations in constructing and reconstructing knowledge on cell division (mitosis) and in encouraging students to play an active and critical role in their own learning.

Methodology

The undergraduate biology students of first year were separated into two groups: *animation group* and *control group*. To verify the comparability and knowledge about mitosis of the groups, a pre-test was conducted by using a multiple choice questionnaire. The control group (61 students) was taught in the traditional lecture format by using blackboard and transparencies and guided the students to read and answer questions in the text-book. The other group i.e. animation group (63 students) were taught in the traditional instruction like control group but integrated with animation activities.

Three types of questionnaires were developed and used i.e. multiple-choice written questionnaire containing 20 questions, open-ended questionnaire containing 10 questions and another open-ended questionnaire containing 5 questions for personal interviews. In addition to these, students were asked for a pictorial presentation of structure of chromosome and various phases of mitotic cell division.

Students were asked to answer the open-ended questionnaire first and after that multiple-choice questionnaire were given. Multiple-choice and open-ended questionnaires and pictorial presentations were used for both pre-test i.e. before teaching and post-test i.e. after teaching for control and animation groups. Ten students, each from control and animation groups were randomly selected for personal interview. The questions in the three research instruments were grouped under two main categories of subtopics:

A. Questions dealing with the structure of chromosome, centriole and microtubule filaments.

B. Questions dealing with the process of cell division.

Results

The students' understanding of mitotic cell division was investigated in two groups (animation group and control group), using multiple-choice and open-ended questionnaires as well as individual interviews. In the pre-test, mean scores of control group was 27 and animation group 28 for multiple-choice questionnaire and mean scores of control group was 25 while animation group 26 for open-ended questionnaire. Comparison of the two groups' pre-test revealed no significance differences amongst the groups. Therefore, these groups are comparable.

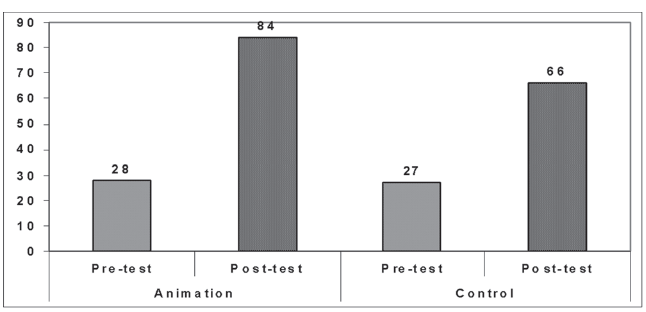

Figure 1: Average scores of the pre-test and post-test for the multiple-choice questionnaire

Average scores of responses to multiple-choice questionnaire are 84 and 66 of animation and control group respectively. Figure 1 shows significant improvement of animation group over control group. Analysis of students' answers to the open-ended questionnaire showed that, similar to the findings from the multiple-choice questionnaire, the average scores of the responses to the open-ended questionnaire of the animation group (82) differed significantly from that of the control group (60). Figure 2 shows animation group has developed better understanding of the mitosis than

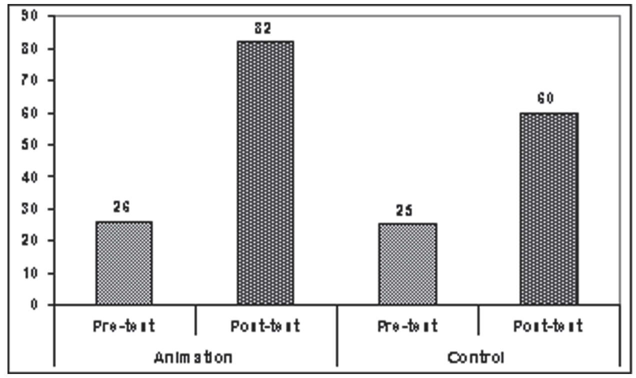

Figure 2: Average scores of the pre-test and post-test for the open-ended questionnaire

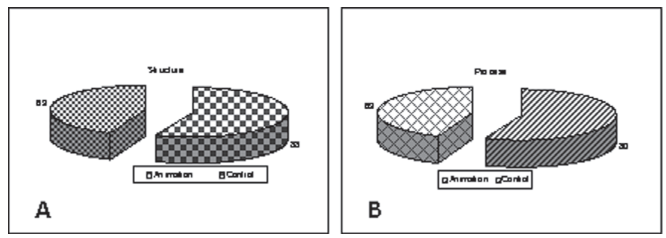

Figure 3: Average scores (percentage) for groups of questions related to subtopic A and subtopic B of the multiple-choice questionnaires

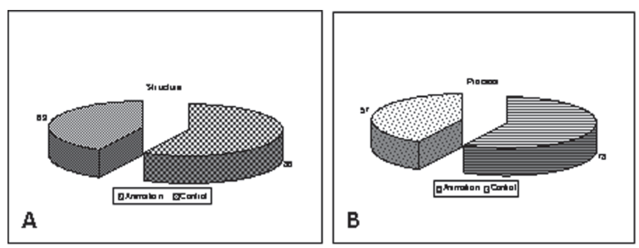

Figure 4: Average scores (percentage) for groups of questions related to subtopic A and subtopic B of the open-ended questionnaires

Figures 3 and 4 the composite scores (percentage) regarding the multiple-choice questionnaire and open-ended questionnaire, calculated for each of the two categories.

1. Structure of chromosome, centrioles and microtubules: A total of eight questions (six multiple-choice and two open-ended) were grouped under this sub-topic (A). Inspection of the average percentage scores of the multiple-choice questions concerning this sub-topic shows that the average scores for the animation group is 88% which is higher than the average scores of the control group i.e. 69% (Figure 3A). The same pattern occurred with the scores of the open-ended questions of this sub-topic, in which average animation group score is 86% which is much higher than the control group score i.e. 63% (Figure 4A).

In the individual interview, students were asked to characterize the structure of chromosome. Most of the students from both groups stated that chromosomes consists of two chromatids, attached to each other at centromere and contains DNA, proteins and RNA. Differences among groups were evident, especially concerning the molecular level of organization. About 85% of the interviewees from the animation group referred to the various level of packaging, whereas only 39% of the interviewees from the control group referred to the packaging of DNA in chromosome.

2. The process of mitosis: A total of 22 questions (fourteen multiple-choice and eight open-ended) in the two questionnaires were concerned with the process of mitosis (sub-topic-B). These questions explored two aspects of students' understanding: the behaviour of the chromosomes and the events occurring in different phases of mitosis. Inspection of the average scores in the multiple-choice questions concerned with the processes of mitosis shows a similar pattern to the one found in the first sub-topic (A): the average scores for the animation group is 80% which is significantly higher than the control group i.e. 63% (Figure 3B). Similar significant difference was observed in the responses to open-ended questions for the same sub-topic (Figure 4B) between animation group (78%) and control group (57%).

In the interviews concerning the process of mitosis, students were asked to answer the question: *How are microtubules formed?* The responses showed major differences between the animation and control group. Majority of students from animation group (80%) correctly explained the formation of microtubules, whereas only one-third of the students did so in the control group. In response to the question: *How the chromosomes move towards the opposite poles during anaphase?* – showed differences between the animation group (79%) and control group (31%). But in response to question: *How nuclear membrane breaks down in prophase and is reformed in telophase?* – students of the animation group explained in a better way than the students of the control group.

3. Students' views about the animations: When students of animation group were asked: *Did the animation activity help you in gaining a better understanding of the mitosis?* All the interviewees gave an affirmative answer to this question. They reported that *"the animations represented the subject matter in a more concrete manner. It demonstrated the process, since we can't really see it. It was like we could see it in front of our eyes, and so we could connect different concepts with each other, much easier to understand and helped us more than the lesson in the class".*

Discussion

Several researchers (Cho, Kahle, & Nordland, 1985; Kindfield, 1994; Oztap et al*.,* 2003; Yip, 1998) have shown that cell division is perceived as difficult by science teachers. It has been shown that especially, chromosomes movement was the hardest part to explain to pupils. It is possible to speculate that during the teacher's higher education, subjects such as cell division and the DNA chromosome relationship were not well-grasped by them and therefore their understanding of the topics or confusion is reflected in their subsequent teaching. Therefore, it is expected that students, as a result, will have contradictory and confusing knowledge of cell division. In fact, Lewis and Wood-Robinson (2000) showed that students have a poor understanding of the nature and differences between mitosis and meiosis, chromosome and genetic information. Why do these difficulties occur? An answer may lie in the methods of teaching these topics. Teaching needs to emphasize the dynamic nature of the process using a variety of teaching aids such as photographs, film, video, building models etc. (Brown, 1995).

The learning skills encouraged by the computer animations appeared to be an effective way of assisting students to emphasize understanding rather than the acquisition of factual information (Norton & Crowley, 1995; O'Hagan, 1997; Sneddon, Settle, & Triggs, 2001). An effective teaching makes student more aware of their own knowledge and cognitive processes, as well as aware of how compatible these processes were with a given learning situation (Pastoll, 1992). Computer animations appeared to allow students to achieve this, compared with being passive recipients of information as in lectures (Norton & Crowley, 1995; Ramsden, 1996).

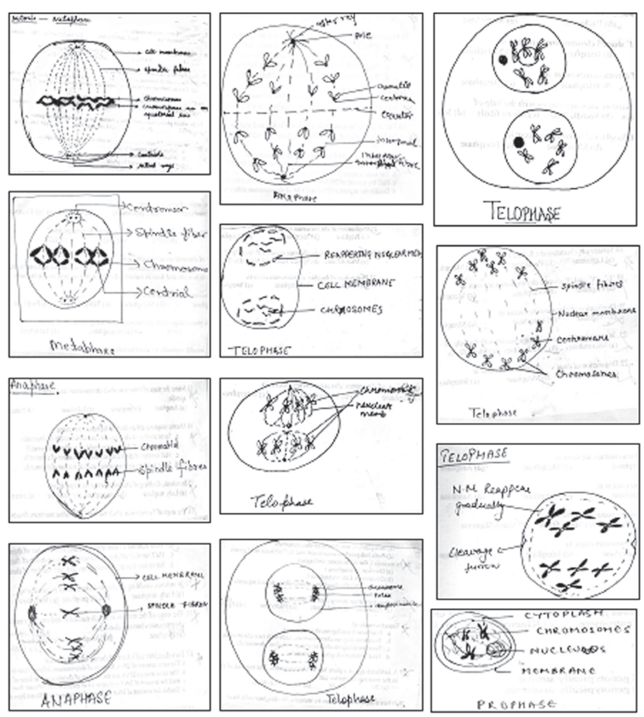

Figure 5: Pictorial presentation of different stages of mitosis showing misconceptions by the students

This study has focused on the use of animations in cell division instruction. The findings of both the multiple-choice and the open-ended questionnaires showed that the students in the animation group significantly improved their knowledge compared with students in the control group. The differences were highly significant in both the subtopics examined: (A) Structure of chromosome, centrioles and microtubule filaments and (B) Process of mitosis. Overall, answers to the open-ended questions from the students in the animation group were accurate and profound than the answer from the control group students. Thus, we concluded that the integration of animation in cell division instruction results in better understanding when compared with traditional lecture format. Similar findings have been reported by Stith (2004) on the topic 'apoptosis', by McClean et al. (2005) on 'protein synthesis' and by O'Day (2006, 2008) on 'signal transduction'. All these investigators observed that students who saw the animations obtained significantly higher test scores than those students that didn't view.

There were significant differences between the animation and control groups in the multiple-choice and open-ended questions that dealt with the subtopic A i.e. structure of chromosomes, centrioles and microtubule filaments. In the computer animation activities, students were shown how long thin chromatin fibres are undergoing condensation to become short thick rod like structures i.e. chromosomes (DNA packaging), fibrillar arrangement in the centrioles, structure of microtubule filaments and they could watch it over and over. The contribution of the animation activity to the understanding of the DNA packaging and structure of microtubule filaments were also mentioned by the students in the interviews: *"In the text book I couldn't understand the text and the illustrations…. While here, the animations really helped…that's what really helped me to understand the packaging of DNA and microtubule structure…"*.

In the subtopic B i.e. process of mitosis, answer to open-ended questions coming from the animation group were more accurate and profound than those from the illustration group. We believe that the computer animations offer a unique contribution to the understanding of the dynamic process of mitosis. Repeated replaying with interaction by the teacher of an animation can focus on specific parts and actions. Animations that allow close-ups, zooming, alternative perspectives and control of speed are even more likely to facilitate perception and comprehension (Marbach-Ad, Rotbain, & Stavy, 2008; Tversky et al*.,* 2002). The satisfaction and confidence level of animation group students were very high which was clearly reflected in their interviews: *"for all these years we were not knowing the exact mechanism of movement of chromosomes in anaphase and how the nuclear membrane disintegrates and reformed…but now everything is clear…"*.

The findings of the present study concerning the advantages of animation activities over the traditional lecture method in terms of learning the dynamic process of mitosis accord with Williamson and Abraham (1995) and Marbach-Ad et al*.* (2008) who explored the effect of computer animations on college chemistry students and high school students achievement in molecular genetics respectively and found that instruction with animations may increase conceptual understanding by prompting the formation of dynamic mental models.

Conclusion

This study has revealed the effect of animations on students' achievement in mitosis. In doing so it integrates the two leading research areas in science education today: students' understanding of mitosis and the use of computers in science education. The results of this study confirm the idea that proper use of technology can enhance students' achievement in biology and encourage wide ranging educational research on approaches to teaching scientific topics. The present findings specifically prove that animations work, especially in teaching about dynamic processes leads to more meaningful learning.

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