

Hands on group work paper model for teaching DNA structure, central dogma and recombinant DNA

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Abstract: Understanding life on a molecular level is greatly enhanced when students are given the opportunity to visualize the molecules. Especially understanding DNA structure and function is essential for understanding key concepts of molecular biology such as DNA, central dogma and the manipulation of DNA. Researches have shown that undergraduate students typically lack a coherent view of concepts and their relationships when studying molecular biology within instruction-based lecture with no other pedagogical applications. In this study, we have designed an experimental to investigate the effect of a hands on paper models exercise within group work (Jigsaw Cooperative learning) on student biology teachers' academic achievement and attitudes to biotechnologies. Our goal was to develop a manipulative activity using inexpensive but graphic materials. The sample for this study consisted of 42 student teachers in the department of Biology Education during the 2005-2006 academic year. We have divided the students in two different classes. One of the classes was randomly assigned as the non-paper model (control, n=21) and the other as the paper model group (n=21). In experimental group cut and paste paper models exercise within cooperative groups, in control group traditional instructional design has been applied in teaching DNA structure, Central Dogma and Recombinant DNA. The posttests of the groups in achievement and attitudes to biotechnologies show significant differences. The results indicated that the paper model group was more successful than the non-paper group.

Key words: paper models; cooperative learning; DNA; central dogma; recombinant DNA

1. Introduction

Biotechnology and associated technologies like recombinant DNA technology are poised to become one of the most important scientific revolutions of the 21st century. We recognize the enormous potential that biotechnology holds for improving the quality of our lives. Therefore, it is important that the general population understands the concepts behind the recombinant DNA technologies. Such technologies have presented and will also continue to present society with some very difficult ethical problems. In the future, every member of the population will need such knowledge in their careers and in their daily life as they participate in the public debate on the impact of these new technologies. Will our students, as adults, sufficiently understand the issues involved when they are called to solve those problems?

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Researches have shown that undergraduate students typically lack a coherent view of biotechnology concepts (Stencel, 1995; Eckdahl, 1999) and their relationships when studying molecular biology (Jenkins, 1987; Malacinski & Zell, 1996; Bohrer, 1997; Wagner, 1998; Kirkpatrick, et al., 2002). The study of molecular genetics and biotechnology demands that students understand the key concepts of molecular biology such as DNA, central dogma and the manipulation of DNA. Many students have heard the term biotechnology or recombinant DNA, but most of them probably could not explain the difference between the concepts. Students also have trouble in visualizing the structure of DNA, replication, central dogma, protein synthesis, and the techniques of DNA cloning. Instruction-based lecture with no other pedagogical applications yields unsatisfactory results. Students lack a motive to learn the subject as they find classroom learning inadequate. This contradicts with today's cognitive theories which view students as active participants of the learning process. So, educators have new ways such as cooperative learning, to help learners solve their learning problems and be independent learners. There is much support for using cooperative methods, since important instructional aspects, such as elaboration of new information, can easily be realized by methods like "jigsaw". Jigsaw (Aronson, et al., 1978) is preferred by researchers since it can be used in the classroom and makes it easy for students to understand the subject. The jigsaw cooperative learning structure enhances cooperative learning by making each student responsible for teaching some of the material to the group. In this structure, students are members of two different groups, the "home group" and the "jigsaw group". Initially, students meet in their home groups and each member of the group is assigned a portion of the material to learn as an "expert" (Slavin, 1991). While in the jigsaw groups, the students discuss their particular material to ensure that they understand it. All groups in a class may cover the same topic or different groups may have different parts of the topic. Jigsaw cooperative learning has positive effects on achievement (Colosi & Zales, 1998; Koprowski & Perigo, 2000; Brown, 2003; Smith & CHANG, 2005; Holbrook & Rannikmae, 2007). Student attitudes towards the learning subject influences more positively in cooperative setting than it does in classical classroom teaching (Johnson & Johnson, 1999). Learning is active and more productive because students who need explanations can often get them quickly and personally when other students explain, and students who do the part of the whole studying material strengthen their understanding in the process (Harmin, 1994; Maloof & White, 2005; Honeycutt & Pierce, 2007). Active learning and increased motivation to learn are common benefits of time spent in classroom during specific abilities that can be exercised, including social interaction skills within teams and small groups, exploratory time, teaching skills and creativity (Chang & Lederman, 1994; Lazarowitz, et al., 1994; Hedeem, 2003).

As to teach main procedures of recombinant DNA technology, the activities that follow illustrate in paper of the structure of DNA, replication, protein synthesis, and the techniques of DNA cloning within Jigsaw cooperative learning groups. Since many schools in Turkey do not have access to the expensive equipment required for such technologies, the paper model activities would provide an opportunity to understand the concepts of recombinant DNA and biotechnology. We have designed an experimental design to investigate the effect of hands on paper models work exercise on student biology teachers' academic achievement and attitudes to biotechnologies. The cut and paste paper models can be used at any level of biology classes, especially in teacher education who have the mission of sharing own experiences with their students (Peebles, 1987; Colosi & Zales, 1998, Koprowski & Perigo, 2000; Reed, 2001; Wood, 2007; Jensen & Moore, 2008). We have adapted cut and paste paper models of the biotechnology concepts from Kreuzer and Massey (2001). Our goal was to develop a manipulative activity using inexpensive but graphic materials and also an active learning environment that will support learning in molecular biology classroom.

2. Method and materials

The sample for this study consisted of 42 students in Biology Department of Buca Faculty of Education cited in Dokuz Eylul University in Izmir. In experimental group (n=21) cut and paste paper models exercise, in control group (n=21) traditional instructional design has been applied in teaching recombinant DNA and biotechnology concepts. In experimental group, the student teachers studied in groups of four. Each group member was responsible to teach a specific part of the learning material. While constructing models within the groups, each student explained the structure and function of the molecular concepts, subjects and systems. After having completed the lectures on each unit subject, every group was given one sample pattern of the paper models. They have worked together discussing on the procedures and assigning each for a particular piece of work while constructing the models (Figure 1). In traditional group, lectures with no other activities were given.

The subjects for the cut and paste paper models (Kreuzer & Massey, 2001) are:

- (1) Constructing a paper helix of DNA;
- (2) From genes to proteins;
- (3) DNA scissors (restriction enzymes);
- (4) Recombinant paper plasmids;
- (5) Electrophoresis;
- (6) Polymerase chain reaction.



Figure 1 Students use the models to explain the concepts with DNA paper model in the left image

The data were collected by an achievement test consisted of 40 questions and an attitude scale of 50 questions. The validity and reliability trial tests are made before the research. Kuder-Richardson 20 reliability test statistics value for achievement test is 0.78 and Cronbach's Alpha statistics value for the attitude scale is 0.75.

3. Results

There was no significant difference between the mean scores of the control and experimental group's pretests (Table 1 and Table 2). That means that initial achievement grades and attitudes towards biotechnologies do not significantly differ within the group members.

Table 1 The pre-tests solutions of achievement test

Groups	n	Mean	SD	df.	t-value
Experimental	21	38.690	12.005	40	1.114
Control	21	35.000	9.287		$p < 0.05$

Table 2 The pre-tests solutions of attitudes scale

Groups	n	Mean	SD	df.	t-value
Experimental	21	173.476	14.062	40	0.352
Control	21	171.952	13.969		<i>p</i> <0.05

The posttests of the groups in achievement and attitudes to biotechnologies show significant differences. Visualizing difficult concepts by using cut and paste paper models exercise in jigsaw cooperative is found to be more successful than traditional design (Table 3 and Table 4).

Table 3 The post-tests solutions of achievement test

Groups	n	Mean	SD	df.	t-value
Experimental	21	75.857	11.997	40	3.946
Control	21	61.238	12.012		<i>*p</i> <0.001

Table 4 The post-tests solutions of attitudes scale

Groups	n	Mean	SD	df.	t-value
Experimental	21	189.333	17.327	40	2.483
Control	21	176.095	17.218		<i>*p</i> <0.05

4. Discussion

Biotechnology represents an important field for the development of new educational tools. While the activities are very brief and simple, its value of clearly visualizing and illustrating the basic techniques of genetic concepts and biotechnology can not be disputed.

As shown in findings (Table 3 and Table 4) such simple activity had a highly positive effect on student learning, improving academic achievement and permanence of knowledge. Student interest and curiosity had also been positively influenced. Accompanied by the group work discussion and assignment, students were able to pertinent events of DNA and biotechnology. Working as teams promotes active learning by encouraging involvement and supports and new learning approaches. The majority of the students participating in the activities in experimental group have delivered more useful information and communicated easily with other students. The continuous communication and interaction between students seemed to be a powerful learning tool. Such activities capture student attention because students are working and experiencing their knowledge of the subjects when manipulating concrete models of them.

The findings also support the positive effects of cooperative learning on students' academic achievement, attitudes and social development. Having students work in groups enhances group interaction, interpersonal cooperation and management skills. Explanations and giving help to others encourage reorganization and clarification that may help the person understand the learning material better, develop new perspectives and construct more elaborate cognitive understanding. Cooperation enhances student satisfaction with the learning experience by actively involving students in designing and completing class procedures and course content. Effective teams or groups assume ownership of a process and its results when individuals are encouraged to work together toward a common goal, often defined by the group. This aspect is especially helpful for individuals who have a history or failure. Group work also develops positive student-teacher attitudes. Lines of communication are opened and actively encouraged.

The student attitudes towards biotechnologies also positively influenced in experimental group. Students' attitudes, motivation and interest are greatly enhanced when students are given the opportunity to visualize and

manipulate the molecular concepts. Group work also develops positive attitudes towards the lessons and the course content. Biotechnology is the object of considerable debate in most countries in the past decade. A number of factors have an important role in shaping the public image towards biotechnologies. One of the factors is that “Do students completely and accurately understand the concepts behind biotechnologies?” Such practical and inexpensive cut and paste activities can support visualizing concrete concepts and visualizing the molecules.

Potentially these models can be used in a number of different educational situations. An obvious application of the genomics project will be a high school biology, genetics, or agriculture classroom. The models can be used as a supplement to the existing curriculum, or it can be used extension education. Also the models can serve as good activities in major laboratories to reinforce concepts.

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