

The Effect of Different Molecular Models on High School Students' Conceptions of Molecular Genetics

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Abstract

Our main goal in this study was to explore whether the use of models in high school molecular genetics instruction can contribute to students' understanding of concepts and processes in genetics. Three hundred and nineteen students from four comparable groups of 11th- and 12th-grade students participated. The control group (116 students) was taught using the traditional lecture format, while the others received instruction that integrated one of the following models: Bead model (71 students), computer simulation (61 students), or illustrations typically used in textbooks (71 students). Each group was provided with similar instructions and the same guiding questions. We used two assessment instruments; a written questionnaire and personal interviews. The written questionnaire (post-test) comprised 10 open-ended and 13 multiple-choice questions. Six of the multiple-choice questions were also given to students before receiving their genetics instruction (pre-test). We conclude that it is worthwhile to integrate activities with specific instructions and guiding questions in the teaching of molecular genetics in high school. Moreover, the open-ended questions brought out the differences among the groups, revealing that activities with the bead model and computer simulation were significantly more effective than the illustration activity. (This paper is a summary of Marbach-Ad, Rotbain, & Stavy, 2005; Marbach-Ad, Rotbain, & Stavy, 2008; Rotbain, Marbach-Ad, & Stavy, 2005; Rotbain, Marbach-Ad, & Stavy, 2006; Rotbain, Marbach-Ad, & Stavy, 2008)

Genetics is generally regarded as very difficult both to teach and to learn (Fisher, 1992; Hildebrand, 1986, 1991; Marbach-Ad, 2001; Marbach-Ad & Stavy, 2000; Simmons & Lunetta, 1993), especially at the microscopic level. In molecular genetics, teachers and textbooks usually use chemical-formula models to represent the structure of molecules such as DNA, RNA, and protein. Since many biology students have difficulty in understanding the language of chemical formulae, researchers taking a constructivist approach have recommended enhancing the teaching of molecular genetics through the use of instructional tools such as models (e.g., Evans, 2003; Malacinski & Zell, 1996; Peebles & Leonard, 1987; Schollar, 2003; Templin & Fetters, 2002a, 2002b; Tsui, & Treagust, 2004). The great value of models is that they enable objects, events, or ideas, whether they be complex or abstract, to be rendered into forms that are either simpler or visually more concrete (Gilbert & Boulter, 1995). As students work with the models, they are more likely to remember and transfer their learning to new situations (Berenfeld, Pallant, Tinker, Tinker, & Xie, 2004; Mayer, 2003). There are different ways of integrating models in class, from demonstrations to hands-on model activities (e.g., Bennett, 1998; Fink, 1990).

Our main goal in this study was to explore whether the use of specific model-assisted activities in high school molecular genetics instruction contributes to students' understanding of genetics concepts and processes. All activities dealt with DNA and RNA structure, DNA duplication, and the processes related to protein synthesis. Three model-assisted activities were used: Physical bead model (Marbach-Ad, Rotbain, & Stavy, 2005; Rotbain, Marbach-Ad, & Stavy, 2006), dynamic computer simulation (Marbach-Ad, Rotbain, & Stavy, 2008; Rotbain, Marbach-Ad, & Stavy, 2008), and illustrations derived from textbooks (Rotbain, Marbach-Ad, & Stavy, 2005).

Methodology

Three hundred and nineteen students from four randomly-selected comparable groups of 11th- and 12th-grade students were examined. One group (the control group) was taught about DNA replication and DNA transcription translation using the traditional lecture format (116 students from eight classes), while the others received instruction that integrated one of the following models, as illustrated in Figure 1: Concrete bead model (71 students from six classes), computer simulation (61 students from five classes), or illustrations (71 students from seven classes).

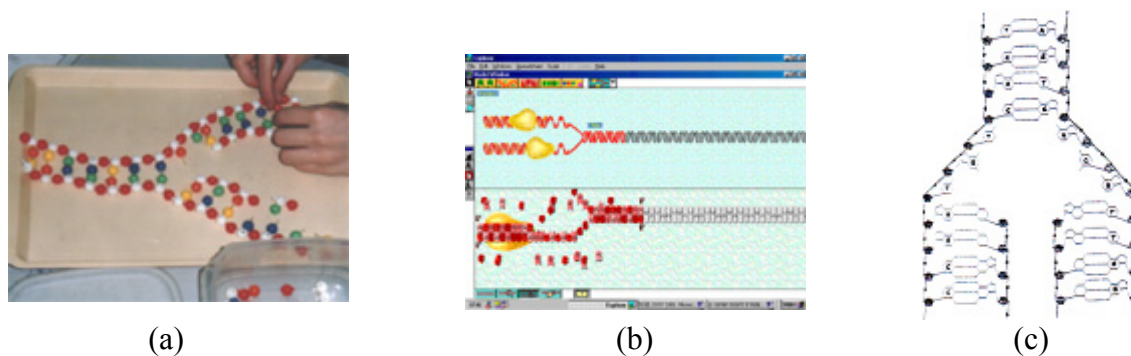


Figure 1. The DNA replication process as represented by three models: (a) Bead model, (b) computer animation model, and (c) illustration model.

The three modelling activities were accompanied by a similar set of instructions, as exemplified in Figure 2 for the illustration activity for the translation process. These instructions included activities such as drawing, painting, figure completion, and finding missing words. Embedded within the instructions for each model was the same set of guiding questions designed to focus students' attention on main issues so as to help them select the relevant information and organize it coherently. These questions asked students to explain what they did in the activity, relate between concepts and processes, find regularities, predict the next step in the process, and draw conclusions based on having done the activity.

While students worked on the activities in pairs, each student was required to answer the questions individually. In all activities, the teacher and the first author helped those who needed technical support with the model or required clarification regarding the guiding questions.

Two assessment instruments were used in this study; a written questionnaire and personal interviews. The written questionnaire, which comprised 10 open-ended and 13 multiple-choice questions, was given to the students after the molecular genetic instruction (post-test). Appendix A contains these open-ended questions, together with examples of the multiple-choice questions. Six of the multiple-choice questions were also given to students before receiving their genetics instruction (pre-test). For the six pre-test questions, we constructed a composite score that used analysis of variance (ANOVA) to check on the comparability of the groups. Composite scores were separately calculated for students' answers to the 10 open-ended questions, as well as the 13 multiple-choice questions. Differences among the four groups were analyzed using one-way analysis of covariance (ANCOVA). Finally, the first author individually interviewed all students (both control and treatment) about their experience of the instruction.

The Translation Process

Figures A-F represent major stages in the translation process. The figures are arranged in their actual order in the process.

- Fill in the missing words (mRNA, Peptide bond, Amino acid, Anti codon, tRNA).
- Each of the following six sentences describes one stage in the translation process, and is compatible with one of the Figures A-F, but the sentences are not in this order. For each sentence, choose the correct figure and write the appropriate letter near the sentence:
 - ___ Peptide bond is formed between the first amino acid of the growing protein chain (which is on *P* site) and the second amino acid (which is on *A* site).
 - ___ Bonding of second tRNA-amino acid complex to the mRNA at site *A*.
 - ___ The ribosome moves down the mRNA one codon, and the tRNA with the amino acids chain is now at site *P*.
 - ___ Bonding of third tRNA-amino acid complex to the mRNA at site *A*.
 - ___ Release of uncharged tRNA from site *P*.
 - ___ Bonding the first tRNA-amino acid complex to the mRNA at site *P*.
- Which step will follow Figure F?
- When does the translation process come to an end?
- Based on your previous assignments, write a short paragraph that describes the translation process.

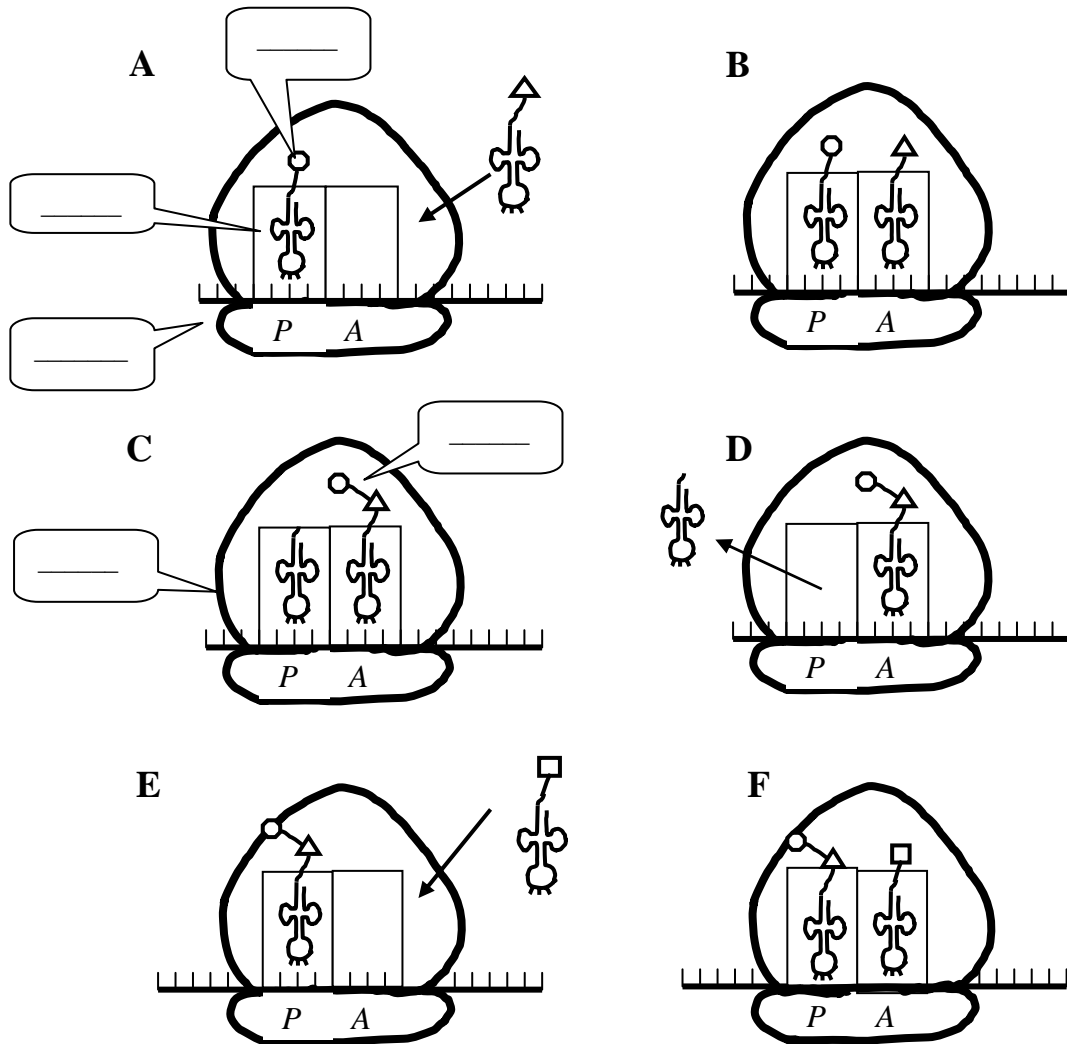


Figure 2. The illustration activity used to teach the translation process.

Findings

Comparison of the pre-tests of the four groups verified that the groups were equivalent. There was no significant difference between the performance of the three activity groups on the multiple-choice questions (average scores for the bead activity, computer simulation, and illustration activity students were 71%, 70%, and 68%, respectively), but these students scored significantly higher than the control students (average score 59%, $p < 0.01$).

Analysis of students' answers to the open-ended questions also showed significant differences between each of the three activity groups and the control group (average 46%). However, in this case, the performance of the groups who used the bead model (66%) and the computer simulation (68%) were significantly higher ($p < 0.001$) than that of the illustration activity group (59%).

Discussion

This research shows that students who received a set of instructions and guiding questions, along with use of one of the three types of models, improved their knowledge in molecular genetics more than the control group. However, the open-ended questions brought out the differences among the groups, revealing that activities with the bead model and computer simulation were significantly more effective than using an illustration activity. Interestingly, the average scores of the bead model group and the computer simulation group were nearly identical.

During the interviews, students who worked with the beads or the computer simulation pointed out that the activity mainly helped them to gain a better understanding and to visualize the abstract concepts. Students also mentioned that the models were fun to work with. Students who worked with the illustration activity mentioned that the activity mainly helped them to organize the subject matter.

In sum, the findings show that using a three-dimensional model (i.e., the bead model) or a computer animation model can improve students' understanding of molecular genetics. Moreover, engaging students in activities with two-dimensional illustrations can also improve their achievement in comparison to traditional instruction, and illustrations are more readily available than three-dimensional models. It would be interesting to also examine the use of such illustration activities in the teaching and learning of other biology topics.

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Appendix A: Items From the Written Questionnaire

Open-Ended Questions

1. What is DNA?
2. Write a sentence that includes the concepts nucleotide and nitrogen base.
3. Complete the following sentences:
 - (a) The four nucleotides of DNA have in common
 - (b) The differences between the four nucleotides of DNA are due to
4. Is information about the sequence of one strand of DNA sufficient to determine the sequence of the other strand?
5. How does DNA replication occur in the cell?
6. Write a sentence that includes the concepts DNA and protein.
7. What is the genetic code?
8. Can the translation process occur without the transcription process? Explain your answer.
9. Can protein synthesis occur without the presence of t-RNA? Explain your answer.
10. You are asked to design a gene that codes for insulin. What information do you need in order to do it? Explain your answer.

Sample Multiple-Choice Questions

1. Pea seeds were planted in the garden. The plants that grew from these seeds had flowers of different colours. What are the differences between the seeds that produced the different flower colours?
 - (a) The seeds include different types of pigments.
 - (b) The seeds include DNA that consists of different kinds of nucleotides.
 - (c) The seeds include DNA that consists of different nucleotide sequences.
 - (d) The seeds include different types of ribosome.
2. What is a gene?
 - (a) A gene is a trait in the organism.
 - (b) A gene is a trait that transfers from one generation to the next.
 - (c) A gene is a segment of the DNA that codes for protein.

- (d) A gene is a sequence of amino acids (in the DNA) that is responsible for the transmission of a trait from one generation to the next.
3. The accuracy of the DNA replication process is due to:
- (a) The presence of genes in the DNA molecule.
 - (b) The pairing between the DNA nitrogen bases.
 - (c) The sequence of the DNA nitrogen bases.
 - (d) The sequence of the DNA nucleotides.

Outdoors Environmental Education for the Service of Peace: Lessons From a 2-Year Youth Program for Reconciliation in Cyprus

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Abstract

This paper examines the merits of the proposition that outdoors environmental education can be used as a means to promote reconciliation, and in essence peace, among communities in Cyprus. It does so through an examination of an outdoors youth program called CAFE (Camping, Fitness, and Education) that aimed to promote the awareness of members of two conflicting communities, Greek Cypriot and Turkish Cypriot, about local environmental issues. More specifically, the objectives of this program were to determine whether a specially-designed outdoors environmental program can assist in bringing the two communities together. In this paper we describe the nature of the program activities and provide some participant perspectives as anecdotal support for the program's success. The evidence suggests that the outdoors environmental activities provided the participants with opportunities to view socially constructed "realities" and "truths" from the other's point of view, while concurrently developing an understanding of local environmental issues.

In 1976, The Belgrade Charter: A Global Framework for Environmental Education (UNESCO-UNEP, 1976) summarized the goal of environmental education as to develop a world population that is aware of, and concerned about, environmental and associated problems and that has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones. These goals were better defined 20 years later by five objectives outlined in UNESCO-UNEP (1996). These objectives are to improve:

- *Awareness.* To help social groups and individuals acquire awareness and sensitivity towards the environment as a whole, and issues, questions, and problems related to the environment and development.
- *Knowledge.* To help individuals, groups, and societies gain a variety of experience in, and acquire a basic understanding of, what is required to create and maintain a sustainable environment.
- *Attitudes.* To help individuals, groups, and societies acquire a set of values and feelings of concern for the environment, and the motivation to actively participate in protection of the environment.
- *Skills.* To help individuals, groups, and societies acquire the skills for identifying, anticipating, preventing, and solving environmental problems.