Learning Genetics through a Web-Based Research Simulation in Bioinformatics: How Do Students' Approaches to Learning Influence their Learning Outcomes?

Hadas Gelbart
Weizmann Institute of Science
hadas.gelbart@weizmann.ac.il

Anat Yarden
Weizmann Institute of Science
anat.yarden@weizmann.ac.il

Abstract

A web-based simulation of an authentic research in genetics was developed for high-school biology students on the basis of a research paper in the field of genetics in the current genomic era. The simulation enables learners to participate through a guided inquiry in a simulation of a research using authentic computer-based bioinformatics tools and genetics procedures. The purpose of the study described here is to examine how students' approaches to learning using the simulation influence their learning outcomes. Two types of learners were identified in the course of this study, Research-oriented and Task-oriented, on the basis of the differences in the ways they seized opportunities to recognize the research practices, which in turn influenced their learning outcomes. The Research-oriented learners expanded their genetics knowledge more than the Task-oriented learners. In addition, the learning approach taken by the Research-oriented learners enabled them to recognize the epistemology that underlies authentic genetics research, while the Task-oriented learners referred to the research simulation as a set of simple procedural tasks. Thus, Task-oriented learners should be encouraged by their teachers to cope with the scientists' steps in the context of the genetics research, while learning genetics through the environment in a class setting.

Keywords: simulation, learning approaches, bioinformatics, genetics, authentic inquiry.

Introduction

Computer-based simulations can be designed to engage learners in activities similar to those carried out by scientists, by giving them opportunities to learn by doing as they explore authentic problems of a scientific discipline using authentic tools and procedures normally used by scientists (Edelson, 2001). Such activities can offer students opportunities to invoke the reasoning that scientists employ and the epistemology underlies authentic inquiry (Chinn & Malhotra, 2002), can represent important discipline-specific aspects of science (Samarapungavan, Westby, & Bonder, 2006), and can provide students with a concrete experience that they can use to support construction of abstract knowledge (Edelson, 2001).

One of the fields in which students' understanding could benefit from such simulations is modern genetics. Learning of modern genetics has been reported as challenging for students (Bahar, Johnstone, & Hansell, 1999). One of the major obstacles students' encounter when learning genetics is to form a link between a trait (phenotype) and the associated molecular mechanism (genotype) (Marbach-Ad & Stavy, 2000). Several researchers suggested that for

Proceedings of the Chais conference on instructional technologies research 2008: Learning in the technological era
Y. Eshet-Alkalai, A. Caspi, N. Geri (Eds.), Raanana: The Open University of Israel

students to truly comprehend modern genetics, they should be given some experiences with authentic research practices (Cartier & Stewart, 2000; Finkel, 1996).

The current geneticists’ toolbox is composed of classical genetics approaches, laboratory-based molecular biology methods and computer-based bioinformatics tools. Equipped with this markedly improved repertoire of research tools, geneticists are now able to address the problem of connecting phenotype to genotype at an unprecedented level of molecular detail (Collins, Green, Guttmacher, & Guyer, 2003), Toward this end, a basic heuristic of comparing between the normal and mutated forms of a certain character to correlate the mutated version of the normal gene with the phenotype of affected individuals is used (Vance, 1996).

This rationale was addressed in a web-based simulation of an authentic research in genetics and bioinformatics developed for high-school biology students (Gelbart & Yarden, 2001, 2006). This simulation enables learners to apply their knowledge in genetics by giving them an opportunity to participate through a guided inquiry in a simulation of a research in the discipline of genetics using authentic genetics practices. This includes the use of bioinformatics tools and genetics procedures. The learning environment was developed on the basis of a research paper in the field of genetics in the current genomics era in which a mutated gene, which causes deafness in an Israeli family, was identified (Vahava et al., 1998).

Through the guided inquiry, the students are introduced to the research goal of identifying the gene in the genome and are invited to follow, step-by-step, five sequential assignments. Those assignments are designed in a similar manner to the methods used by geneticists, including the use of the original data, and through authentic tools and procedures which are presented in the original paper.

The purpose of the study described here is to examine how do students' approaches to learning using the authentic simulation influence their learning outcomes?

Methods

Qualitative methodological approach was used in this study in order to answer the research question. Four high-school biology students (12^{th} grade, 17-18 years old) participated in the research towards the end of learning genetics in their class. The students were chosen according to their self motivation to take part in the activity, and were grouped into two pairs that chose to be partners (each dyad included a boy and a girl, Rina and Ron, and Tania and Tom) and were considered high achievers. The two pairs were videotaped while learning using the environment in a laboratory setting. The learning process lasted about 4 hours.

The data was qualitatively analyzed following Shkedi (2005). Episodes were first analyzed with respect to students' approach to learning using the environment and iteratively analyzed with respect to students' understanding of genetics. The differences found between the students' approaches to learning using the environment served as a perspective for the analysis of their understanding of genetics.

Results

Characterization of students' approaches to learning using the simulation

Differences were found between the ways the two student pairs coped with the learning environment. One pair, Rina and Ron, were constantly involved in the research. They followed each assignment with sustained interest, and sought meaningful understanding before moving to the next one. We recognized a learning pattern in which they made an effort to understand the scientific tools and procedures in each of the research steps represented in the assignments and then engaged in interpreting data and autonomously deciphering the meaning of the scientific data.

In contrast, the other pair of students, Tania and Tom, did not often seek for understanding the scientific tools and procedures in each of the research steps in detail. Instead, they often focused only on the procedural level of the problem by superficially using the tools and procedures looking for the correct answers to the guiding questions in the data presented. They merely demonstrated further interpretation of the data, and concentrated on answering each scaffolding question in such a way that will enable them to move to the next question.

Due to the differences between the ways the two student pairs coped with the learning environment, we characterized Rina and Ron as Research-oriented learners, and Tania and Tom as Task-oriented learners.

Description of the students' learning outcomes

The Research-oriented learners. The involvement of Rina and Ron in the genetics research enabled them to recognize the genetics research practices. This includes perceiving the problem that has to be solved, following the sequence of the research steps, while using tools and procedures that geneticists use and interpreting data. The interpretation of the data enabled them to generate inferences, to provide explanations and to develop theories, following each of the assignments. In this way they were able to coordinate results from different stages of the study. While doing so they became aware of causal connections between the research steps and acquired an ability to refer to each of the research steps in the framework of the genetics problem. In addition, they became aware of the basic heuristic that geneticists' use.

In complement to the recognition of the genetics practices, the students were able to expand their genetics knowledge through generating causal explanations and inferences which explicitly referred to the phenotypic level (i.e. the hearing characteristic), and connecting it to the molecular mechanism involved (i.e. referring to the gene of interest using different biological organization levels). The students also utilized opportunities to examine their understanding of some critical characteristics of those concepts. Thus, the Research-oriented student pair expanded their genetics understanding through the recognition of the genetics research practices.

The Task-oriented learners. By not being constantly involved in the research steps, the Task-oriented student pair generated only a general understanding of the research practices. The students focused on understanding the genetics practice in detail only in the second assignment. During this stage, they could connect between the phenotype and the gene involved, and became aware of the basic heuristic that geneticists' use. During the next sequential assignments, they gave little attention to the research sequence. Their answers were general and did not refer to the particular problem. They did not tend to examine their understanding of certain concepts when applying the concepts in new situations of the genetics practice.

Thus, in contrast to the Research-oriented student pair, the Task-oriented student pair acquired a general understanding of the research practices and the research heuristic, but did not acquire an ability to refer to each of the research steps in the framework of the genetics problem. Thus, the Task-oriented student pair did not fully recognize the genetics research practices and they expanded their genetics knowledge only partially compared to the Research-oriented student pair.

Discussion and conclusions

The comparison between the learning processes of the two student pairs revealed that the learning outcomes of the two student pairs can be described using the same "scale" that describes the understanding of genetics. Here, following the research steps, the Research-oriented student pair seized more opportunities than the Task-oriented student pair to recognize the genetic-research practices, which in turn enabled them to seize more opportunities to expand their genetics knowledge.

Chinn and Malhotra (2002) developed a theoretical framework which enables evaluating inquiry tasks in terms of how similar they are to authentic science. We argue that the different learning strategies applied by the Research-oriented student pair enabled them not only to recognize the cognitive activities of genetic research, but also to recognize the epistemology underlying authentic genetic research. In contrast, for the Task-oriented student pair, the research simulation reflected an epistemology that is not significantly different from simple school inquiry tasks.

Thus, the study described here indicates that students can utilize the opportunities provided within the environment to expand their genetics knowledge in different ways: to understand the practical meaning of genetic research and to generate an understanding of the epistemology that underlies the discipline-specific research. The latter requires consistent involvement in the research steps, including understanding the scientific tools and procedures in each of the research steps, and engagement in interpreting the meaning of the scientific data.

We suggest that in a class setting, learners should be encouraged by their teachers to cope with the scientists' steps in the context of the genetic research, while learning genetics through the environment. The teachers' involvement is especially important for students with a Task-oriented approach to learning science.

References

Bahar, M., Johnstone, A. H., & Hansell, M. H. (1999). Revisiting learning difficulties in biology. *Journal of Biological Education, 33*, 84-86.

Cartier, J. L., & Stewart, J. (2000). Teaching the nature of inquiry: Further developments in a high school genetics curriculum. *Science and Education, 9*, 247-267.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*, 175-218.

Collins, F. S., Green, E. D., Guttmacher, A. E., & Guyer, M. S. (2003). A vision for the future of genomics research. *Nature, 422*, 835-847.

Edelson, D. C. (2001). Learning-for-use: A framework for the design of technology-supported inquiry activities. *Journal of Research in Science Teaching, 38*(3), 355-385.

Finkel, E. A. (1996). Making sense of genetics: Students' knowledge use during problem solving in a high school genetics class. *Journal of Research in Science Teaching, 33*(4), 345-368.

Gelbart, H., & Yarden, A. (2001). Bioinformatics - Deciphering the Secrets of the Genome. The Amos de-Shalit Center for Science Teaching. Available: http://stwww.weizmann.ac.il/bioinformatics.

Gelbart, H., & Yarden, A. (2006). Learning genetics through an authentic research simulation in bioinformatics. *Journal of Biological Education, 40*(3), 107-112.

Marbach-Ad, G., & Stavy, R. (2000). Students' cellular and molecular explanations of genetics phenomena. *Journal of Biological Education, 34*(4), 200-205.

Samarapungavan, A., Westby, E. L., & Bonder, G. M. (2006). Contextual epistemic development in science: A comparison of chemistry students and research chemists. *Science Education, 90*, 468-495.

Shkedi, A. (2005). *Multiple case narrative: A qualitative approach to the study of multiple populations*. Amsterdam: John Benjamins Publishing.

Vahava, O., Morell, R., Lynch, E. D., Weiss, S., Kagan, M. E., Ahituv, N., Morrow, J. E., Lee, M. K., Skvorak, A. B., Morton, C. C., Blumenfeld, A., Frydman, M., Friedman, T. B., King, M. C., & Avraham, K. B. (1998). Mutation in transcription factor POU4F3 associated with inherited progressive hearing loss in humans. *Science, 279*, 1950-1954.

Vance, R. E. (1996). Heroic antireductionism and genetics: A tale of one science. *Philosophy of Science, 63*, 36-45.