COMPUTER–AIDED GENETICS TEACHING

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ABSTRACT

The main aim of the research was the attempt at finding the answer to the question regarding the influence of the way of realizing curriculum problems in genetics on the achievements of junior high school students in this respect. Among cognitive aims were, among others, establishing the conditions for effectiveness of the didactic process supported by use of computer programs at genetics classes and specifying the influence of computer aided teaching on the quality of students' knowledge. Practical aims of the research included, among others, establishing criteria that educational computer programs used at biology classes should meet as well as specifying the possibilities of using various types of tasks in interactive genetics learning with computer use. Research procedure included introductory research and two stages of proper research. The main research method applied in the course of proper research was teaching experiment. At the first stage of proper research one can talk of measuring dependent variables in simulated experimental situation, as the research was carried out in the first grade of high school (9th year of school learning), and the experimental factors were, among others, ready fragments of computer programs connected with the genetics teaching contents available at the Polish publishing market at the moment of beginning the research. The second stage of the proper research included the proper teaching experiment, as students of junior high school second grade participated in it (9th year of school learning), and the teaching aids applied in experimental classes included the author's own computer programs. The applied measuring tool was one-grade checking test, whose aim was showing the influence of experimental factors on the students' amount of knowledge and skills. In general, 984 students and 448 teachers participated in all the stages of the research, and altogether 379 class observation charts in 31 classes were analyzed. The obtained test results allow to state that there is a strict interdependence between the students' achievements in genetics and the way of presenting and realizing the curriculum problems. In case of classes participating in the second stage of the proper research one can talk about a significant influence of the own program of realizing teaching contents on the genetics learning and teaching effectiveness.

INTRODUCTION

Modernization of teaching methods is associated with the necessity for the development of didactic aids. It is not enough that they play, for instance, motivational, exercising, synthesizing or supervising function, they are to be made an independent source of reliable, easily comprehensible information, given in a way that activates students (Burewicz, Gulińska, Miranowicz, 1995; Pfligersdorffer and Weiglhofer, 1997). It is also important not to replace various functions and tasks of didactic aids applied in the process of teaching-learning Biology with each other, but only to interfere skillfully. What is meant here above all, is the proper choice of didactic aids depending on the contents they carry (Stawiński, 1992).

In view of the rapidly increasing amount of information what becomes most important is their understanding and skilful use of various kinds of 'information storages' (encyclopedia, computer software, the Internet), and not permanent, mechanical memorizing (Stawiński, 1989).
Research on the quality and usefulness of computer programs meant for school (and extra-school) teaching and learning is taken up. It is underlined that school practice requires methodically grounded

application of these aids in the processes of teaching and educating (Lindner-Effland, 1997; Pfiligersdorffer and Pfligersdorffer, 1997; Pondorf, 1997).

The research regarding the application of computers in the processes of teaching and learning Biology and other subjects is connected with an attempt at answering the following question: 'Does using a computer have a positive influence on student's achievements?"

SYSTEM DESIGN AND DEVELOPMENT

Research Model

The main aim of the undertaken research was an attempt to find the answer to the question regarding the influence of the manner of realization of curriculum issues in genetics on the students' achievements in this respect.

Definitional, empirical and inference indexes were attributed to specified variables in order to find out if the examined facts or phenomena appear in the case that is of interest here.
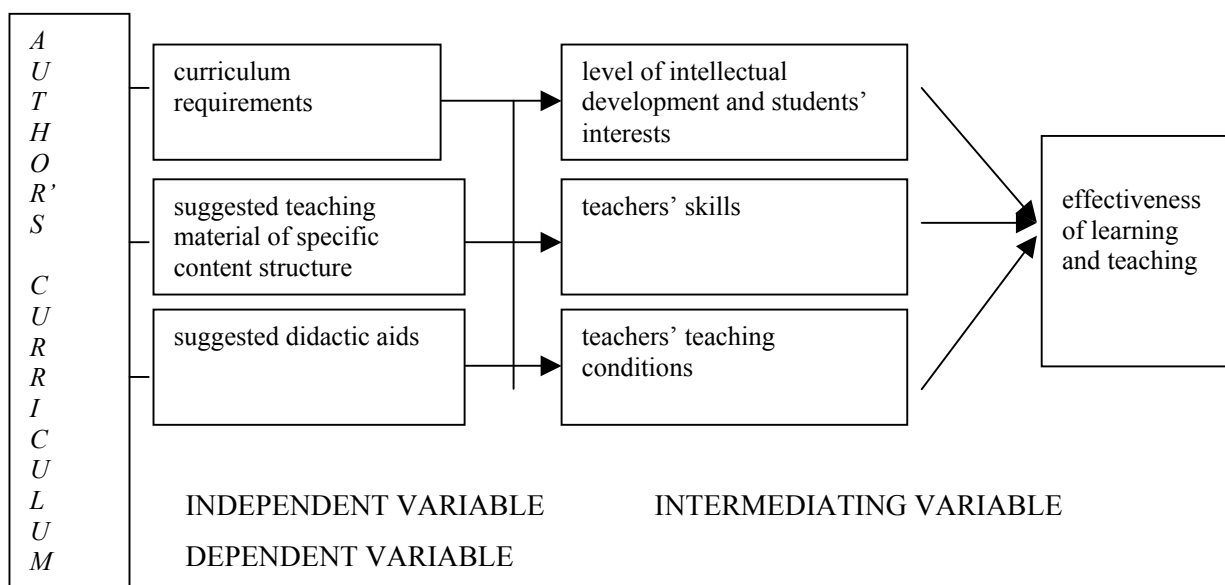

Figure 1. The kinds of variables

The research procedure included initial research and proper research. The main research method used at the stage of proper research was teaching experiment – a method that is complex in nature, which assumes that the method of observation is used at the same time. Its aim was gathering the data on the existence of interdependence between the two variables (curriculum and didactic solutions and the results achieved by students) and the evaluation of the suggested solutions.

Within the research on the problems of didactic transformation of the genetic contents at the level of junior high school the author developed computer programs topic-wise associated with the teaching genetic issues at this stage of education. The simplest of them provide only some information through a drawing, animation or written word, and sometimes they supervise the degree of their learning. Slightly more difficult programs allow the students to, for instance, actively participate in the course of an experiment regarding the generations of hybrids, the degree of revealing a given characteristic or the calculation of gains and losses resulting from specific activities.

These programs can also provide the teacher with auxiliary elements in preparation for the lessons – a collection of illustrations and other materials may be used in lesson conspectuses, students' papers, filmograms. Charts with tasks can be used for a written revision test in the given issues. It was the

author's aim to make interactive elements of the program support the build-up of knowledge and the process of shaping notions, reinforced research, independent searching and processing of information and increase the intensity of working on particular problems, and thus increase the students' attention and ability to memorize.

Didactic Concept Characteristics

The author's assumption was to develop a spiral structure of contents, i.e. grouping the teaching material in consecutive cycles. The first cycle (first part of curriculum) contains the whole teaching material in its basic form, understood as general interdependencies between the structure and function of genetic material, the second cycle (second part of curriculum) develops the information from the first cycle in order to make the students aware of the relationships between a genotype and a phenotype of organisms, the next cycle (third part of curriculum) extends the range of information and required skills, moving within the same curriculum notions. In such a type of curriculum it is not essential to master the previous cycle fully as the next cycle will revise and complete the information in the same range of contents anyway. Within each cycle material is presented in a linear way; spiral structure regards only the repeatability of contents in consecutive cycles.

Modifications of the author's curriculum regarded the applied computer programs. The programs applied in the first stage of proper research did not match that particular stage of education, particular teaching contents and topic units. Their application in a junior high school is connected with the need for carrying out a profound reduction and reorganization of the contents, which in effect makes the didactic process extremely difficult. Furthermore, these programs were biased in nature. They were only conducive to shaping the ability to search for information. Hence the need for developing the author's own computer programs, that could be used by teachers in the second stage of proper research.

Their writing was preceded by the choice of topic units, in which there is a need for using various types of computer-aided tasks.

All the programs created by the author assumed the realization of teaching aims due to interactive tasks which were solved by students in experimental classes while working with the curriculum. Examples of tasks and operational teaching aims assumed for realization during lessons carried out with computer use are presented in Tables 1a and 1b.

The tasks presented in Table 1b aim at controlling and evaluation of the degree of mastering by students the knowledge and skills regarding planning and predicting the results of the undertaken theoretical and practical activities.

Table 1a. Examples of formulating teaching aims and tasks predicted for the realization during lessons. 'Dominance and Recessiveness' and 'Blood Group Inheritance'

Teaching Aims	Tasks which should be carried out by students while working with computer program	Operational aims

Knowledge:
- Understanding the phenomena of dominance and recessiveness on the example of selected man's characteristics,
- Understanding phenomenon of independent inheriting of characteristics,
- Understanding the phenomenon of recombination as one of the sources of changeability in nature,
- General knowledge of Mendel's work and laws.
Skills:
-Using the foregoing notions,
- Interpreting the results of Mendel's experiments,
- Solving simple genetic crossings over regarding inheriting selected organism characteristics
	- Specifying a genome on the basis of phenotype.
	- Specifying genotypes and phenotypes of parents and offspring (independent inheriting of 2 or 1 characteristic).
	-Filling in Punnet's chessboard
	  • Doing exercises following instruction,
	  • Graphic presentation of exercises results.
		-To define the notion of 'dominance' and 'recessiveness and give 3 examples of such characteristics in man.
		-On the basis of parents' characteristics specify characteristics of offspring resulting from the phenomenon of recombination
		-Explain why generation F1 is uniform as far as phenotype and genotype are concerned.

'Dominance and recessiveness' program construction:
1. Introduction – phenotype and genotype description of Mendel's experiments – possibility of explaining new notions through entry screen display (vocabulary) and charts.
2. 'Decision tree' test and a task of filling in Punnet's chessboard.
3. Confirming a well - solved task.

'Man's Features Inherited in accordance with Mendel's Laws' program construction:
1. Student chooses any two pairs of features, establishes phenotypes and genotypes of parents and offspring.
2. Confirming the result of a well-solved problem in case of error; granting a clue allowing for completing information.

Table 1b. Examples of formulating teaching aims and problems for realization in lessons in 'Importance of Genetics'

Teaching aims	Problems which should be solved by students while working with the computer program	Operational aims
Knowledge: - Knowledge of possibilities to apply the results in experimental genetics in medicine and animal breeding, - Knowledge of the latest discoveries in developmental genetics, - Knowledge of the notions: 'biotechnology', 'genetic engineering', and the subjects of interest of these areas of knowledge. Skills: - Performing a simple classification of genetic research applied in medicine and animal breeding, - Perceiving relations between activities used in biotechnology and genetic engineering and their consequences.	- Analysis of text chart of the computer program. - Specifying the essence of procedures used in a given area of genetics as well as advantages and disadvantages of suggested activities. - Establishing possible consequences of man's intervention in genetic material of plants and animals.	- Point to 2 areas of knowledge in which biotechnology is applied. - Explain the meaning of the notion 'transgenic animals' on the basis of the text chart.

'Importance of Genetics' program construction:
1. Text chart – introduction to the subject of research methods and techniques applied in experimental genetics.
2. 'Cards' (to be chosen by students) presenting: various species of adult and young animals, equipment, type of undertaken activities, additional drawings with explanations.
3. Experiment's protocol – selection made by students.
4. Assistance – guidelines complementing the knowledge, vocabulary.
5. Consequences of undertaken activities and conclusion regarding the possibilities of their carrying out (ban or permission).
6. Check-up questions – mini-test – possibility of self-checks.

Tasks of this type require revealing the following abilities by students :
- associating the contents of a specific task and the more general natural problem,
- formulating hypotheses regarding predicted solutions and research methodology scheme,
- perceiving practical importance of the performed task.

All the above mentioned computer programs created by the author are electronic version of problems and tests contained in 'student work charts' (Potyrala and Chorazki, 2002).

EVALUATION

Design and participants

At all the classes carried out within the experiment (Table 2), transformation of genetic teaching contents was performed. During carrying out the experiment the following ways of transformation were taken into consideration: didactic structural reduction, reorganization and reconstruction of content, data updating, giving information that is practical in nature, making genetic knowledge available to students due to using various didactic aids.

Differentiating control classes, one group working exclusively on the basis of excerpts from available computer programs or data from the Internet and the other group working exclusively on the basis of models and a textbook (Table 3), was associated with an attempt to answer the question: do and to what extent do computer programs as a didactic aid applied at genetics lessons in junior high school influence the achievements of students in that respect.

Table 2. Number of people participating in the research, number of classes and watched lessons

Pupils	Students	Teachers	Number of classes	Number of watched lessons
984 (altogether at all the stages of the research)	240 (in the diagnostic survey)	448 (altogether in the diagnostic survey and in experimental study in schools)	31 (6-in initial research , 4 control classes and 7 experimental classes at the 1st stage of proper research , 6 control classes:K1-3, K4-6 and 8 experimental classes at the 2nd stage of proper research)	36(in initial research) 175 (at the 1st stage of proper research), 168 (at the 2nd stage of proper research)

Table 3. Initial concept of the genetic teaching process at the level of junior high school in experimental (E) and control (C) classes

	Classes E	Classes C
Basic range of teaching contents	Nucleic acids - location in the cell. Structure and function of DNA. Chromatin as an interphase form of chromosomes. Selected stages of mitosis and meiosis. Genes. Independent characteristics inheritance. Phenotype and genotype. Physical, psychical and physiological features of man inherited in accordance with Mendel's laws. Inheriting sex in man. Features associated with sex. Kinds of changeability. Genetically conditioned diseases. Application of genetics.	
Number of hours for the realization of genetics issues	8	
Predicted methods and strategies of teaching	- Laboratory method connected with organization of observing and experiments as well as displays - Modelling method - Work with various sources of biological information - method of didactic games (simulation, brainstorming, decision tree) - discussion - application of the said methods in a problem approach	- giving methods – description, lecture, pupil's project(1st and 2nd stage of proper research) - work with various sources of information (2nd stage of proper research , classes K1-3) - modelling method (2nd stage of proper research, classes K4-6)

RESEARCH RESULTS

Results of survey research
Results of survey research carried out at all the stages of the research pointed to the increase of the phenomenon of using computer programs and the Internet in the process of searching for and presenting facts at Biology lessons. The data updated in the second years of proper research reveal that over 3 years of the research the number of computers at schools has increased three times, the number of schools in which teachers use biological educational programs doubled, and the number of people who cannot use a computer on their own has decreased twice.

Pedagogical observation results
At the stage of proper research the sequence of teacher's and student's activity resulting from work with the author's computer programs (according to instruction) conditioned the accordance with the project as far as material structure is concerned. In experimental classes at the level of junior high school teacher in 95% used teaching methods and didactic aids assumed in the project (60 lessons).

Only at 4 lessons there was no agreement with the project in this respect for organizational reasons (lack of division into experimental groups or lack of access to computers).

Analysis of data contained in the lesson observation chart in experimental classes at junior high school allows for a statement of the student's activities' advantage over those of the teacher, in particular in practical activities connected with:
- carrying out experimental work
- deepening the knowledge of facts and rules
- task solving.

It was closely connected with the ways of performing the didactic transformation of teaching contents proposed by the author.

Didactic effects of experimental genetics teaching
The results of the carried out test point, among others, to the fact that the way of transforming genetic knowledge considered at this stage of research influences students' achievements positively. Higher average number of tasks correctly solved by students in experimental classes proves the favourable influence of planned teachers' activities at the level of students' knowledge and skills.

It results from the analysis of data regarding the performance of the test tasks in the examined groups of students that the students from the experimental class cope well with the tasks requiring use of genetic notions in situations that are either typical or problematic. These skills were much weaker in the control group. The achievements of students of experimental and control classes regarding the level of the aims of memorizing and understanding the facts and mastering skills in genetics by analyzing all the results of the test tasks' solutions were compared. The best results of testing regarding the teaching aims were achieved in the experimental group, slightly worse in the control group K1-3 and the worst in the control group K4-6. The students in the control group (altogether) gained worse results, statistically differing significantly from the results of students in the experimental group. Students' achievements at the level of aims regarding skills in genetics constitute the basic source of information on the influence of suggested methical solutions on the realization of the curriculum due to the interactive nature of computer program tasks, which were the experimental factor in the second stage of proper research.

Received results authorize the author to claim that there exists a close relationship between the students' achievement in genetics and the way of approach and realization of the curriculum issues.

Elaborating the structure of students' genetic knowledge at the level of junior high school and allowing students to build these structures (e.g. through various types of interactive tasks) increased the thinking operability in using theoretical laws, and thus created convenient conditions for building up new

knowledge on the basis of the knowledge already held. Solving e.g. tasks regarding the structure and functions of genetic material established the basis for considering scientific and ethical problems connected with practical application of genetics' achievements and simulating experiments carried out in research laboratories.

Result discussion

The degree, to which the dependent variable is specified by the group of independent variables considered in the research, was conditioned by the fact that in some situations the dependent variable was almost entirely specified by the independent variable (suggested didactic aids). It was so in case of control classes K1-3 and K4-6. And in case of all the control classes (altogether) we can talk about a situation where several independent variables to a slight degree shaped the dependent variable. It is similar to the research results on the manner of making biological knowledge available to students, didactic effects of teaching these contents (research on understanding the process of mitosis and meiosis by Biology students and pupils) and lesson observation results (Potyrala and Wojciechowska, 2000; Unterbruner ,1999). In case of the classes participating in the experiment at the second stage of proper research we can talk of significant influence of author's program of realization of genetic contents on the effectiveness of learning and teaching genetics. Possibility to carry out the experiment due to suitable material basis of schools and teachers' skills influenced the impartial evaluation of the author's project of teaching and learning genetics at the level of junior high school in actual school conditions. Teachers should apply suitable strategies and methods, which will help students not only to form scientific views, but also to use the knowledge and skills they have at further stages of education and in everyday life (Margel at al., 2002).

It is often noted that effective introduction of computer to school requires on the one hand the change of its organization, and on the other – accepting interdisciplinary and systematic approach to knowledge and introducing problem teaching (Siemieniecki, 2000). It is also noted that one of the reasons why school should teach in an integrated way, should be departure from encyclopedic approach and introducing a different subject structure of integrated teaching, aiming at modernization of didactic aids and measures applied in regard with students.

CONCLUSIONS

The applied methods and didactic aids, among others, influence the correct understanding of information constituting the basis of knowledge on heredity. Application of computer-aided teaching connected with the methods that activate students gives better results than those that are achieved while using traditional teaching methods. For instance, application of modeling method and using a computer program during the lesson regarding the structure and functions of genetic material turned out to be the best way to understand these issues. Tasks that are interactive in nature activate students, fix the acquired knowledge and influence the form of their presentation by students. More time should be devoted to such teaching. In case of genetic knowledge also the proper order of acquiring information is essential. It is a misunderstanding to transfer genetic contents from the level of high school to the considerably lower level without considering the principles and stages of didactic transformation of biological knowledge. It contradicts psychological and pedagogical criteria and leads to excessive burdening of students' minds, and hence to thinking chaos and decreasing of interest in this area of knowledge. Building up the new genetic knowledge should occur gradually, basing on the material basic knowledge.

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