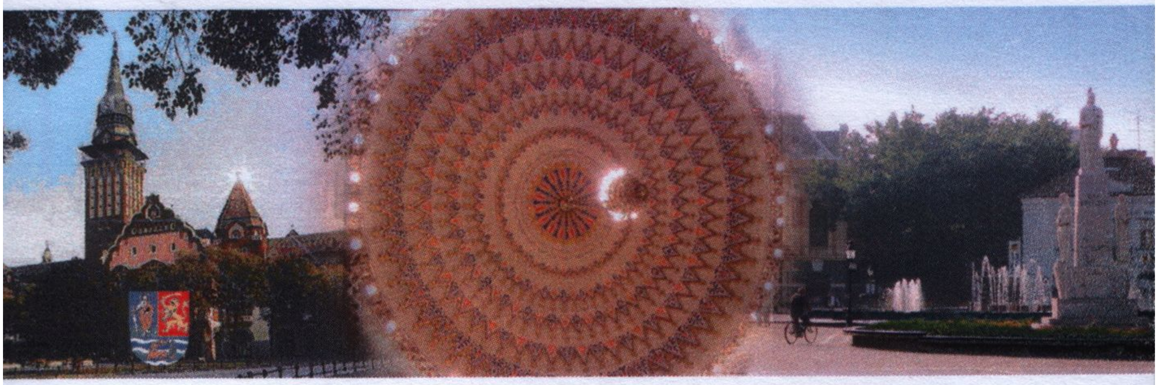
SISY 2009

7th INTERNATIONAL SYMPOSIUM ON INTELLIGENT SYSTEMS AND INFORMATICS

September 25–26, 2009 • Subotica, Serbia



PROCEEDINGS

IEEE Catalog Number: CFP0984C–CDR
ISBN: 978-1-4244-5349-8
Library of Congress: 2009909575

IEEE

SISY 2009 Proceedings

Proceedings Editor
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Computer modelling in mathematics education

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ABSTRACT

According to Aebli's operative method (1963) and Bruner's (1974) theory of representation the development of the process of thinking in teaching has the following phases - levels of abstraction: manipulation with specific things (specific phase), iconic representation (figural phase), symbolic representation (symbolic phase).

Modern information technology has contributed to the enrichment of teaching and learning processes, especially in the fields of natural sciences and mathematics and those of production and technology. Simulation appears as a new possibility in the representation of knowledge. According to Guetzkow (1972) simulation is an operative representation of reality from a relevant aspect. It is about a model of an objective system, which is dynamic in itself. If that model is material it is a simple simulation, if it is abstract it is a reflective experiment, that is a computer simulation.

This present work deals with the systematization and classification of simulation methods in the teaching of natural sciences and mathematics and of production and technology with special retrospective view on computer simulations and exemplar representation of the place and the role of this modern method of cognition.

Key words: *Representation of knowledge, modeling, simulation, education.*

Playing is the most natural activity of children and an unsurpassed pedagogic method when dealing with younger children. The biggest advantage of computers is that they make it possible for children to learn through games and fun. Didactic games represent a situation in which the child faces some problems, which they either cannot solve or can only partially solve on practical-perceptional and reflective level using their own earlier experience. In this study we are going to present, with specific examples, the realization of teaching geographic notions with the help of multimedial, interactive, didactic computer games in the lower grades of elementary school.

The experience of those developed countries which have introduced computers into their state school system - with additional, obligatory equipment to free children from using letter keyboards –says that the period of childhood before and during elementary school is the "period of sensitivity" – the best time to start working on computers. Dr Emil Kamenov in his discussions about the child – computer relationship mentions the conclusions of Meartin and Haf from 1989 where they state that computer is a way for practising fine motorics, coordination of eyes and hands. Also using a computer makes it possible for children to learn about the nature of objects and differentiate between them (e.g. colour and shape), about cardinal and ordinal numbers, series and sets and solving logic problems. This later, according to Meartin and Haf, makes it possible for them to improve different strategies (for example to choose the correct answer from the offered ones).

Those children who have computers at home, use them mostly for entertainment, then for studying and, in the third place, for communication on the Internet. According to some data, the capital that is invested and that circulates in the world of computer games today is 10 billion dollars which is as big as, or even bigger than the capital in cinematography. On the basis of statistics, computers are present in 70% of American households with children, and are quite used in the process of studying. It is believed that the linguistic learning with the help of the computers is 3 times, while numeral (mathematical) even 5 times faster when compared to traditional learning.

Computer technology and softwares enrich children's environment making it very incentive, which makes it possible to discover new aspects of experience, speeds up intellectual maturation and helps in the development of creative potentials. It is also important that children feel they can understand and control events in their environment, which can help them to adapt themselves to it more successfully thus preparing them for a more complex technological civilisation in which they are going to live. In this civilisation computer literacy will be inevitable. The question arises which are those characteristics that develop in children when using computers:

Intellectual development:

- Development of all intellectula processes: memorising, assumption, cognition...
- Logical reasoning
- Integration of lots of facts learnt one by one and taken these out from context connecting them into a complex unit

Development of character

- Independence – children understand that they can control media, that things happen depending on their actions, that is they take part actively in learning - playing and not just passively accept information
- Social – emotional openness – reaction of children to the heroes of games, emotional disapproval of negative characters, team play
- Development of view point
- Dealing with maturity
- Critical thinking
- Need for a true viewpoint
- Persistence
- Diligence
- Punctuality
- Accuracy
- Consequence

Development of willingness (control of willingness and attention)

- conscious control of one's behaviour which gradually leads to children's ability to learn on their own with the specific purpose to learn
- Adaption of some rules of behaviour
- High level of motivation with computers and feeling of satisfaction in work
- Independence in discovering the world around them
- Self-respect

Development of aesthetic skills

- Perspicuity
- Tidiness
- Clarity

Didactic games are those games which, apart from having all the general characteristics of a game, have special inbuilt activities (perceptive, exploring, logic, speaking, musical and others). These games are subordinate to some special educational tasks which are set in advance. With the help of didactic games children gain new experience starting with lower collective development heading towards its higher and more perfect forms. Through these games children are motivated to act in the world around them using the methods they have already experienced on themselves, this way improving their mental and other skills. Since the games are spontaneous and random (which is the biggest difference between them and other forms of learning, especially learning at school), learning through games has its own specialty. The list of facts that children meet one by one taken out from context become a unit thank to the game. It is also important that during the learning process while playing, curiosity also develops, which is different to other forms of learning (learning by models, learning by mistakes, learning by problem solving, etc.).

The game has a didactic value if it responds to any of the basic needs of the child and suggests them with its structures, rules and content.

Didactic games represent a situation in which problems emerge, problems that children either cannot solve or can only partially solve on practical-perceptional and reflective level using their own earlier experience. Since children in the game improve much, they are able to solve both practical and symbolic problems.

These games belong to the group of games with rules set in advance. The function of those rules is to regulate the content, the course of the didactic game as well as the child's behaviour. Apart from the rules, there is a set goal which represents a challenge for players to reach it as quickly, as well, as precisely and as cleverly as possible since it is about a problem the solution to which is only yet to be found. The conclusion about the names of the didactic games comes from this theory. We often find games with the titles 'find', 'discover', 'confirm', 'notice', etc.

Lots of didactic games require quick and skilful manipulation with small objects (cards, dominoes, etc) which means that besides skills of perception the fine muscle skills of the wrist are also developed as well as the coordination of the eyes and the hands as very important elements of graphomotoric development.

In didactic games all the planned elements of games are present, which means they contribute to the realization of educational goals.

Besides the fact that the rules, since children have to respect them, require the ability from children to identify themselves with the situation, they also help children to gradually differentiate game from work.

According to Aebli's operative method (1963) and Bruner's (1974) theory of representation the development of the process of thinking in teaching has the following phases - levels of abstraction: manipulation with specific things (specific phase), iconic representation (figural phase), symbolic representation (symbolic phase).

Depending on the subject of the study and the age of the students the role and the importance of the concretization (representation) of mathematical notions and structures are different. Sometimes "multiple representations" are understood as separate notions in relation to the notion that is being studied – the problem of going from one to another level of representation emerges. On the other hand the richness of the observed connections, similarities and differences is ensured, it is different on various levels of expertise. If the representations are 'artificial' and meaningless even though they are seemingly the concretizations of an abstract notion, or if the knowledge about a specific representation is superficial, they might seem contra-productive.

The active-iconic-symbolic spiral of knowledge implies inner movement in the attaining of awareness and security, from the manipulation with objects to the manipulation with symbols. The dominant method in the study of natural and production-technological field is based on:

- directing students' attention to subjects and phenomena that they can experience
- collecting known facts
- experiments under favorable circumstances
- formulation of definitions and conclusions and, on further levels, specification of laws
- application in everyday and other problems

In the education programs of first and second levels of most of the subjects there are two different concepts. One is mostly intellectual; the other is politechnically oriented and mostly practical. The first has to develop researching spirit in the students and to introduce them the scientific method, the other has to reveal interests and to direct them towards a specific profession.

If the state of being polytechnic in education is understood, among others, as the setting up of relations between knowledge, skills and habits and practical problems, then we are talking about the following implications of this notion:

- Solving practical problems in everyday life, in technology and production rises to a higher level thus intellectualizing the set task.
- In order for the practical problems to get to a theoretical level it is crucial to possess specific knowledge (knowing the principles and rules of the given sciences, knowing some specific methods and techniques, etc.), skills (being able to differentiate between important and not important, abstractization, creative thinking, orientation in new situations, etc.) and habits (being systematic, rationality, precision, being critical and self-critical, persistent, etc.).

- Applying scientific principles and laws in practical problems includes:
  - handling with deeply founded and understood theories,
  - applicable, "technizide" form of those theories,
  - compatibility and operativity of the applied laws (that the laws are expressed in the same form, in the same 'language'),
  - possible interpretations of the theoretical results

Mathematical-cybernetic modeling can mean important contribution in the solution of contradiction between theory and practice in many fields. Unique and rational form of expressing the laws of different, internally separated sciences, with the help of mathematical symbols and relations takes these theories to a common ground, thus making operations with them possible. This means that mathematical models appear transmission between scientific technical-technological and organizational-economic systems. Mathematical-cybernetic models are those abstract models, which, with the help of mathematical-cybernetic symbols, relations, terms and similar, represent reality from given abstracts and are used for its further study.

The process of the formulation of specific laws and their expression in mathematical form has to start at objective reality, so that with the help of analysis-synthesis, abstractization, generalization, in brief with the help of modeling we could arrive at them. At a certain point the formed laws, in the form of mathematical-cybernetic models can be used for further, more thorough study of the modeled phenomena, that is research, and thus experimenting can be continued on models (model experiments). With the transmission of information from the models to the original the dialectic path of cognition is closed.

The basic role of the model is to replace the object of the research, which applies in a specific way, and to give new information about them. While theories reflect objective laws in the immediate, in the model these laws appear in an idealized, 'clear' form. *The model in reality mediates between theory and the subject of the research, 'technizing' opinion.*

Experimenting on some real systems would be irrational and often impossible. Intuitive approach to some complex problems can also be inefficient. Applying the mathematical-cybernetic modeling in the study of objective reality in many cases can highly increase the efficiency of the research. Modeling makes deeper insight into the secrets of complex systems possible, thus revealing the essential and multiple relations in those systems. Those complex connections are reflected through relatively simple mathematical relations, which are suitable for research. Mathematical-cybernetic models make giving new information about systems possible. These are extrapolations of information about systems on the basis of well-known states and relations in a well-known, objective system. Elements, structure and other specialties of the original, of course, have to be reflected in the model in an appropriate way, accordingly there has to be an isomorphic or homomorphic connection between the model and the original. So model has to:

- join the essentials of each original from a given aspect
- be heuristic to make the discovery of new connections and structures in the original possible
- to signalize future states of the original - that they are prognostic

The method of model experiments, that is simulations, study of the original with the help of systems similar to them (systems that have the same mathematical-cybernetic model) play a significant role in the field of indirect research of systems, first of all those dynamic ones. So indirect study of objective systems can be carried out with the help of other similar physical systems, and with the help of symbolic mathematical-cybernetic models. Symbolic simulation is most often done with the help of a computer. This process can be represented with the following chart:

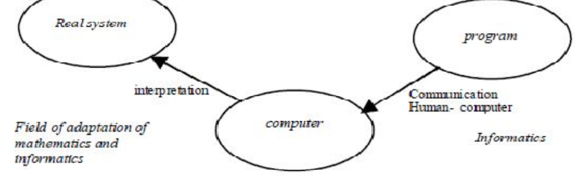

Figure 1. Scheme of simulation with the help of computer

During the analysis with the help of mathematical-cybernetic model, model becomes the subject of the analysis, and the conditions of the analysis also represented by specific parameters in the model.
The concept of the model is often identified with the form, with the representation of real systems with the help of abstract ones, or material analogue ones. Mathematical or cybernetic description does not yet mean modeling. Mathematical or cybernetic device (material analogue one, too) is considered to be a model of phenomena if:

- it reflects specific aspects of the analyzed original adequately and
- it is used for further analysis of the phenomena

There are the following stages of mathematical-cybernetic modeling:

- Detection and creation of adequate mathematical, cybernetic models in each science and field
- Abstract operations on the improvement and upgrade of the model
- Adaptation of the model

The creation of new models in each field of human activity is simply pushed out from modern mathematics, and inside many of these fields this process has not developed in satisfactory way. Mathematics, as a science, arrives at new mathematical concepts, models, etc very often and in a very abstract way, but it does not find adequate connection with reality. This is how social needs have led to the emergence of a new science, science of modeling, to cybernetics. With the spread of modeling in many sciences and fields of life and work the concept of cybernetics is also spreading. Sam N.Wiener stated that cybernetics is a science about analytical study of isomorphism of structures of communication in living organisms, society and technology. V.Cubef defined cybernetics even as a science of study, description and construction of the model. Mainly it was about mathematical models as bridges between theory and empirics.
Mathematical models are very diverse and developed, strict and reliable starting from algebraic and differential equations, through calculation of probability to graph theory, topology, mathematical logic, linear programming, etc. However the study of complex dynamic systems asked for new ideas and new methods. Cybernetics, besides using classic mathematical models and methods, has developed its own methods, models in two ways:

- forming of logical, symbolic, graphic, finally mathematical models
- creating real , functional, material aggregates

In cybernetic models relations are constituted between the model and the function of the original, in other words models are isofunctional; the original and the model react with the same output quantity to the same input quantities. Like the models of control and regulations of complex, dynamic systems, cybernetic models are most often informational models, schemes, block diagrams, charts, drawings, symbols that are not mathematical models, and these models are usually followed by quantitative mathematical descriptions. Programs that realize electronic, computing machines are also cybernetic models of specific thinking processes.
Strict mathematical representation of the original is often impossible on an existing level of mathematics, or the mathematical problem that that describes the phenomena is insolvable because of its structure or dimension; in these cases descriptive or simulation models are used. Simulation, as an empiric method of modeling, can be found on the periphery of the immediate and theoretical possibilities of cognition.
When solving problems in the field of technology and production mind activity is on the same path, like when creating natural laws and their mathematical models, it is only their direction that is opposite.
Mathematical-cybernetic modeling and using computers play more and more important role in modern control of production and other systems, so in education, too. Operational studies, theory of programming and many other sciences, with the help of modern computer machines, make cybernetic method efficient and more and more topical.
Science entered the study of more and more complex problems the object of which are often inaccessible and their study is complex and inefficient when using the classic methods, this is why modeling appears as a crucial method of cognition and identifies more and more reliable methods of indirect study in each field of science.
Hypotheses about the possibility of modeling in every single science indicate that the existing problems in that filed are of temporary character. According to Pálvölgyi (Pálvölgyi L., 1981) these hypotheses are:

- "If something can be known explicitly, than it can be modeled,
- if something can be modeled, than it can be simulated,
- if something can be modeled, it can be mathematized."

Differentiation of sciences on a specific level goes with the integration of the same through modeling. So it is good to observe the relationship between mathematical and cybernetic models.
Cybernetics has, with the development of abstract models in a specific direction, broadened and woken their content and with the help of modern electronic computers made them very efficient.
Therefore in the field of abstract modeling of systems it is reasonable to talk about mathematical-cybernetic modeling and understand it as classic, perfect, strict mathematical models and descriptive, often not satisfactorily perfect cybernetic models, which develop and improve more and more in the direction and with the help of mathematics. Programming and electronic computers are functioning material complements of the abstract, mathematical-cybernetic models and together they make a dialectic unity. They serve the demand of lot of sciences and modern practice in the field of methodology of study.

The classification of the mathematical-cybernetic model can be done in the following way:

- analytical models
- graphic models

Analytical models represent system behavior with the help of sets of mathematical and logical symbols and relations. Graphic models use graphic device and symbols for presenting the observed original.

Both models can be:

- deterministic
- stochastic

in other words:

- static and
- dynamic.

Among analytical models important ones arte:

- functions,
- equations (algebraic and differential),
- models of mathematical logic,
- models of probability calculation
- statistical models
- models of programming (linear, non-linear, dynamic, heuristic)
- algebraic structures

- matrix models, etc.

and among graphic models:

- graphs
- net diagrams
- block diagrams
- charts
- schemes, etc.

These models are most often used combined and modern computers are more often used with them.
In the teaching of natural-mathematical and production –technological field of modeling, model experiment, that is symbolic simulation with the help of computers, is used for:

- demonstration of well-known phenomena and laws
- knowledge acquisition and
- adaptation of the acquired knowledge

Depending on whether the student knows the simulation model or not, simulation can have inductive or deductive role. If the mathematical model of the simulated phenomena is well-known, then the experiment is used for the study of the behavior of the described phenomena; in the other case simulation is used for discovering of laws in the phenomena.
According to Percival (F.Percival, 1976) the method of simulation in the acquizition of basic concepts is not more efficient than the traditional method, but it is much more important in those fields which expect deeper analysis - synthesis and certain comparison. Because of this, this method is good as a supplementary method in teaching for deepening and supplementing the acquired basic knowledge, or when studying complex and dynamic phenomena.
During the simulation of specific phenomena on the computer students acquire knowledge indirectly, but it is important that they observe the phenomena in motion and that they have active relation with it, because they are able to – by changing some parameters of the phenomenon – arrive to a conclusion about the role of those parameters in the observed phenomenon. This is where the advantage of simulation over television, films, verbal and graphic-illustrative methods lies.
Therefore learning with the help of mathematical-cybernetic modeling and simulation with modern computers plays more and more important role in the study of complex systems besides the original, verbal, iconic and symbolic representations.

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