Sustainable Development and Curriculum change: a systems viewpoint

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Objectives

- To analyse and discuss the educational implications of rapid changes in modern Information society, to formulate the requirements for the future specialist skills and knowledge needed for sustainable development;

- To present a possible way of transformation of these requirements into modern curriculum settings making essential use of computer based modelling method as a modern teaching and learning method;

- To show exemplary educational (classroom) models that cover a range of different subjects problems and, to encourage educational decision makers as well as teachers and students to introduce and to use the computer based modelling across the curriculum as a proper tool for sustainable development.
New Demand for ICT Skills in Information Society

• New ability to store and to access all the world’s information
• The shape of work is changing
• Demand to keep learning throughout lifetime
• To learn how to select and make choices
• To learn how to deal with information: analyse, store, retrieve, predict, make decisions
• To determine what is certain and what is virtual

...
Society development and learning

J. Jensen (*Perfect learning*, 1998), Jones (*Cyberschools*, 1999) and others have analysed the USA job market trends and emphasize the following changes:

- increase of so-called “scientific workers” whose main criteria of success is an ability to learn;
- basic education cannot give a steady profession anymore;
- brisk global request for higher education;
- traditional role of teacher to be a “supervisor” and “knowledge conveyor” is to be changed to “learning catalyser” and “knowledge navigator”.

So, the learning paradigm needs to be changed from “what to learn” to “how to learn”.

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Curriculum development

M. Joung (Curriculum of the future, 2000) introduce the notion of “connective specialisation” based on:

- new relations between institutions where knowledge is produced and accumulated (school) and where knowledge is applied (workplaces and communities);
- integration of codified knowledge with context-based situated knowledge and skills, i.e. subject learning (solid body of knowledge), practical experience of learner (know-how and social competence) and unified study aim and objectives.

Similarly: Y. Engestrom — “expanded learning”, Wenger — “learning as participation in communities of practice”.

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## Model of future specialist

<table>
<thead>
<tr>
<th>traditional activities</th>
<th>IT based activities</th>
<th>new skills and knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Examining the situation and defining the problem</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>searching for literature, consultations with colleagues</td>
<td>dialog with information system, model formulation</td>
<td>basic IT and telecommunication skills</td>
</tr>
<tr>
<td><strong>Framing the system studied</strong></td>
<td></td>
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<tr>
<td>verbal description</td>
<td>model construction</td>
<td>modelling</td>
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<tr>
<td><strong>Experimenting</strong></td>
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<tr>
<td>set up the experiment, data reading, control the experiment</td>
<td>scenario construction, automatic computer simulation</td>
<td>mathematical statistics, design of experiments</td>
</tr>
<tr>
<td><strong>Data collection and data processing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>observations, simple methods</td>
<td>complex statistical methods, telemetrics, simulation</td>
<td>biometrics, monitoring, modelling</td>
</tr>
<tr>
<td><strong>Data storage, access</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper fold to the data storage</td>
<td>user friendly database, GIS, telecommunications</td>
<td>DB and GIS knowledge, telecommunications skills</td>
</tr>
</tbody>
</table>

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New knowledge body required

- **Basic concepts** of informatics, ICT literacy skills (for example, ECDL — European Computer Driver License);
- **Data** storage and **analysis** methods, mathematical statistics (neural networks, data mining, knowledge discovery);
- **Systems analysis** methodology and **mathematical modelling** methods and tools.

While first two components are already introduced into modern school and higher school curriculum the systems modelling is just started and therefore delayed.

Main difficulties here are: interdisciplinary nature of modelling, lack of modelling specialists, teachers, experience and tools.
Learning theories and modelling

- Traditional instructive teaching is based on the connectivistic paradigm of learning where main emphasis is put on the observation of stimuli and responses (changes in behavior). Although, such behavioristic believe is not in favor now it is still widely used as a theoretical foundation of “programmed learning” and distance education (ex. D. Rowntree, 1992).

- Modelling belongs to the constructivistic paradigm (Kant, L.S.Vygotsky, F. Bartlett, J. Peaget, W.James, J. Dewey, etc.) where the learning process is considered as an active either individual or social knowledge construction process. Seems to be confirmed by recent concordant findings of physiology, neuroscience, computer tomography, AI (S. Lamon, 1997; Greca, Moreira, 2000).
Constructivistic Learning

Meaningful learning for cognitive psychologist is a process of attaching new information to the existing cognitive structures (schemas). Neuroscience confirm that saying that learning is a process of forming new connections between neurons. This process is most intensive in childhood, then it gradually decreases with age, probably, because young people have to develop new problem representations (cognitive structures) whereas with age (experience) problem representation means activation of already established connections (important to start in early childhood!). Neuroscience says: growth of dendrites requires more resources than electrochemical communication between neurons.
Conclusions:
Modelling and Learning

- Growth of cognitive structures (learning) is facilitated by solving problem tasks that also make the further learning easier.

- Modelling being a *purposeful problem solving activity* directly serves for learning process and allows to individualise the knowledge acquisition in a best suited way, from the both psychological and physiological points of view. (Greca and Moreira, 2000).

- Modelling is a real and already proven alternative to the traditional, non-problemic, instructive teaching method, based on the repetition of questions-answers practice and standard exercises solving.
Modelling in the curriculum

Still collision of different opinions in ongoing discussion:

- Modelling is a compulsory component of Informatics subject (Bydogorov et al., 1994; Gein, 1994, Cox, 1992);

- Nearby the traditional hardware and software parts of the subject there appeared so-called brainware component which is belonging to the modelling competence (Makarova, 1998);

- The main objective of the whole Informatics subject is none else as various tasks solving by means of modelling (Bočkin, 1998).

In higher school (gymnasium, colleges, universities) modelling is usually taught as separate independent subject, although logical relations with other subjects also exist (Ambrasas, 1996; Jones, 1997; etc.).
Different Learning Styles
(Kolb, 1984; Mumford & Honey, 1992)

- Doing
  concrete experience

- Testing
  simulation, active experimentation

- Thinking
  reflective observations

- Concluding
  abstract conceptualisation
Modelling process

(Gelovani, 1990; Watson, 1992; Cox, 1992; Samarskij, Michailov, 1997)

- Model exploit.
  concrete experience

- Model analysis
  simulation, active experimentation,

- Defining goal
  reflective observations

- Model formalization
  abstraction, analogy

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Conclusions: place of modelling within the curriculum

- Modelling as a generic scientific method should be applied in teaching of all subjects that have a scientific foundation.
- An essential introduction to the modelling procedure as well as software tools for models development and use is one of the main objectives of the subject of Informatics.
- Teaching and learning of various processes, phenomena, objects and their interactions by using and/or developing computer based mathematical models — should become a teaching objective of other school curriculum subjects.
Software tools for educational modelling

- Programming languages and environments (Delphi, C++ Builder, JBuilder, Visual Basic, etc.).
- Spreadsheets (Excel, Lotus123, SuperCalc, etc.).
- Mathematical systems (MathCAD, Maple, Mathematica, MatLab+Simulink, etc.).
- Simulation systems and specialised modelling languages, Open source software (Stella, PowerSim, ModelMaker, Model Builder, Modellus, ithink, Promethy, etc.)
Example: Modelling Interactions

Classical Lotka-Volterra (predator-prey) model

\[
\frac{dX}{dt} = m \cdot X \cdot (1 - X / X_{\text{max}}) - pr \cdot X \cdot Y; \\
\frac{dY}{dt} = pr1 \cdot X \cdot Y - dr \cdot Y;
\]
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Software tools: spreadsheet

Lotka - Voltera bazinis modelis
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Software tools:
mathematical systems
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Software tools: simulators

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Properties of computer based mathematical model

- **Static** $y = f(x)$ *versus* Dynamic $x(t), u(t), y(t)…$

- **Continuous** $f(t), t \in R, u = f(u(t))$ *versus* Discrete $t = 0, 1, 2, ...; u^{t+1} = f(u^t)$

- **Infinite-dimensional** *versus* Finite-dimensional, Finite ($m$)

- **Empirical** *versus* Theoretical (mechanistic)

- **Stochastic** *versus* Deterministic
Computer modelling in a classroom settings

- Lectures, presentations — demonstrative models
- Laboratory work — experiment design and simulation, virtual laboratories.
- Drill practice, task solving, - development and application of subject models.
- Independent studies, homework — integration of all opportunities.
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Physics textbook: free fall and energy conservation law

\[ E_p = m \cdot g \cdot h, \quad E_k = 0 \]

\[ E_k = m \cdot \frac{v^2}{2}, \quad E_p = 0 \]
Modelling free fall in a lesson
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Physics textbook: lens images

5.15 pav.

5.16 pav.

5.17 pav.

5.18 pav.

5.19 pav.

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Modelling lens images

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Main Conclusions (I)

- Computer based modelling is an effective combination of experimental and theoretical methods. It allow us to investigate both structure and behaviour of various systems even when their direct observation is either impossible or requires resources that are not available.

- Models development and application motivate the learner to concentrate on the study of the whole problem or phenomena instead of splitting attention among separate elements and facts.

- Abstract thinking, active search for analogy facilitate the development of mental structures and make further learning easier.
Main Conclusions (2)

Educational computer based modelling change the role of teacher, his/her relations with learners, and, therefore the whole traditional learning environment making it more attractive and creative:

- teaching process is not anymore a repetition of standard tasks and questions-answers practice;
- a combination of traditional classroom environment with computer settings is more open and attractive to learners and motivate them additionally;
- dynamic, visible presentation of teaching material allows saving time and other resources and provides freedom of creative work for both teacher and learner.
Thank You!
Dėkoju už dėmesį!
Danke schön!
Спасибо!

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