

Simulation Models in Education

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Summary

This paper introduces the use of simulation models in an e-learning environment. Nowadays, simulation models are a part of computer-assisted learning and thus an important guide for lifelong education. E-learning systems, combined with the use of simulation models as tool for interactivity, are the best way to provide some kind of virtual reality in education. Important techniques for building a usable simulation model are also presented. A good model has to be accompanied by texts, demonstration material, worksheets, teachers' guides, student manuals, as well as tools for the teacher in order to be able to make changes in the computer simulation program, like a text-editor, a graphic editor as well as a resource editor. In addition, the paper describes why it is important to follow the building scheme and discusses the problem of credibility. Then, these models are explained as a method of learning dependent on and independent from the use of computers and a view of its valuable aspects is shown. After presenting various examples from the primary and secondary schools to

the university and in lifelong learning, examples of their use in information sciences have been presented, as well as need to include the course of building simulation model in the curriculum.

Key words: simulation model, computer simulation, computer assisted learning, lifelong education, building scheme

Introduction

Simulation is a particular type of modelling. Building a model is a well recognised way of understanding the world; it is a simplification of some structure or a system. On the other hand, it can be a prediction, a substitute for experiential learning, or simply for entertainment. Here, we must mention the major difference between simulation and experimentation – in simulation one is experimenting with a model and not with a phenomenon. In our modern world we sometimes don't have the time to deal with a phenomenon, thus new technologies have brought us models which complete Aristotle's saying – *The things we have to learn before we do them, we learn by doing them.*

The use of simulations represents the natural way of "learn by doing". Just as children do simulation activities by role playing, adults use computer simulations in order to understand complex systems, real situation or dynamic processes. Computer simulations allow also analyzing situations or processes that would be difficult, impossible, dangerous, too long or too expensive to perform in real life.

There are different types of simulation models (ref. Wiki: Simulation) physical simulation (referring to physical objects or real things), interactive simulations (physical simulation with human operators included, e.g. flying or driving simulator), computer simulations simulating an abstract model of a particular system, with or without graphical output, etc. Computer simulations are formalized through mathematical models, using mathematical models, have become very useful in economics, chemistry, physics, psychology, in social sciences, in the process of engineering, technology, traffic, etc.

Computer simulation

According to Fishwick, computer simulation is the discipline of designing a model of an actual theoretical system, executing it on a digital computer and analyzing the execution output. A simulation model is actually a mathematical model calculating the impact of certain inputs and decisions on outcomes. Such a model could be created in a programming language, by statements or using formulas in spreadsheets. Regardless its expression, the output in the simulation models depends on an uncertain input, and therefore we are dealing with uncertain variables and uncertain functions (according to "Simulations on Internet"). Emulation, in contrast to simulation, duplicates the system so that the second system behaves like the first one. It is related to imitation of another

program (e.g. printers that emulate HP LaserJet printers because then the printer can work with software for HP printer).

Why is computer simulation worth mentioning? It is interactive and it can be performed in different forms. Today it is very important for it to be used by pupils and students of different background knowledge, and different possibilities. That makes education focused at a student and his needs. We think that e-learning is one of the best models of learning environments today and a computer is the tool that connects pupils and students with lifelong education.

Interactive simulation is today's best form of putting simulation models into education in their fullest form. Computer simulation plays a big role in that implementation; it is a cognitive tool and a learning object. Nowadays, computer literacy is one of the key elements in basic education. Thus, computer, and all its possibilities and options, is a prime-mover for experiential and lifelong learning. Computer simulation has become a useful part of modelling many natural systems in physics, chemistry and biology, and human systems in economics, social and information science. A good example of the usefulness of using computers to simulate can be found in the field of network traffic simulation. In such simulations the model behaviour will change each simulation according to the set of initial parameters assumed for the environment. "Computer simulations are often considered to be *human out of the loop* simulations."¹

The use of computer in education varies; it can be an instrument, an object, a help tool, a learning environment.

Computer simulation for educational purposes, which uses computer as a learning environment, is called computer assisted learning (CAL). Those so-called "training simulations" typically come in one of three categories, according to Wiki (Simulations):

- "live" simulation – real people use simulated equipment in the real world,
- "virtual" simulation – real people use simulated equipment in a virtual reality, and
- "constructive" simulation – simulated people use simulated equipment in a virtual reality.

It is important to notice that in all three cases people deal with simulated equipment and that shows the difference between simulation and experimentation, as mentioned earlier. Information science includes all of the above mentioned uses of a computer and categories of simulation. That is very important for the development of lifelong learning, with a very significant aspect of interactivity.

¹ Simulation. 28 August 2007. <http://en.wikipedia.org/wiki/Simulation> (6 August 2007)

Virtual learning environment (VLE)

Taking the aspect of interactivity into consideration, we must mention it can only be realized in a virtual environment. That virtual learning environment is the main pillar of today's information science education. It consists of multimedia, it facilitates e-learning, and it enables everyone to take part in lifelong learning. In such an environment, computer can be used in all of its varieties, as a source of information (as an instrument), in computer science or in electronics (as an object). Further, what is most emphasised is the learning environment, in which it can be used as a tutorial, practice, simulation, modelling, gaming, problem solving or an expert system.

Today, in education and especially information science everyone has to know what a computer is; in its latest form: the World Wide Web. A large amount of didactical and informative content is digital and the business of everyday life demands the possibility of distance learning. No one in the academic world can escape the powerful influence of the World Wide Web. It is increasingly being used for the development, distribution and usage of course materials, texts, books, animations; it is a "multimedia library"².

Ordinary model-driven computer simulation can be used as a learning tool and teachers and educational planners just love to use such learning tools in education. It is very important to mention the relevance of feedback in such interaction. Feedback, as maybe one of the most important didactical elements in education, therefore in this form of learning cycle also, can be expressed in many ways. On one side there is learning at distance with a possibility of immediate feedback and that is a really solid ground for strengthening the idea of lifelong learning. On the other side there is an individual approach to every student, what is very important for gaining the right evaluation of one's performance.

World Wide Web is a form of virtual learning environment, and in combination with didactical simulation models, it creates an environment suitable for experience learning. On the Web we can learn languages in so many ways and every tool there is, is a kind of a simulation model. There are dictionaries with suggestions, audio samples, interactive translators and all of these are just one part of a simulation. In an educational environment, the goal is to evolve and thus again feedback comes in the bigger picture. There are open learning environments for insight training or exercising, with little or no instruction. There are also learning environments where everything is stored in large complicated data files. Here intelligence and sometimes visual dynamic feedback play a major part. This complex, dynamic, intelligent feedback is very important to keep learning processes going. Sometimes this feedback is wordless, sometimes graphic, sometimes with all kinds of animations and/or animation-objects.

² Min Rik. Simulation and Discovery Learning in an age of zapping and searching. <http://users.edte.utwente.nl/min/> (13 August 2007)

We could say that in a lifecycle of a simulation the first factor is imagination and the last one realization. In our opinion, to have a chance to put imagination into action is the best way of learning. In the educational process that is very important for the learning process of an individual, for the learning process within a group, where people can share their ideas and meet different opinions. Of course, that would also make the education of today more developed. Before the learning process is over students should be involved with simulations that in virtual learning environment allow them trying out ideas without risks and a possibility to learn on their own mistakes and have a chance to show (in a new attempt) that they had made progress. That is, once again, the role of feedback.

Simulation and learning

Simulation models could be used as a tool in education system, from primary and secondary school implemented from the users with educational and fun purpose, up to a high school system where use of specific simulation models helps certain research, helping in decision-making, or in the course relation to creation of simulation models.

Simulation model programs in education carry many advantages. A number of these do not specifically relate to simulation only but to its validity and credibility. Simulation model programs give

- the opportunity to experiment with phenomena or events,
- a sense of reality in abstract fields, like information science.

“Simulations are excellent discovery learning techniques that often offer insight or 'gestalts' not gained through more traditional didactic methods”³. Stated quote mentions discovery learning, that is the oldest form of learning and it is relevant to notice that modern simulations are encompassing that technique.

Further, there are disadvantages and the biggest problem is with credibility, because if credibility is doubtful, there is a problem with the reality that the simulation model presents.

A computer simulation model developed for the education system at the national University of Tres de Febrero enabled to foresee the impact of education policies in cultural, technological, social, educational and economic context, before their real implementation and to conclude whether planning, teaching, research and knowledge transfer matched the aims of the institution.

Learning on creation of simulation models includes basically three basic sub processes: model design, model execution and model analyses. Simulation models include notions such as modelling of the system, technology, safety, testing, training, acquisition of valid source information, key characteristics of the behaviour, simplifications, fidelity and validity of outcomes and education.

³ Min Rik. Simulation Technology and Parallelism. <http://projects.edte.utwente.nl/pi/Book/Contents.html> (13 August 2007)

Simulation models can put students in the positions they will find themselves later in their professional lives. The simulation models e.g. can show them how to put together and optimise the computer, how to organise and fine-tune a network or a web-server depending on the number of users or information requests, how to work with a program, how to work with the fragile archival, library or museum materials, how to preserve them most efficiently (deterioration simulation in different environmental conditions), how to conduct the restoration a work of art, how to organise or digitise a collection, to name just a few possible applications. Even this small list shows various levels of expected knowledge.

On the web site Educational simulations students use simulations to understand different social processes, to simulate life events, to develop critical thinking strategies by identifying, recording facts, ideas and events, analyzing and synthesizing information and learning in social studies, English language, technology and geography. Other application enables them to create personal journal chronicling a simulated life for a specific region in the world. That emphasises the importance of individual approach in learning and shows how the possibility of learning at distance, in combination with the methods that use simulation, brings education to people and makes learning anything but a luxury.

The "Electronic United Nations" is an interactive educational simulation, intended for use in primary and secondary school where users by role-plays create classroom country and complete it with constitution, economy and judicial system. After connecting through the web with another classroom country, they interact on issues of global concern. The effect of this simulation method is, beside factual knowledge, learning about leadership, politics, and importance of law, order and politics.

Dynamic simulations are those that change in response to input signals (e.g. traffic simulation models). Continuous dynamic simulations are often used in simulation games (e.g. flight simulators) and in science (e.g. electrical circuits, chemical modelling). Computer simulations are used in a variety of practical context, such as weather forecasting, analysis of air pollution, noise, logistic system, flight simulators), etc. Computer graphics and animations can be for the graphic display and better visualisation.

Recent advances in computer technology have enabled to create three-dimensional (3D) dynamic models and simulate them within 3D environment. The uses of such models are very useful in teaching of simulation models, during construction of processes, in exploitation of visualising.

Simulation models could be also used in the language processing field, such as an intelligent interface helping modellers document simulation and synthesis models with controlled English (ref. Walling, R. C.; Pradeep, V.). The system is designed to enforce the writing of clear, high quality comments for models or programs. The quality of comments is regulated through the constraints on syntax and vocabulary and if the comments meet standards, they are inserted into the model.

Another example is comparison of user simulation models for dialog strategy learning (ref. Ai, H.) exploring what kind of the user simulation model is suitable for developing a training corpus to automatically learn dialog strategies.

There are simulation models developed to teach on new therapies, treatment and diagnosis, or in the use of placebo drugs in medicine. In finance, computer simulations are often used for risk analysis, discount rates, interests, etc.

Simulation models could be also used in primary and secondary education, e.g. at Chevening School, Sevenoaks children are encouraged to use simulations in order to discover patterns, rules and make predictions. One of online models is a simulation “Plant Force” (<http://puzzling.caret.cam.ac.uk/game.php?game=plants>) simulation where the user or a student working for a plant development company can find the optimum conditions for its growth and generate a profit. In the model “Food chain simulation” (<http://puzzling.caret.cam.ac.uk/game.php?game=foodchain%20>) children can learn about food chain components, like consumer, producers, time, production and ecosystem.

In the model “Mophases” (<http://www.morphases.com/editor/>) it is possible to simulate different characteristics of the face. With “Robot Constructor” (<http://www.channel4.com/science/microsites/R/robots/>) it is possible to create the own robot using different materials and components. With “Supercity Planner” (http://www.channel4.com/science/microsites/B/buildingthebest/game_city.html) having your own budge you can construct you own Supercity, or with “City Creator” (<http://www.citycreator.com/>) you can build towns and cities. The model “Dumptown” ([http://www.epa.gov/recyclecity/gameintro .htm](http://www.epa.gov/recyclecity/gameintro.htm)) is a recycling simulation.

Simulation models and curriculum

Learning tools are almost always intended as part of a series of lessons in a curriculum. These learning tools are suitable to motivate pupils and students to research further about the subject under study. In our modern time schools and institutions have increased possibilities, learning tools are more and more focused on designing complete electronic teaching packages which can be downloaded from the web, thus enabling online learning and, most importantly, lifelong learning. One should, however, be aware of the setbacks of poorly designed, integrated, virtual learning environments. In our opinion, setback is when simulation is used as a tool for a visual method of learning, because without the mix of simulation and experimentation, pupils and student cannot actually get to know the real situation. Thus, a method of practical learning, such as writing or some kind of realization of different ideas, is the best method to make the curriculum richer and more suitable for today’s society.

Computer simulation as a learning tool is one of the main subjects in information science education. Computer simulation is an “ordinary” simulation, using a computer – the tool of present everyday life.

Implementation of simulation models as learning tools into the educational process can:

- provide an information or demonstrate/visualise a phenomenon,
- enable practice in learning (e.g. learning languages in many different forms),
- examine and test the knowledge / give individual feedback.

What applies to learning tools also applies to a curriculum – it should be well designed, that is as varied as possible. The basis of every well designed curriculum is the creation of a widely differentiated set of learning tools. In order to create a good curriculum with simulations, one should know the target group or designated community and its exact characteristics. Designers should know which students they are dealing with, what previous knowledge they have and what their individual attitude is. Simulation models can be applied throughout the curriculum, at the various study levels, with or without the requirement of the previously studied knowledge. Then insight should be tested to see if the students can apply (passive) knowledge acquired with the help of the simulation model learning tools.

How to build a simulation model

One form of e-learning that piques learners' as well as developers' interest is educational simulations. Simulations range in complexity from a straightforward reproduction of a software program to more intricate representations of complex environments such as an interactive community of workers. Educational simulations are designed to give learners an opportunity to practice their knowledge and skills in a risk-free environment. However, not all training needs can be met by simulations, and building simulations can be challenging for novice developers.

When implementing simulation model, there are some questions to think about, according Simulations on Internet:

- Was the simulation program realistic?
- Does the simulation represent a real life or fantasy situation?
- How realistic is it?
- Did the same things happen – was there a pattern?
- What are the variables, can you think of any others which might make the simulation more accurate?
- Was there more than one solution to the problem?
- What were good points/bad points?
- What did you find out?

A simulation model of a complex system can only be an approximation to the actual system, no matter how much time and money is spent on model building. There is no such thing as absolute model validity, nor is it even desired. Indeed, a model is supposed to be an abstraction and simplification of reality.

Building of a valid and credible simulation model usually follows these steps (Law, A. M.; McComas, M. G.):

1. Formulation of the problem
2. Collection of the information and construction of the conceptual model
3. Checking the validity of the conceptual model
4. Model programming
5. Checking the validity of the programmed model
6. Design, conduction and analysis of the simulation
7. Documentation and presentation of the simulation

1. Formulation of the problem

The problem of interest is stated by the decision-maker. The scope of the model and the system configurations that are going to be modelled has to be declared.

2. Collection of the information and construction of the conceptual model

It is necessary to collect information on the system layout and operating procedures. After that it is important to check the computer constraints, development timeframe and money constraints. There should not be a one-to-one correspondence between the model and the system.

3. Checking the validity of the conceptual model

One should perform a structured walk-through of the conceptual model before an audience that includes the project manager and analysts. If errors or omissions are discovered in the conceptual model, which is almost always the case, then the conceptual model must be updated before proceeding to programming in Step 4.

4. Model programming

The next step is programming the conceptual model in either a commercial simulation-software product or in a general-purpose programming language (e.g., C or C++) and verification (debugging) of the computer program.

5. Checking the validity of the programmed model

If there is an existing system, then the performance measurement of the model should be compared with the performance measurement collected from the actual system. This is called *results validation*. *Sensitivity analyses* should be performed on the programmed model to detect which model factors have the greatest effect on the performance measures. Those factors will later have the greatest impact on the overall model performance.

6. Design, conduction and analysis of the simulation

For each system configuration of interest, decision on tactical issues such as run length and warm-up period should be made. Analysis of the results and the decision if additional experiments are required should be made.

7. Documentation and presentation of the simulation

The documentation for the model should include the conceptual model, a detailed description of the computer program, and the results of the current study. The final presentation for the simulation study should include animations and a discussion of the model building/validation process in order to uphold model credibility.

There are many examples of simulation models in education which make it easier for students and teachers to explain and understand given lessons. There is a driving test good for coordination (<http://www.learn4good.com/games/simulation/driverseducation.htm>), simulation of credit card interest (<http://vam.anest.ufl.edu/maren/interest.html>), and various experiments-simulations for physics (<http://www.walter-fendt.de/ph11e/>).

The role of instructor in e-learning⁴

Web developers and instructional designers have come to realize that an important part of e-learning is the instructor, i.e. a real person or character that guides, instructs, mentors, and entertains the learner. In a classroom program, the instructor serves that role. He or she ensures that everyone is attentive and answers questions. But how can instructional designers transfer this live person to an e-learning model? Many developers think that the best solution is to use character simulations. Quite simply, character simulation is the practice of creating a relevant, interesting personality who appears and instructs throughout an e-learning program.

Three models for character simulations

The idea of a character simulation is to immerse the learner in a social experience in which a "person" speaks, interacts, and guides learning. This character may have a general persona or be based on a real and familiar personality.

These characters take on a personality through their visual impact, choice of language, attitude, and even voice. He or she appears regularly to help learners remember where they are in the program and to reinforce the learning material at the beginning or at the end of each module.

But before building a character, it's important to think about the role it will play. Typically, there are three roles for characters in online learning.

⁴ <http://www.learningcircuits.org/2004/jun2004/bersin.htm>

Peer

In this approach, the character takes on the role of a peer to instruct or coach. For example, a 19-year old sales representative in a retail store will most likely be more receptive to a program that uses a young representative that wears clothes he/she may wear and discusses topics using slang. The character talks to the learner as a peer, and can suggest, joke, and mimic him.

Expert

In this model, the character takes on the role of an expert to instruct. The character may be a sales manager, flight instructor, or even Albert Einstein. For example, the Air Force program that Bersin & Associates reviewed was led by a flight instructor that wore shiny aviator glasses and talked in a tough voice, while explaining in detail everything the learner must do using his experience as a guide.

Authority Figure

In this model, the character is the boss. In one corporate certification program, for example, the character may be based on the company's actual CEO. She may explain to employees that this particular training program is not only mandatory but will be tracked by the executive management.

Suggestions for the development of the simulated characters

There are several basic suggested techniques that should be kept in mind during the designing process of simulated characters. Some of them are mentioned here.

Create life-like characters

Be deliberate about characteristics that seem minor and non-instructional, such as clothing style, speech and idioms, hairstyle, and voice. These aspects of the personality can make a big difference in the target audience's perception of the character. Before you design the whole program, create one or more characters and test whether the target audience likes and accepts them.

Plan the scenes prior to development

Like other forms of animation, character simulations use built-in scenes. In general, limit scenes to one minute in length, and think about pacing them appropriately for the learners. Storyboarding techniques can be very helpful in the planning process.

Check for understanding

Delivering the information without appropriate user interaction is insufficient for learning purposes. When you use character simulations, make sure that the characters interact with the learner to verify whether objectives are being met.

Have the character simulate common situations and use questions to check the learner's comprehension.

Focus on learning objectives

Get to the point quickly. Character-development products are full-featured and fun, but don't let their features and functions distract the learner. This may seem like common sense to a training professional, but it's easy to get sidetracked.

Use plain text before recording the final script

When you create the audio, create a script first and use plain text on screen until your script is finalised. After the script is ready, record the audio with a real voice. For major, high-stakes programs, hire a professional to record the voice.

Consider a multiskilled team

To do a full blown e-learning program that integrates character simulations into the courses and eventually in the curriculum, you will need writer or developer who can create storyboards and scripts, graphic artist who can develop backgrounds and other artwork and Web developer who can integrate all the files, including Flash, wave, and graphic files.

Run a pilot to gather FAQs

In many cases, character simulations act as a substitute for interactions with real people. It's important that the characters can answer normal questions that come up during the course. Use your pilot program as an opportunity to gather such questions.

Conclusion

In this article we have shown the different categories of computer simulation in connection with the learning process. Such simulation models interactively imitate the reality which would otherwise be very difficult to show to the learners or very dangerous to immerse them in it without the prior knowledge how to react or behave. Simulation models are therefore applicable throughout the learning process – from the school and university levels to the lifelong learning situations. No matter what is the target group level, it is always good to know the designated community of users in order to better customise the learning simulation model to them. Their expected knowledge and experience, or lack of it, is one of the key issues as is their feedback which can later help to fine-tune the model more appropriately.

We think that the issue of simulation models in information science education has at least two main aspects.

First, simulation models can and, in our opinion, should be used as a complement to the process of education. Therefore we can conclude that the simulation models can be used throughout the information science curriculum, from the beginning of the study to the very end of it. Furthermore, the usage of simula-

tion models can be taken as an important factor for differentiating the quality curricula from the curricula that do not incorporate simulation models.

Second, in our opinion information science curriculum should, at the higher levels of study, incorporate course(s) related to development of the simulation models. It could even be suggested to form a curriculum module for the development of simulation modules. With the earlier analysis in the article we aimed at this idea since we think it could be of a great importance for the advancement of the curriculum. In this context it is important to know how to organise a process of building a simulation model, and how to implement the e-educator. Since the application field is very wide we think that not only would the students of the information studies benefit from such course(s) or a module but the field of information sciences could advance also. The future information professionals would know how to build simulation models and thus model the needed environments which could in turn further the research in the field of information sciences more efficiently.

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