SIMULATION EDUCATION IN LOGISTICS: CASE STUDIES IN A VIRTUAL LEARNING ENVIRONMENT

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ABSTRACT

To develop logistics simulation competence does not require just to advance knowledge on the simulation methodology in general and its applicability to logistics problems in particular, but even more to advance abilities and practical skills in creating and implementing a valid simulation model to solve a specific logistics problem. In traditional classroom-based learning this is well established via simulation exercises and labs. The challenge consists in incorporating those case studies in a virtual learning environment in such a way that both self-organised problem-solving at different levels of difficulty and automatic evaluation and assessment of learner-specific approaches and solutions become possible. The paper demonstrates how modelling and simulation might be linked with learning in a virtual logistics learning environment and introduces a virtual simulation lab to enable self-experienced learning-by-doing. With this, the paper sets up a framework for creating interactive exercises and case studies on-the-fly and contributes to improving simulation education in logistics.

INTRODUCTION

When discussing the link between computer simulation and learning in general we have to distinguish learning about simulation from learning by use of simulation (see Neumann et al. 2005):

- In *simulation-focussed learning*, computer simulation is the subject of learning, i.e. modelling concepts, simulation methodology and software tools for modelling and simulation are introduced, explained and practised to enable a student to apply computer simulation for solving practical problems either in general or specific to a particular application area such as logistics.
- In *simulation-based learning*, computer simulation (usually in combination with animation or any other visualisation technique) is used as a means of supporting learning in a particular field such as logistics. Here, simulation models assist explanation and understanding of complex processes, illustrate abstract knowledge, demonstrate connections or interdependencies, and allow experiential learning or situated knowledge application.

This differentiation also applies when talking about cross-connections between simulation and e-learning, i.e. learning assisted by electronic media. According to Jonassen (2001) e-learning technology needs to be used for creating learning-by-doing and perceptual environments for problem-based learning, where you are immersed in making rapid-fire decisions, rushing to gain new information, utilizing the expertise of colleagues, and relying on your ability to create and store useful knowledge that will allow you to innovate and get your products to market way before your competitor. The role of simulation consists in supporting these learning processes:

- Computer simulations might be integral parts of interactive or even gaming-like environments. Students use them eventually being unconscious of simulation methodology and not necessarily having any theoretical simulation background.
- Simulation methodology can purposefully and consciously be applied to a particular context within specialized experimentation environments.
- Education and training of core simulation concepts themselves can make use of electronic technologies including the use of simulations for simulation learning.

E-learning and simulation both use the computer as their central medium, which makes their combination particularly convenient. No change of context or any additional tool is required. Even more, online simulations have been touted as the next big wave in e-learning (Chapman 2005): learners generally prefer them because they offer complexity, realism, and an opportunity to practise new skills in a risk-free environment. Administrators like them because they result in more motivated students and (perhaps most importantly) higher retention rates.

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Consequently, simulation should also be used in a virtual logistics learning environment in both ways, as a means to support and intensify learning and as a particular subject of learning. The following sections will show how this might be achieved and discuss challenges to be mastered.

SIMULATION-BASED LOGISTICS E-LEARNING

Logistics – in its widest scope of understanding – is an extremely rapidly developing field of knowledge and practical applications. The competence profile of a logistics practitioner as requested by industry is a portfolio of wide-area knowledge in engineering and management, various abilities, such as problem finding and problem solving, systems' planning, design and operation, process planning, management and control or knowledge management and knowledge generation, and well-developed logistical and social skills.

Therefore, logistics education and training needs to be designed in such a way providing students with all of,

- *declarative* knowledge in the form of "knowing that…",
- *conceptual* knowledge as "knowing how" and
- *procedural* knowledge which is "know-how" in the domain.

As a matter of experience, students face particular problems in acquiring such kind of knowledge when it comes to:

- reducing real processes to the essentials;
- recognizing fundamental structures and processes;
- understanding parallel processes causing conflict;
- understanding cause-effect relations.

Here, simulation and animation are ideal tools to support knowledge acquisition through illustration, visualization and experimentation. Depending on the focus and purpose they might be integrated into e-learning in two ways:

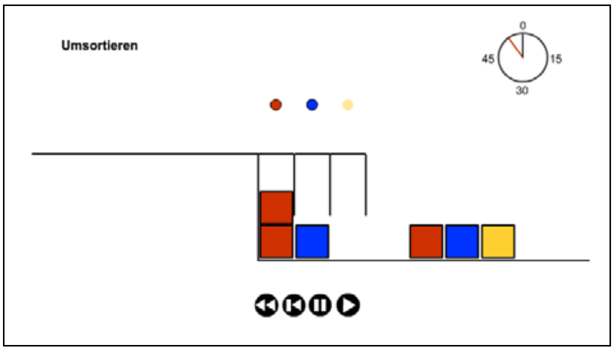

Figure 1: Flash animation to illustrate sequencing operations (in German)

Focus on illustration:
The content and appearance of animation sequences can be fixed in the form of Flash movies or pre-defined simulation-based trace files if animation is used only for a comprehensible and vivid representation of knowledge to be imparted, for example, to illustrate processes and calculation algorithms or presenting alternative process variants for comparison (see Figure 1). In this case animation data are created or generated outside the e-learning environment in advance. The student just starts the animation sequence without paying any attention to how the animation has been developed nor to the means and methods used.

Focus on experimentation:
If knowledge acquisition may be supported by the independent planning, running and analysis of experiments in simulation-based exercises, animation is one of several possible forms for presenting simulation results produced by use of an existing simulation model. Students can change parameters within the range of freedom as defined by the model developer, but cannot create and implement a new simulation model (see Figure 2).

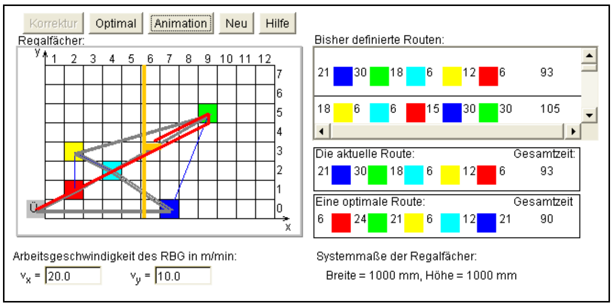

Figure 2: Java applet for solving routing problems (in German)

If experiments are based on a manageable quantity of pre-set parameters and/or model variations, respective simulations could even be run in advance and outside the e-learning environment. One trace file is generated and stored for each possible combination between a model and a set of experimental parameters and the student practically just selects the respective simulation results. Nevertheless and because of the psychology of learning it might be useful to let the student seemingly start a simulation run.

As soon as a user can vary parameter values according to individual intentions, a pre-simulation is no longer possible. Starting the simulation run really causes its execution inside the e-learning environment; simulation results are simultaneously collected for visualization. This requires a working simulation tool (or runtime version of the model) to be integrated in the e-learning environment, even though no model building functionality is accessible to the user.

Both scenarios for using simulation and animation in logistics learning have in common that no advanced simulation knowledge nor any specific model building competence is required by the students. They view or use models and should understand what is represented, but do not need to know how those models are designed and implemented. Respectively, we cannot expect to develop any simulation competence with the student this way. To achieve this and provide the student with sufficient simulation knowledge, abilities and skills required for simulation-based problem-solving in a more complex logistics context, simulation-focused learning related to logistics applications has to be enabled and supported.

LOGISTICS SIMULATION-FOCUSSED E-LEARNING

Simulation is a method approved and established in logistics to support logistics planning, design and management. There is a high demand for logistics experts who at least know about simulation or even better are prepared to apply it to a particular problem. That is why simulation needs to be taught by transferring knowledge about the simulation methodology and its scientific background, but even more by developing and strengthening students' abilities and skills in purposefully applying it, efficiently and effectively organizing modelling and experimental phases as well as understanding, correctly interpreting and attractively presenting simulation results. This can be achieved best by implementing a constructivist approach of problem-based learning. Here, a specific problem to be solved by the student forms the starting point for initiating an individualized, self-organized, highly-motivated learning process. Whenever the student does not know or feels uncertain how to approach the problem, continue in the problem-solving process or apply a particular method/tool s/he might go to and through the respective learning module offered by the learning environment.

Consequently, simulation learning addresses two different goals: (i) *learning about* simulation methodology and applying this knowledge to practical problem solving, and (ii) *learning how* to use a particular simulation tool for model implementation and experimentation. The first requires some sophisticated learning material covering key aspects of logistics simulation; the latter needs to be designed in the form of an interactive tutorial specifically dedicated to understand and master particular simulation software. No matter which of these purposes the learning material serves, it needs to include a variety of interactive elements, support the gaining of self-experience and allow individual learning-by-doing.

Therefore, the virtual logistics learning environment currently comprises a number of modules belonging to the following main categories (see Table 1):

- *Description-oriented modules* summarize basic knowledge on simulation in general and fundamental knowledge on logistics simulation in particular. (What is …?)
- *Instruction-like modules* provide relevant procedural knowledge for identifying, specifying and solving logistics simulation problems or explain how a particular simulation package works via interactive tutorials. (How to …?)
- *Problem-based modules* enable individual knowledge application and evaluation within tests/quizzes at different levels of difficulty with extended feedback being provided to the user (assessments) or free knowledge application within an interactive supply chain scenario by running case studies at four levels of difficulty (case studies).

Table 1: Simulation learning modules in the virtual logistics learning environment

Module	Type	Learning Goals	Contents
Selected basics of simulation methodology	D	Know basic simulation terms and concepts Know mathematical foundations of simulation Understand the simulation methodology	What is simulation? How does simulation work? Introduction to stochastic theory and statistics
Introduction to logistics simulation	D	Know about the use of simulation in logistics problem-solving Understand requirements and challenges related to simulation application in logistics	Simulation application in logistics, incl. typical problems, aims, benefits, tools Logistics simulation database Challenges and procedures in a logistics simulation project
How to run a logistics simulation project	I	Know main phases and stages of a logistics simulation project Be able to run a logistics simulation project	Preconditions and constraints of a simulation project Problem analysis, model building, validation, experiments, presentation of results in a logistics simulation project
How to use DOSIMIS-3	I	Be able to implement simulation models, run simulations and analyse simulation results by use of the DOSIMIS-3 simulation package	Introduction to the simulation package and its functionality Instructions, guidelines and tutorials on how to implement a model, run simulations, view and analyse results
Assessment module	P	Be able to apply simulation knowledge in tests Be able to identify knowledge gaps	Questions and focused assignments on simulation terminology, methodology, procedure, application
Case study module	P	Be able to solve problems in authentic logistics cases	Case studies related to simulation application for logistics problem solving in a supply chain

Types of learning modules: D = description-oriented modules; I = instruction-like modules; P = problem-based modules

These modules are uploaded to a simulation course in a Moodle platform (see Figure 3), which is an Open Source course management system (http://moodle.org/) designed using sound pedagogical principles, to help educators create quality online courses. The software package is available in a wide variety of languages and thus used all over the world by universities, schools, companies and independent teachers. It provides various learning activities and communication functionality, such as forum and chat, glossary and wiki, workshop and assignment, lesson, quiz or survey.

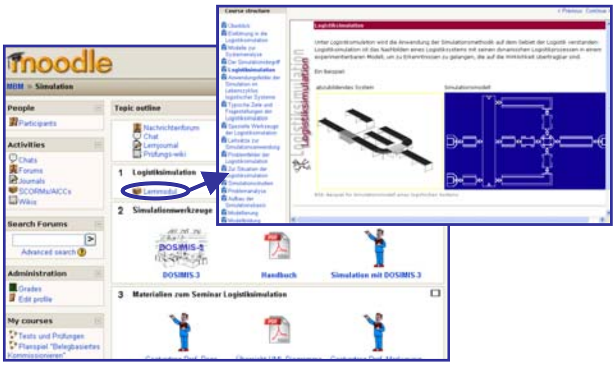

Figure 3: A logistics simulation course in Moodle

Furthermore, a commercial assessment package, Questionmark Perception, is linked into the Moodle platform enabling educators and trainers to author, schedule, deliver, and report on surveys, quizzes, tests and exams (http://www.questionmark.com). This way, a centralized pool of a wide variety of questions (ranging from multiple choice questions via drag-and-drop, hot spot, matching and knowledge matrix questions up to numeric questions – see Figure 4) has been created from which again and again new quizzes are automatically generated by combining on-the-fly questions of a varying level of difficulty and from different topic areas.

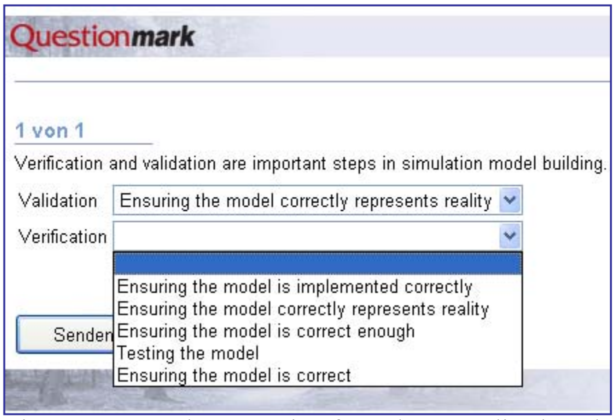

Figure 4: Exemplary question from the centralized pool

Once the student starts an assessment, a number of questions is selected at random from the available alternatives and put into the pre-defined quiz structure. This way, every time a student re-starts the same assessment a quiz new to him/her appears. Assuming the pool of questions contains a sufficient number of questions, the own state-of-knowledge and conceptual understanding can repeatedly be tested without just reproducing what has been learned before.

As to the simulation package to be used, it was decided to integrate a professional tool from the real world rather than an academic toy. DOSIMIS-3 (http://www.sdz.de) is a simulation package specialized to answer questions related to functionality and performance measures of logistics systems and processes and widely deployed in industry as well as logistics education and training in German-speaking countries. DOSIMIS-3 provides an extensive library of components from the material-flow and logistics world, enabling model-building by a few clicks on the basis of a well-structured conceptual model (see Figure 5). The simulation model then consists of the selected components specified by respective sets of technical, geometrical, topological and strategic parameters which are placed in a working area and logically linked to each other by so-called nodes, i.e. directed arrows free of any further information.

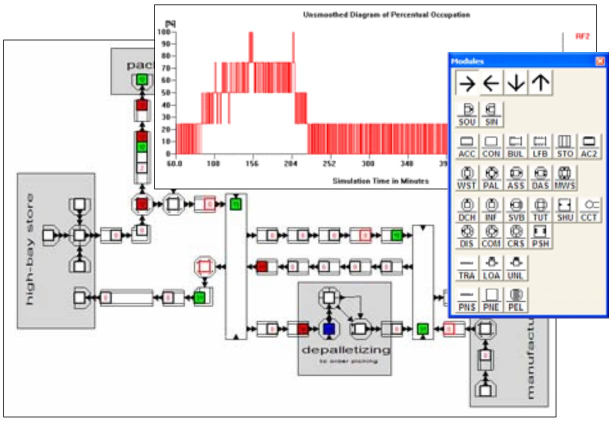

Figure 5: Logistics simulation using DOSIMIS-3

With this, model building and simulation is brought closer to the experts in the application area – in our case material flows and logistics enabling them to implement and use a simulation model themselves. It is very much self-explaining and therefore the perfect tool for logistics simulation education. DOSIMIS-3 runs on PC requiring Windows 95 or higher operating system. The reason for not looking for a fully web-based simulation package was very simple: Students should be able to cut down their times of having to be online to reduce communication costs. Instead a free download was organized, but guaranteeing that copyrights are not violated with this (see Neumann 2003).

Within this educational infrastructure and based upon these kinds of modules, customization and individualisation of a student's learning process and learning path according to his/her needs (resulting from current skills and individual levels of knowledge) become possible. There is no fixed sequence of modules, but just hyperlinks between modules if deeper knowledge and understanding of a certain concept is assumed. In case of insufficient prior knowledge the student can follow this hyperlink and learn about fundamentals first before continuing at more specialized or complex levels. This way of a modularly designed learning environment enables the student to purposefully select the suitable module(s), but at the same time puts more self-responsibility for a successful learning process on the student. In the end (and according to requirements from practice), it only counts whether a student is able to successfully and efficiently perform in an authentic case study.

SIMULATION CASE STUDIES IN A VIRTUAL LOGISTICS LEARNING ENVIRONMENT

In contrast to the assessment module where a student answers questions within quizzes to give proof of conceptual knowledge, the case study module enables free knowledge application within an activity-oriented scenario. Here, the student has to become familiar with new situations and eventually deal with different problems. Thus, s/he is expected to demonstrate competences by understanding situations, applying methods and finding appropriate solutions in an effective and efficient way. To provide an experience as authentic as possible a fictitious supply chain of three partners – raw material supplier, manufacturer of potato chips and retailer with distribution centre and a number of shops – has been created (see Figure 6) which is not just being used in the simulation course, but also serves as case study scenario in other fields of logistics knowledge and learning, like e. g. Efficient Consumer Response (see Neumann and Krzyzaniak 2007). This becomes possible due to the strict separation of information and data (the scenario) from problems to be solved or tasks to be worked on.

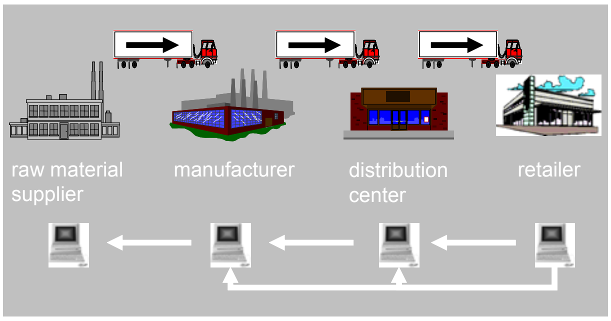

Figure 6: The supply chain scenario

Within the supply chain scenario each partner has a public website and a private Intranet including various company-specific information and data. They cover all aspects of the company from presenting its vision, mission, history, products and services (public information) to providing process descriptions, staff lists, resource data, performance data, customer/ purchase orders, stock levels etc. (private information). Consequently, this scenario serves as case development framework; a specific case study is finally created by attaching problems or tasks to the supply chain as a whole or any of the partners individually. In the end, case studies with different targets and varying levels of difficulty result from this, which can aim at:

(i) *characterizing a situation by conceptual modelling*
(The student describes the situation in the supply chain as a whole or any of the participating companies in particular e. g. by choosing from different descriptions presented. Furthermore, s/he matches this description against a collection of conceptual models selecting the most appropriate one for the subject of investigation. Feedback is returned directly on his/her decision.)

(ii) *identifying problems or potential improvements*
(A list of problems and potential improvements is presented to the user from which s/he chooses the ones s/he identified. In addition to this, there are hot spots in the conceptual model on which students click to specify the problem area. Furthermore, students are asked to suggest an experimentation strategy for figuring out improvement potentials. Feedback is returned directly on his/her decision.)

(iii) *recommending actions to solve problems*
(The student chooses from a set of actions the ones s/he recommends to use. Each of these possible choices is linked to a simulation model. The effects of his or her choices will be presented to him/her in the form of corresponding animation sequences and a set of simulation output data. Based upon this, the student might assess him/herself whether or not the chosen action has been completely solving the problem or contributed to problem solving at least. As consequence further actions might be suggested until the student comes to a final solution in his/her eyes. Feedback is returned directly on his/her submission.)

(iv) *applying methods to solve problems*
(The user applies certain methods to solve the problems as identified and specified before by use of tools (EXCEL-based for input/output data analysis or simulation-based for output generation or others) and models provided to choose from and work with. Even more, the student might also develop and implement own models and run experiments using the simulation package provided. The results need to be self-assessed by the student e.g. according to an exemplary solution.)

It is obvious, that those different types of cases do require different methods to support the student (guidance-on-demand) and also different ways for gaining the student's results. Generally, the student has to work selectively with the material available and delivers his/her results by answering multiple-choice, matching or questions of other types first. This ability to get into a situation, see problems and their causes, relate systems and process to models and link those findings to own knowledge about best practices or suggestions from theory as it is demonstrated by the student here forms the pre-condition for any purposeful and promising problem solving through experimentation and model building at a later stage.

Finally, this way of challenging students at increasing levels of difficulty also allows electronic assessment of at least parts of the complex problem solving processes related to simulation application in logistics. Introduction of e-assessment methods to individual simulation model building and experimentation still remains an unsolved problem, since there is neither just one correct solution to a logistics simulation problem nor exactly one successful problem solving procedure.

CONCLUSIONS

The symbiosis of e-learning and simulation brings many advantages to both fields. Computer simulations greatly help in the presentation of abstract ideas and processes, whose details and implications would otherwise be very hard to understand. On the other hand, e-learning also serves well in support of teaching simulation techniques. Since this is particularly true in logistics education, integration of animation and visualisation as well as simulation case studies into a virtual logistics learning environment was seen as a challenging, but very promising task.

In the end, within the presented logistics e-learning environment a number of learning modules form the basis for encouraging students' application of logistics simulation knowledge. To train students' ability to deal with certain aspects of a simulation project a pool of small examples and problems has been developed. They focus on typical methodological questions like e. g.:

- What are effects of certain control strategies?
- When to use simulation instead of analytical methods?
- How to cope with particular model building challenges?
- How do different validation technologies work and which technology should be applied by when?
- Which role simulation might play in solving optimisation problems?

In addition to this, a general framework, a number of specific problems and a set of dedicated e-assessment tools allow to run simulation case studies to provide a more authentic learning experience.

Further extension and enrichment of available challenges is planned to increase the level of attractiveness and even better achieve objectives of simulation education in logistics: to understand simulation methodology; to gain experiences in logistics model building and validation; to understand logistics phenomena through systematic experiments; to get familiar with a specific (professional) simulation package and practise its use.

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