Learning Management Science in Hyperspace

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1 Introduction

In this paper, we discuss approaches of learning an interdisciplinary subject with many different facets. We consider the field called Management Science (MS) which is closely related to Operations Research (OR). As the essence of management science we understand the application of the modeling approach for managerial decision support. The models are usually built using quantitative methods, such as linear programming, mixed-integer programming, network models, decision analysis, discrete and continuous simulation, queuing models, and so on. The underlying problems arise in fields such as production, financial planning, and vehicle routing. Traditionally, the emphasis in teaching management science, at least in Germany and Finland, has been placed on teaching mathematical methods, such as the simplex algorithm for linear programming.

However, to support managerial decision making we need much more than internal knowledge of complex algorithms. Managers are often confronted with *mess management*: They first have to identify the right problem to be solved, rather then gather the needed information. If a modeling approach is used, the next step is to choose one or more quantitative models to represent the problem and put it into a computer-readable form. Furthermore, some solution technique must be employed to generate a solution which is normally to be approved by the responsible manager.

The use of management science techniques involves skills from different areas such as mathematics, information technologies, business administration, and even psychology. The methods used are often mathematical. Although the user does not need to know mathematical details of each method, an understanding of the basic ideas is advantageous in order to judge appropriateness. Solutions of complex practical problems cannot be found without computers; this means that the methods have to become part of an integrated information systems architecture of a firm. In order to be used, a decision support system has to fit into the organizational landscape of a company. Sometimes psychological skills are needed to win the final acceptance of the users.

According to our experience, teaching only algorithms is not enough to prepare students to face the messy, complex problems of real-life situations. Similar to learning a craft, the ability to apply a technique to a real-life problem has to be learned by training that is carried out by the learner himself/herself – no one can do the job for another person. Otherwise the algorithmic knowledge remains “inert knowledge” that cannot be really used (see [CGTV 90; Reinmann-Rothmeier 94, p. 43]).

The ability to apply mathematical modeling techniques can be trained with case studies. Then methods are bound to a situated context and students have to work out themselves which method should be applied and in which way. This requires far more elaboration than merely using a given algorithm. However, situated learning is more fun, thus increasing the motivation to learn because students can feel an immediate success after constructing a solution themselves.

The traditional, method focused way of teaching management science does not leave much time for case studies, discussions, and student presentations in classroom. Furthermore, because there are often more than one hundred students with different backgrounds and interests (majoring in business studies, business computing, industrial engineering, computer science, or business education) in a university class, it is not possible to adjust the pace so that each student can easily follow a teacher-centered lecture. These were the reasons why we wanted to provide students with a tool which helps them to learn quantitative methods also outside the classroom at their own pace, thus leaving more time for discussions and teamwork during the classes. We believed that an interactive, computer based tool would be better suited than providing the students merely a textbook. With the realization that there was no such tool available, we started the development of ORWelt (World of Operations Research) in 1996. ORWelt is a hypertext-multimedia oriented learning environment for Operations Research/Management Science. In the subsequent sections of this paper we report about the development of ORWelt and first experiences of using it at the University of Paderborn.

2 Initial evaluation

The research project “A hypermedia learning environment for OR/MS” was launched in 1996. To collect information about the current use of computers in this area, we mailed a questionnaire to all professors of OR/MS at German universities. It included questions about the content of classes concerned, the use of software (especially educational software), the additional need for such software as well as instructors’ expectations and concerns. The questionnaire revealed that there is a significant need for educational software. 76% of the instructors questioned considered a learning software to be at least partially useful for teaching purposes, but not one of them intended to develop a system on his/her own (see Figure 1). The relatively high acceptance of computer based tools is not a surprise because of the key role of computers in OR/MS. Due to the complexity of algorithms, solutions to practical problems can only be obtained by using computers. Most instructors use professional optimization software, but only 10% of them use educational software. The massive gap between instructors' usage and demand for educational software is mostly caused by a lack of flexible educational tools covering their area of interest.

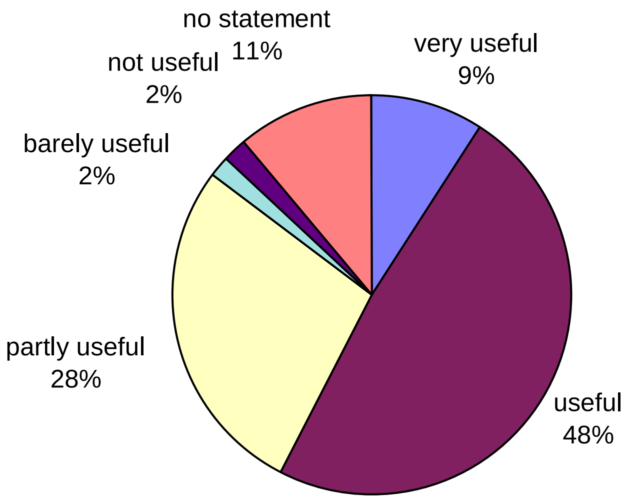

Figure 1: Questionnaire result: "Do you consider a computer based learning environment to be useful?"

Additionally, the study revealed that certain core areas of Operations Research, such as linear programming and discrete simulation, are taught by the majority of all instructors. Therefore, if we develop scalable and configurable educational software for these core areas, it can be used also in other faculties, even if they emphasize different aspects in their teaching. This would make such software usable for OR/MS faculties of other universities, too.

The results of the questionnaire finally convinced us to start the development of ORWelt. The enormous amount of work involved in developing hypermedia applications seemed justified by the huge potential in using it.

Besides professors, we also questioned students about their expectations and preferences considering hypermedia software. This study gave us also very encouraging feedback. This initial questionnaire is followed by a continuing evaluation process where new and experienced students are questioned on a regular basis about their computer literacy, frequency of computer use, available hardware equipment and attitudes towards computer based learning, including expected advantages and disadvantages as well as their own experiences.

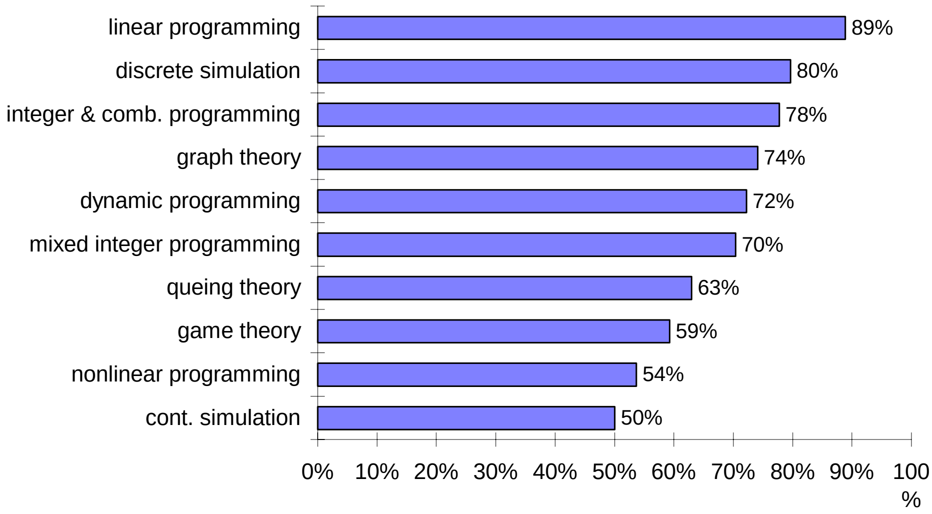

Figure 2: Questionnaire result: content of relevant classes

3 Hypermedia as a Solution

By hypermedia we understand, loosely speaking, the combination of hypertext and multimedia. For a thorough discussion on how to define hypermedia, see [Blumstengel 98]. The information scope covered by a hypermedia environment is also called hyperspace. Hyperspace is basically a network structure, in contrast to a book which always has a linear structure. This means that a hypermedia system consists of nodes being connected with various types of arcs. The nodes contain relevant information in form of text and multimedia items, such as graphics, pictures, video and audio sequences, and animations. The user can move in the network along the given arcs. The main navigation methods are hyperlinks, maps, guided tours, backtracking, history, and bookmarking (see [Blumstengel 98]). Thus, there is no one and only way to move in hyperspace, but the user can freely choose his or her own preferences and sequences. Appropriate navigation methods help the user in the orientation to avoid the “lost in hyperspace” effect.

There are several reasons why OR/MS is a well suited area for using hypermedia learning software. First, as an interdisciplinary area it provides many different points of view on each subject area – this can be supported in a natural way by the network approach. A business student is more likely interested in specific applications of OR/MS in business while a student of computer science might like to know further details of general algorithms. In a hypermedia environment it is possible, on the one hand, to start with a case study based on a real-life application and proceed to the algorithms and software needed, and, on the other hand, start with a specific modeling technique and proceed to its applications. In the network structure it is possible to link together topics that are loosely, not linearly, connected (see [Tergan 97, p. 129]). One topic can be linked to many other topics, since the restriction of linearity has been removed.

Second, many areas of OR/MS can profit from the interactivity and dynamics of hypermedia systems. Mathematical algorithms are characterized by a stepwise dynamic structure which cannot be fully expressed in a static book. An animated algorithm in hypermedia can illustrate the dynamics for various initial settings in a flexible way. In many areas such as network optimization, branch-and-bound, vehicle routing, random number generation, and discrete simulation, the advantages of animations are obvious.

Third, the basic contents of OR/MS are fairly stable over time. Basic techniques, such as linear programming or discrete simulation, were invented in the fifties and sixties, and they are also useful today. More recent approaches, such as neural networks or taboo search are also there to stay. This justifies the high amount of developing effort necessary to create such systems. The stability of content makes it relatively easy to maintain the whole system. Developing multimedia is very expensive; changing major parts of the system on a regular basis would not be affordable.

To summarize, hypermedia provides various advantages over traditional forms of education, such as the following:

- Pace: Students control learning speed and number of repetitions. In contrast to a teacher centered lecture, a hypermedia learning environment gives students an individual choice of how long to spend on a topic and how often to repeat it.
- Sequence: In a hypermedia net there is no sequence at all. Although guided tours are offered, students control which way they progress through the net (guided tours are optional, not obligatory). This structure fits the manifold relations between different subject areas better than a linear one.
- Learner control: Students are in control, they decide which learning style they apply to the material. Some prefer a sequential approach with strong guidance, others tend to quickly glance over certain topic areas while studying other points down to the smallest detail. A learner centered hypermedia environment supports both types of learning while the traditional teacher centered lecture is restricted to only one (see [Ravnborg 98]).
- Availability: Students control place and time of learning. Students can learn anywhere and at any time, at home or at the university, early in the morning or late at night.

- Interactivity: Students can become more engaged in the learning material, not just passively receiving. To achieve this goal, however, one has to use interactive elements, e.g., simulations, in the learning environment. It is not sufficient to transfer a book to a linear, electronic form. The degree of interactivity is a crucial factor for the success of a hypermedia learning environment (see [Haack 97, p. 152, Schulmeister 96, p. 388ff]). Especially offering the possibility of "direct manipulation" of relevant objects plays a key role. Direct manipulation occurs throughout the whole learning environment, such as dragging objects, popping up additional information, etc.

There are also some possible disadvantages involved with the use of hypermedia learning systems:

- The well-known problem of disorientation describes the phenomenon that users navigating through hyperspace are often not sure about their actual "location" in relation to the whole net, thus "getting lost in hyperspace". Disorientation can be softened by providing additional navigational tools (see [Tergan 97] for further details on this issue).
- Students fear less personal contact between the teacher and themselves.
- Students fear that their learning behavior will be supervised by the system. This is a point that must be considered during development, since the success of the system depends entirely on user acceptance. If user actions are logged for evaluation purposes, you will have to dispel these objections by explicitly including the user and, e.g., using anonymous log files without any specific user references.

4 The Project ORWelt

4.1 Subject of the project

The ORWelt project started in February 1996 with the intent of providing a hypermedia learning system that would cover all standard introductory material, supplemented by tests. Furthermore, case studies were provided in order to support different approaches to the same contents.

The purpose of ORWelt is not to replace the lecture but to give the lecturer more time to discuss real-life case studies with the students. We do not expect that computer based learning approaches will replace face-to-face communication in realtime between students and lecturer. The personal contact between teacher and student is still important because goals such as motivating students for the subject matter, i.e., providing input which affects the student in a positive manner, can hardly be achieved by a computer-based system alone.

Figure 3 shows a typical screenshot of ORWelt. Unfortunately, the paper medium is not suited to expressing the dynamics of the application. The learner views an animation showing the 2-opt algorithm, the corresponding matrix and a graphical representation simultaneously. The learner can run the algorithm step by step while the different representations are updated according to the algorithm step, e.g., new arcs are drawn in the graph representation and the corresponding coefficients in the matrix are marked. Moreover, the animation is interactive, i.e., the learner can move the nodes in the graph representation and thus create his or her own network. It is well-known that animations contain the risk of overloading the learner; he or she might not be able to process all information presented ([Weidenmann 97, p. 119]). In ORWelt, users can slow down animations, step back and forth and repeat steps. They are supported by fading in text explanations for each step.

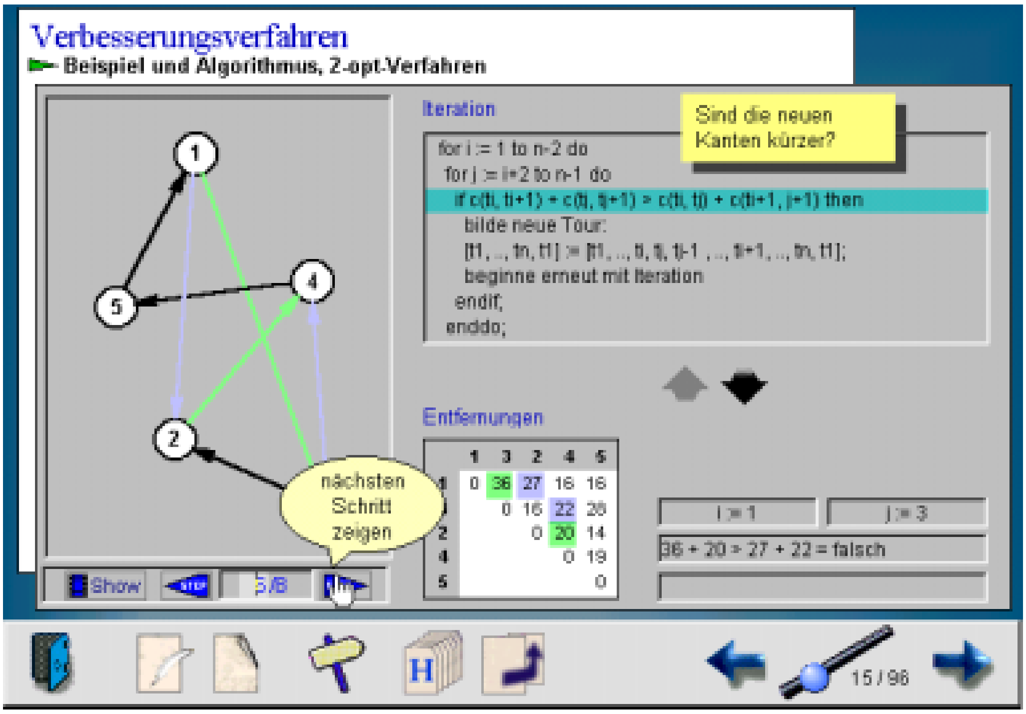

Figure 3: Page of subject module “vehicle routing and scheduling”

Currently, ORWelt comprises 19 subject and 15 test modules covering the main subjects of OR/MS on an introductory level. A graphic browser provides direct access to all modules and supports structural orientation. Footprints, bookmarks and history are implemented as standard navigational tools. Additionally, guided tours can be defined in order to avoid the “lost in hyperspace” effect. An assistant allows the tailoring of tours according to the needs of the individual user. Guided tours are designed to support especially less experienced students by providing sequences suggested by a teacher. The contents covered by ORWelt are shown in Figure 4. Shadowed nodes labeled in italics denote subject modules supplemented with test modules. In addition to the subject modules, ORWelt includes test components to allow students a self-assessment of their comprehension. The tests are usually not multiple choice, but a wide range of interactive methods is used in order to allow the exploration of the test. Our goal is that students get engaged in learning instead of merely receiving information.

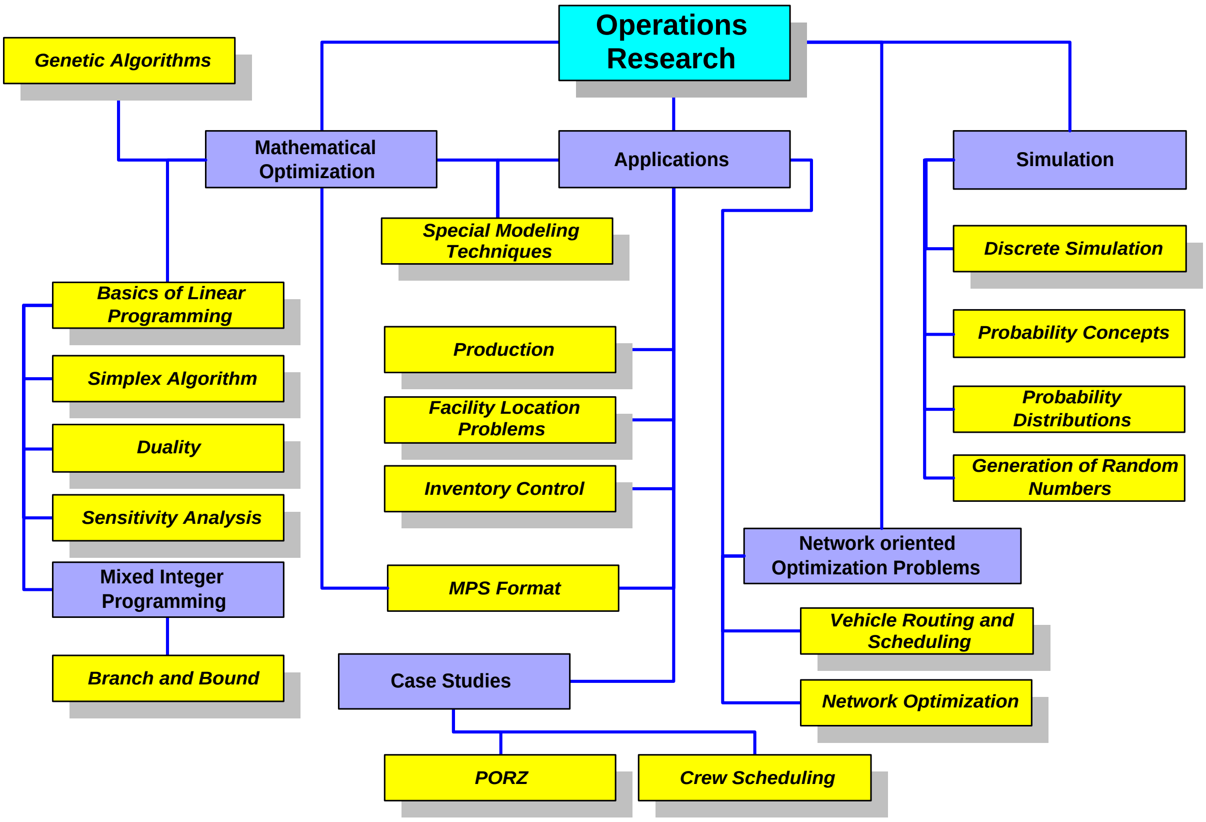

Figure 4: Content covered by ORWelt

A key feature of ORWelt is the integration of the professional optimization code MOPS (Mathematical OPtimization System, [Suhl 94]). MOPS allows the user to solve predefined optimization models while varying parameters of the model. The solver itself resides in the background, and the output does not necessarily have to be a tabular numerical report. It is left up to the developer as to how to visualize the results. Most MOPS models in ORWelt visualize the resulting solution graphically, for example using pie charts, indicating the way to interpret the solution. These "dynamic models" add a new quality of teaching that is not possible to achieve by means of a normal textbook. The dynamic representation allows the learner to interact with the model: he or she can alter parameters, compare solutions and explore the structure of the problem formulation.

4.2 The development model

The ORWelt project started with an experimental phase followed by iterative refinements of the development process. Students were participating in the development of ORWelt from the beginning. We use teams of typically 2-3 students attending a project seminar with a total of 2-6 groups per semester. The seminar is held by a group of two knowledge domain specialists and one or two programming specialists. The authoring environment we use is Asymetrix Toolbook®, currently version 6.1 (Instructor II).

Due to the lack of resources we choose a participative approach with the participation of students. Writing hypertext is not intuitive and requires certain skills in structuring information. “Unfortunately, even though you can easily get some ideas about hypertext authoring from your experience as a hypertext reader, we face the general problem that people have not learned how to structure information in hypertext networks the same way they have [sic] learnt to write linear reports through writing endless numbers of essays at school” [Nielsen 95, p. 309]. Furthermore it is quite demanding for students to develop educational material. Intensive coaching of students is necessary, but it is possible to achieve high quality software. See [Blumstengel, Kassanke 98] for a more detailed description of the development model.

4.3 Curricular Integration

At the moment, ORWelt is a supplementary offer for students, they can use it, but are not required to. The long-term goal of the ORWelt project is to alter teaching methods in the direction of application-orientated learning [Blumstengel, Kassanke, Suhl 97]. Lecture time should be used more efficiently to discuss real problems while teams of students learn part of the material, especially basic algorithms, supported by the learning environment. It can also be used as a reference and for exam preparation.

4.4 Evaluation

The development and introduction of an educational offer is outlined in Figure 5 (see [Alexander 94] for further details). ORWelt has already passed the first three steps.

At the end of each term students answer a questionnaire concerning questions about the usefulness of animations, usefulness of the navigational aids and questions about the user interface in general. Furthermore, the system protocols user actions in a separate log file. This log file is explicitly rendered anonymous and its content can be viewed to avoid resistance to ORWelt due to supervision issues.

It was interesting that some students assessed a certain feature (annotations) to be quite useful, but they never actually used this feature as the log file clearly revealed. This would indicate that evaluating a system can not solely rely on self-assessment by students. In order to obtain clear results, you have to keep automated log files.

As a preliminary result, students assessed the overall quality of ORWelt to be good, especially animations and tests were considered to be particularly helpful.

ORWelt is still under development, further modules are being added and existing ones improved. The current version of ORWelt can be downloaded at http://dsor.uni-paderborn.de/downloads.

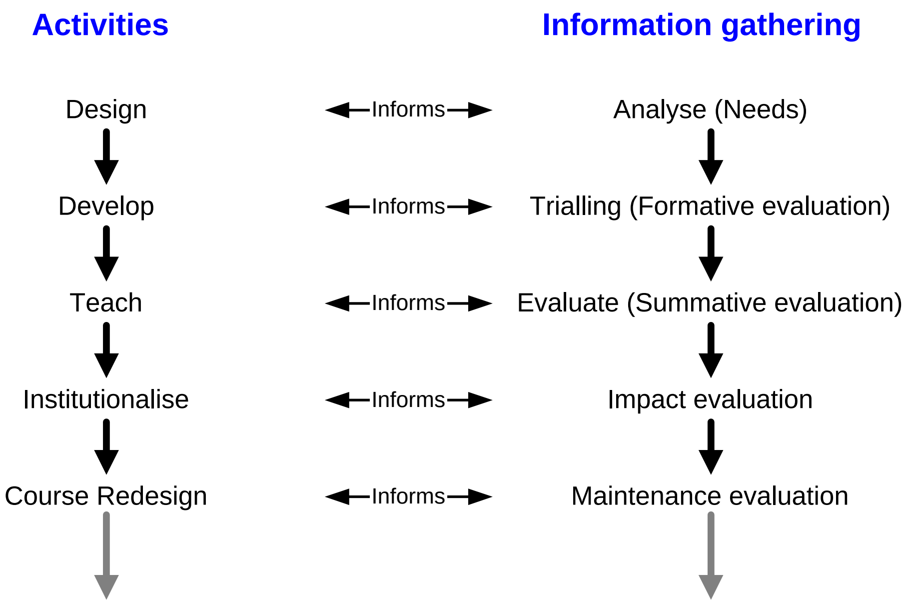

Figure 5: Activity and information gathering cycles ([Alexander94])

5 Extending the Learning Environment

In ORWelt, our students have the possibility to solve optimization models in MPS format. Students can use ORWelt as a cognitive tool to solve self-formulated models without having to worry about formulation syntax of other solvers, since the MPS format is an industry standard for optimization models. Although they can solve these models using MOPS, the model representation is not interactive in the sense of direct manipulation. Modifying a single coefficient requires altering the MPS file and reloading it. In ORWelt it was not possible to provide an interactive model representation due to technical restrictions of Toolbook. Optimization models can become very large and Toolbook does not properly handle large amounts of data.

This led us to the idea of combining ORWelt with other PC based systems and utilizing spreadsheets for educational purposes. Plain Spreadsheets already offer:

- a set of tools including graphical visualization capabilities,
- formulas,
- comfortable cell editing methods,

and last but not least:

- the user is – in most cases – already quite familiar in handling the spreadsheet program.

There is no need to learn another command language for formulating the optimization problem. The model is represented in an intuitive matrix form and the spreadsheet program facilitates data entry and modification. The first prototype of the spreadsheet solver "ClipMOPS" was developed for the Free University Berlin and is designed as an add-in extension for Microsoft Excel®. Although Excel already contains a solver module, the results generated are not necessarily reliable (see [Thiriez 98]). ClipMOPS can be used as a stand-alone tool or in conjunction with ORWelt as well.

In the future, we intend to extend the learning environment by a platform independent component. At the time the ORWelt project was started, the technical possibilities of the World Wide Web lacked basic interaction mechanisms. This has changed dramatically since advanced JAVA technology became available. We are working on a customized framework for a learning environment based on common web standards (JAVA, HTML, etc.).

To summarize, the use of ORWelt and additional computer aided learning resources contributes essentially to a more efficient use of lecture time for discussion and case studies. ORWelt is the first step in the redesign of lectures toward a more learner-oriented approach.

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