

# Teaching Integrated Technique Assessment based on Open-Source Software

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**ABSTRACT:** Using new media technology and the Internet offers possibilities to enhance e-learning methods and deepen the understanding of technical and economic backgrounds. In this work the focus is on the academic teaching within seminars. Students work in teams on corporate strategic planning simulations furthering professional competence through research papers and social competence through group presentations and discussions. Different production scenarios are defined in order to portray the spectrum of different processes for reducing environmental problems before these scenarios are characterised by relevant decision parameters. A special focus is placed on environmental management, which comprises the techno-economic evaluation of mass and energy flows within and between enterprises and analyses of input and output dependencies. Besides emissions into the environment the industrial production process including location and investment planning, logistics etc. will be considered. The students can modify the process models according to their developed production strategy in order to play different scenarios. Input from students and teachers will ensure constant improvement the open source software for e-learning.

**KEYWORDS:** mass- and energy flow management, supply chain, technique assessment, education, open source, teaching material, applied Operations Research, emission reduction, environment, sensitivity analysis

## INTRODUCTION

Using new media technology and the Internet offers possibilities to enhance e-learning methods and deepen the understanding of technical and economic backgrounds. Especially the teaching of industrial engineering requires tools that support the precise numeric calculation of technical and financial data on the one hand, and the consensus-oriented balancing of reasons within discussions and negotiations on the other. This calls for background information from various disciplines, like Engineering, Operations Research and Business Administration. However, it is not only in academic education, but also in business or vocational training that these issues prevail, and they are often accompanied by differences as well as similarities [1]. The application of Operations Research methods in this context provides an opportunity to further analytic understanding as well as insights into the technical background of industrial applications.

From the above perspective the idea of open source plays an increasingly important role. The access to information, software and most advanced knowledge will become one of the most important objectives in the future. In this context open source does not mean the prevention of copying or modification of the material, but the explicit permission of modification and redistribution [2]. After starting with open source software the concept of open source or open content is now applied to various fields including training and teaching material.

There is no general difference between open source software or open content material to commercially supplied software or material. The inherent difference stems from how it is generated, improved and distributed [2]. No single vendor, but instead a virtual community which can be quite elusive promotes the development. The right of using and changing the software comes along with certain responsibilities. The following definition of open source software or material [2], based on the notes of Bruce Perens<sup>1</sup>, is taken for the proceeding work in this paper.

The user may execute, edit and redistribute the program; furthermore he may redistribute the edited version of the program or any other program based on that program. At the same time he commits the responsibility (1) to provide the

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<sup>1</sup> These notes are published on [http://www.opensource.org/docs/definition\\_plain.html](http://www.opensource.org/docs/definition_plain.html)

program based as a whole or in parts on the original program under the same licence agreements; (2) to indicate all editing of him with date and comment and (3) to distribute the source code with the program.

The focus of this paper is on the various requirements and possibilities of open source teaching and training material including open source software, open content material for classroom sessions and web-based training material. Open source software and distant or asynchronous learning methods both have a long tradition which can be combined to an improved learning concept. Special attention is paid in this paper to the field of mass- and energy flow management as taught in industrial engineering. This framework of industrial production and environmental protection is characterised by a high complexity and conflicting objectives, the challenge being the inclusion of this given set of real problems into open source teaching material. Furthermore, the different requirements and challenges for various student groups (academic teaching, vocational training, business training etc.) and their specific application are analysed.

The first part of this work deals with the different industrial applications that are focused on and their context in the field of integrated technique assessment. The second part is about the different requirements necessary for a software to improve learning and to provide learning material for others to be used. Finally, the paper describes how the open source concept can be used to improve education.

## INDUSTRIAL APPLICATIONS AND OPERATIONS RESEARCH ENHANCING THE ACADEMIC TEACHING CONTEXT

In this work the focus is on the academic teaching of ten to twelve students in seminars of industrial engineers at the Technical University of Karlsruhe. The students work in teams of three to four persons on corporate strategic planning simulations. These business games include a combination of different elements which further professional competence through research papers and social competence through group presentations and discussions. By acquiring concentrated background knowledge in their field beforehand and then bringing this topic into the discussion, the students are motivated to learn the academic lecture content. Furthermore, competency in creativity, proactive collaboration, teamwork and discussion are encouraged [3, 4]. A special focus is placed on environmental management, which comprises the techno-economic evaluation of mass and energy flows within and between enterprises and analyses of input and output dependencies. Besides emissions into the environment the industrial production process including location and investment planning, logistics etc. will be considered.

The elaboration of the seminar paper incorporates optimization algorithms. Herein the focus is not on complex algorithms, but on the appropriate mapping of the given context. This mapping involves the discussion of the input parameters for the computer model, e.g. the Learning Curve in industrial applications. The purpose is not the calculation of a specified result given one certain input parameter, but to explore the different perspectives of stakeholders (Controller; Production Manager; Environment, Health and Safety (EHS) Officer; Customer; Environmentalist; Politician etc.). By defining different parameters, different results can be evaluated according to a sensitivity analysis approach.

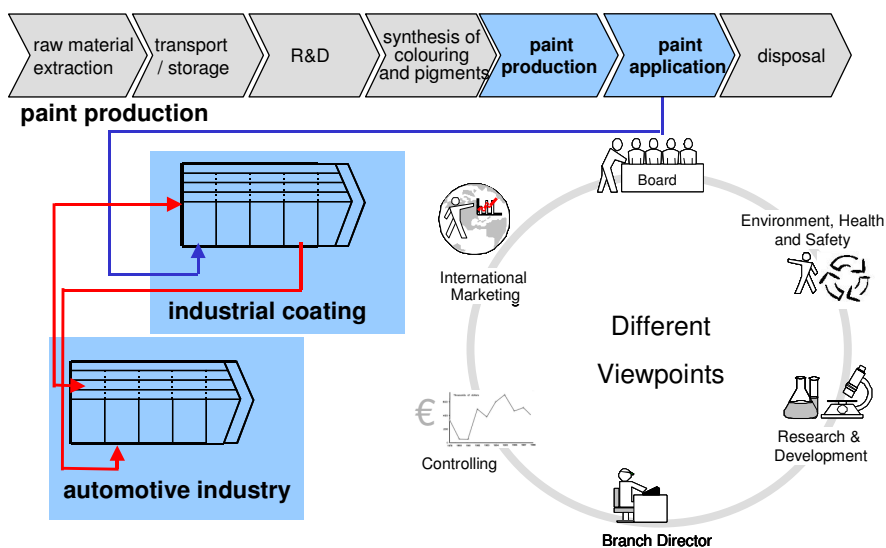


Figure 1: Case Study of the industrial coating process

For example one team has to develop a production strategy for an industrial job coater [see Figure 1]. The case study is based on a completed research project in cooperation with a job coater on mass- and energy flow management [5, 6]. Different production scenarios (conventional spray application, product substitution, robots, thermal incineration, biofiltration, absorption) are defined in order to portray the spectrum of different processes for reducing environmental problems before these scenarios are characterised by relevant decision parameters. Emission relevant data are derived from the mass and energy flow model, while investments and operating costs are calculated according to the VDI guidelines [7]. The mass and energy flow models of the current coating process for mobile phones and PVC parts were mapped with the commercially available software tool UMBERTO ([www.umberto.de](http://www.umberto.de)) by describing all emission and cost relevant coating steps and their interdependencies. The adequate consideration of all media (air, water, land) and their relevance and impact is essential in this context and transmedial problem shifting must be taken into account.

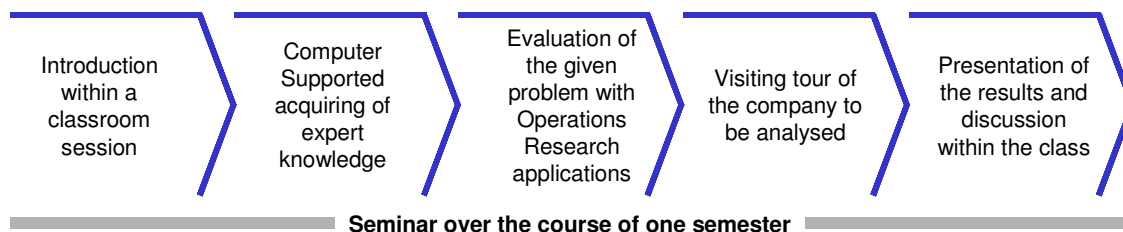
The students can modify the process models according to their developed production strategy in order to play different scenarios. Important aspects in the context of plant layout planning are the evaluation of Economies of Scale, different methods of investment planning or capacity forecasts. Consequently, appropriate methods are required for the impact assessment of the different scenarios, which include conflicting objectives and trade-offs between various attributes. The minimisation of energy demand, water demand, waste water generation or certain input mass flows raises different options, which may contradict each other. Furthermore, different scales must be compared with each other, for example costs, energy demand and solvent emissions, which are all measured in different units.

In situations like these different multi-criteria methods can be used to rank the various alternatives by their environmental impact and to investigate the effect of different weighting factors of the various stakeholders. MADM (multi-attribute decision making) methods are suited to the difficulty of selecting or evaluating a set of well-defined, discrete alternatives [8]. By applying a chosen MADM method a ranking of the different investigated alternatives can be achieved. Spreadsheet-based tools can incorporate different multi-criteria decision support methods. These tools can be used by different groups to discuss certain emission reduction techniques.

The robustness of a decision is very important and therefore it is essential for the decision maker to use sensitivity analysis to learn how the output of a model changes with variations in the input [9]. There are different reasons for executing a sensitivity analysis as [10] shows:

- to build and explore consequence models
- to explore the relationship between science and consequence models
- to support the elicitation of judgemental inputs to an analysis
- to develop efficient computational algorithms
- to design experiments
- to guide the making of inferences, forecasts and decisions
- to explore and build consensus
- to build understanding

Of special interest is the sensitivity of a ranking to changes in the data of all alternatives for certain criteria [11] and hence the stability of a calculated result [5]. Consequently, a software supported sensitivity analysis is an important step in the decision process for measuring the uncertainty and evaluating the risk [12-14]. Thus an important objective of the seminars is the insight that different viewpoints of the various stakeholders lead to different results for the same given initial problem or case study. Such an investigation of a variety of parameters is hardly possible in a lecture.



**Figure 2: Course of action within a seminar**

Figure 2 summarizes the course of action within a seminar on integrated technique assesement. The acquisition of expert knowledge and the application of Operations Research algorithms can be supported by e-learning software. Providing these tools in open source software offers the possibility for the students to attune the calculation models to their case study. Moreover the tools can be used in different universities for running international and interdisciplinary seminars. The same scenario can also be used in different European universities to find compromises on technical

issues, thus furthering discussion between students in an international context.

## OPEN SOURCE AS A MEANS TO IMPROVE TEACHING FOR DIFFERENT AUDIENCES

Different contexts in academia, vocational training, business training and political decision making lead to different demands for teaching components. While in business training the assessment centre and the audit of management potential is prevailing [15], the academic teaching is focussed on the individual knowledge of each student. Business games generally offer the possibility of furthering professional and social skills within academia and corporate professional development (see Figure 3).

	Business Training	Academic Teaching
Assessment - Centre	■	
Audit of Management Potential	■	
Group Decisions within Working Teams	■	■
Business and Strategic Planning	■	■
Dynamics of Group Processes	■	■
Organisation Simulation	■	■
Networked Models	■	■

**Figure 3: Use of Business Games**

[16] note that there is a lack of opportunities for gaining the appropriate professional qualifications required. E-Learning with detailed descriptions of the materials to be used would provide increased access and thus close the gap between university and business training. In the context of the described seminars a combination of e-learning and classroom sessions is considered.

For many training needs, the best solution may not be pure web-based training or pure classroom training, but an appropriate combination of the most suitable features of both [1]. Classroom sessions have the strength of face-to-face communication and motivation, flexible presentation and full interaction, whereas computer-supported methodologies offer increased access to expert knowledge and individual time schedules. Depending on the audience the different elements can take different lengths of time. Providing all the material to all possible participants allows a knowledge-dependent learning pace.

Key requirements are not only the availability of software tools, but also the internationally shared use of the teaching material and the existence of the electronic material in a common format. Hence, the development of teaching material and the development of a tool supporting this must consider not only provided formats for texts, but also presentation, mathematical equations and multi-lingual contexts.

Here, Open Source software provides some inherent advantages, which in Europe are analysed by the Working group on Libre Software<sup>2</sup>. They emphasise the availability of the source code and the right to modify it. Especially in the context of e-learning, this permits the tuning and improvement of business games to the given legislation in different countries or the incorporation of further optimisation or decision support algorithms. The right to use the software and restriction of per-copy fees makes use in academic training easier, especially for long-term planning where software licences are not required. The availability of software also advances correspondence between teachers and students. Another advantage is that the software is freely accessible for teachers and students, such that input from students and teachers will ensure constant improvement the software. There are already open source software tools available which can be used for e-learning, like Claroline ([www.claroline.net](http://www.claroline.net)) or Moodle ([www.moodle.org](http://www.moodle.org)), which are virtual learning environments helping teacher to create online courses. An innovative aspect of this work is the open source development of e-learning material with respect to free available teaching material and (not included in this work - but also within the EDUKALIBRE<sup>3</sup> project) a software platform for the development of open source e-learning material.

<sup>2</sup> Working Group on Libre Software; <http://eu.conecta.it>

<sup>3</sup> <http://edukalibre.dat.escet.urjc.es/> & see acknowledgements

## SUMMARY

Including complex scenarios in academic education and professional training necessitate a software supported e-learning environment. Only with computer-based algorithms can different scenarios be calculated in order to compare results, discuss different pollution prevention measures and illuminate various facets of one given problem. Business games pave the way to the implementation of e-learning and in so doing further soft skills at the same time.

Given the current status of academic education and vocational training, there is a significant demand for the detailed description of the underlying technical processes of business games and for the different involved departments within a company as well as their interdependencies. In addition, developing the objectives of business games including EMAS (Eco-Management and Audit Scheme), Life-Cycle Assessment and strategic planning, is essential for incorporating a broad range of aspects. This would provide an initial status in which different software tools support the discussion and advance the consensus towards a compromise. Open source development of these corporate strategic planning simulations not only allows the far-ranging use of this material, but also the incremental sophistication of the given material.

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