

Material Efficiency in Higher Education - Requirements Regarding Teaching and their Practical Realisation in a New Simulation Game

René Keil, Mario Schmidt

Pforzheim University, Institute of Applied Research, D-75175 Pforzheim

Corresponding author: René Keil, rene.keil@hs-pforzheim.de

Abstract

Universities play an important role as a multiplier for the subject of material efficiency. To transfer knowledge with consideration given to material efficiency, basic knowledge of production engineering, controlling, management and environmental protection are just as necessary as specific methodological knowledge. In practical applications it turns out that pure knowledge transfer is not sufficient in itself. Realising material efficiency successfully in enterprises requires further competences, such as problem solving competence. Such skills cannot be taught by pure knowledge transfer.

Simulation games can fulfil the requirements mentioned. For this reason a new simulation game was developed at Pforzheim University. It simulates the production site of a medium-sized enterprise in the automobile supply industry, as well as different roles in the enterprise. The task for the students consists in analysing and optimising the energy and material flows of the production process.

Practical use of the simulation game in higher education has led to very deep comprehension on the part of the students of the use and potentials of material flow analyses in practice in manufacturing enterprises.

Keywords: material efficiency, simulation game, higher education, role play

1 Introduction

Material Efficiency has become a diversified topic which is applied in miscellaneous ways and displays numerous connections with other topics. In politics and research, material efficiency is now considered very positively. However, the response in companies is still restrained, although the positive economic aspects of material efficiency have already been covered in various studies.

Why material efficiency achieves only little response in manufacturing enterprises in the face of these potentials is the subject of some research projects. Arthur D. Little et al (2005: 6) name four main barriers:

- Information deficits regarding profitability, applicability and risks
- Lack of qualified staff (planning, project management and execution)
- Lack of capital for investments
- Lack of technical and organisational solutions

So the question arises of multipliers who are able to remedy the information deficit and trained staff who have the corresponding competence to recognise and to solve such

problems well in practice. Universities must play a special role in this respect.¹ The question, is how can material efficiency be communicated in higher education and also be used later in work situations.

2 Requirements Regarding Teaching

To increase material efficiency successfully it is necessary on the one hand to have basic knowledge which concerns the topic either directly or indirectly (“hard skills”). On the other hand, a number of competences making it possible to apply this basic knowledge in practice are also needed (“soft skills”).

2.1 “Hard Skills” - Basic Knowledge and Methodological Background

Since material efficiency makes sense primarily in material-intensive production facilities, technical knowledge is essential with a view to subsequently realising the cost reduction potentials. It must also be ensured that solutions leading to an increase in material efficiency do not also lead to conflicts of goals in connection with important production parameters like capacity utilisation or cycle time.

An important tool for increasing material efficiency is to analyse production systems as networked systems by modelling. Modelling is a major instrument for understanding a system and for analysing different scenarios with consideration given to corresponding targets.

Finally, the results must lead primarily to the fulfilment of economic targets in the enterprise. Knowledge with respect to cost accounting and controlling therefore forms important basic expertise.

Furthermore, knowledge regarding management theory and management techniques as well as environment-relevant knowledge regarding the material and energy flows play an essential role.

Recapitulating, the following "hard skills" can be mentioned:

- Technical knowledge regarding production of goods
- Comprehension of networked systems and modelling
- Knowledge regarding cost accounting and controlling
- Knowledge regarding management theory and techniques
- Knowledge regarding environment-relevant material and energy flows
- Knowledge regarding specific analysis methods and applications

2.2 “Soft Skills” - Important Competences

Expert knowledge is not generally sufficient to be able to operate successfully in practice.² Looking at the sequence of a material efficiency action from identification of the problem to

¹ See also Martin et. al. (2001), 329 p.

² Stark et. al. (1995), 289; Jensen et. al. (1997), 163 pp.

implementation of the final solution, four different competences can be identified (Fig. 1).¹

- Problem solution competence: the competence to identify a problem and to work out proposals for solution
- Decision competence: the competence to find the optimal solution from a variety of proposed solutions
- Action competence: the competence to implement the final solution in the enterprise
- Communication competence: the competence to communicate or to work together during all four steps with persons or departments concerned.

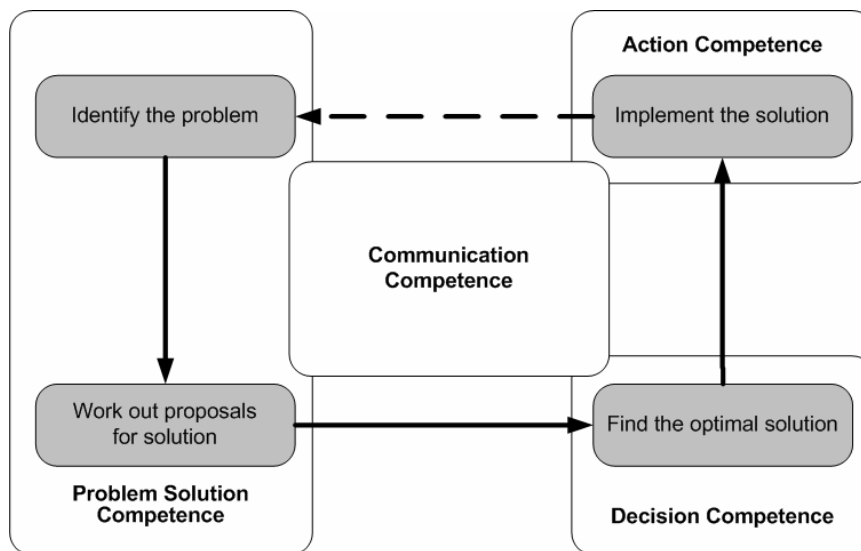


Figure 1: “Soft Skills” to operate material efficiency successfully

2.3 Teaching Forms in Higher Education and their Suitability for Material Efficiency

In higher education different teaching forms are available for different teaching contents. In principle, one can distinguish between the following forms:

- Teaching forms without direct student participation (e.g. lectures) and
- Teaching forms with direct student participation (e.g. case studies, simulation games and practice projects).

It must be stated that lectures primarily support the transfer of knowledge, while this knowledge is presupposed in case studies, simulation games and practice projects. These teaching forms contribute more to transferring the corresponding competences. Of course practice projects are suitable for optimal transfer of all competences required. However, it must be considered that practice projects are not necessarily successful projects. Experiences with student practice projects in the area of material efficiency show a high frustration potential. Furthermore, it must also be considered that the effort of project acquisition as well as the student support is very high by comparison with other teaching forms.

¹ See also Buddensiek (1992), 9 pp.

Therefore simulation games are considered an optimal teaching form for comprehensive and successful transfer of the material efficiency topic.

3 Practical Realisation in a New Simulation Game

A market investigation showed that no simulation game is currently available for teaching material efficiency. For this reason a simulation game was developed and tested at Pforzheim University.

3.1 Key Data and Procedure

The simulation game has been developed for students of business administration and engineering, or business administration, since these already cover some areas of the expert knowledge required.¹ The lacking expert knowledge (e.g. special analysis methods) is transferred in supporting lecture units, which are embedded in the procedure of the simulation game. The actual simulation game runs for four rounds, with the first two rounds serving to prepare the methodological background.² The main aim of the simulation game is to optimise a production site from the point of view of material efficiency. For this the students are divided into groups with 4 to 5 participants.³ Each group represents the same enterprise with the same starting point and the same data.

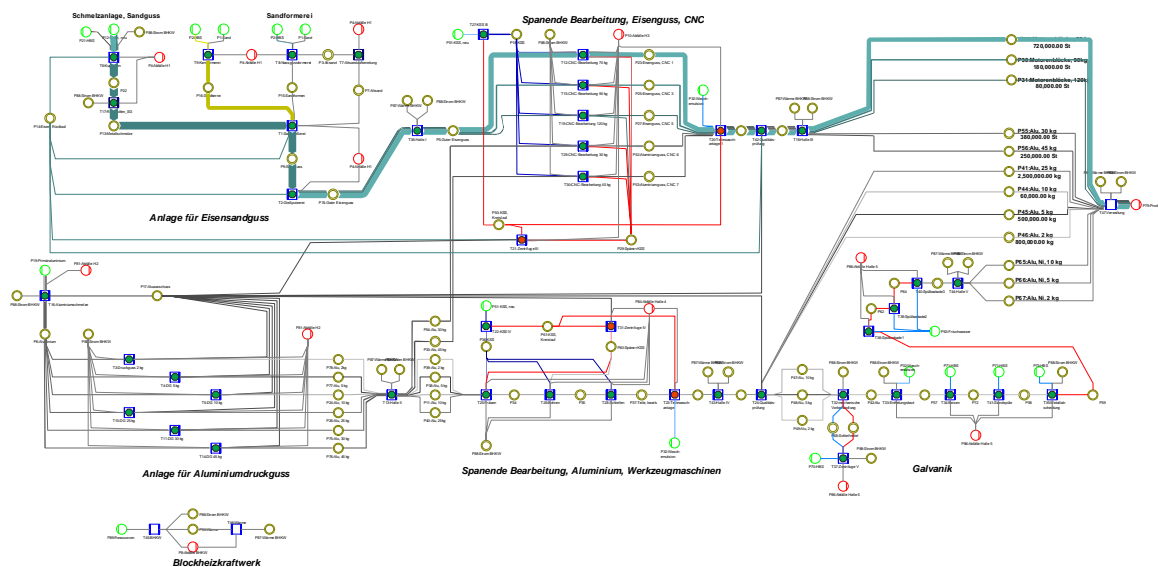


Figure 2: Sankey diagram of the material flow model

A material flow model which includes all energy and material flows of production and provides the complete data set of the simulation game works in the background (Fig. 2).

¹ See also Dominik et. al. (2003), 17 pp.

² Stark et. al. (1995), 294 pp. describe this as "guided problem-solving" and refer to the higher learning successes.

³ Re. learning in teams - see Kayes et. al. (2005), 330 pp.

Furthermore, the proposals for solution and the action recommended by students as well as the changes in production these cause can be simulated by the model. The model is not available to the students. They receive the data and results exclusively on paper.

In rounds three and four the different teams compete with each other. Specific key figures of the competitors are public knowledge for everyone. However, the actions executed are presented in a common presentation at the end of the simulation game.

After every round group-specific meetings are held at which feedback is given to the groups for the solutions worked out and the group behaviour.¹

3.2 The Enterprise “PMG Schwäbele”

The enterprise PMG Schwäbele is a German, medium-sized supplier to the automobile industry. The enterprise produces engine blocks from sand casting with iron as well as further parts from pressure casting with aluminium. The production is spread over five halls with the following processes:

- Sand casting
- Pressure casting
- Shape cutting with modern CNC machines
- Shape cutting with various individual machines
- Electroplating

The enterprise makes a profit and apparently works optimally. However, numerous inefficiencies actually exist in production concerning use of energy and material. The participants must identify these inefficiencies and eliminate them by simple to complex actions. The identification of the inefficiencies, the working out of proposals for a solution, the finding of the optimal solution, as well as simulation of the realisation in the enterprise are components of the simulation game.

3.3 Roles and Conflict of Goals

As in many other fields, difficulties often lie in different roles which are involved in the process of implementation. Different entrepreneurial and personal aims of the participants involved clash and constrain cooperation. In many cases a project is not executed or technical or process-related changes are not implemented due to the conflicts of goals.²

The simulation of these conflicts is integrated in the simulation game by role playing. The participants act in different roles such as CEO, executive producer, controlling and environmental protection officer. Each role has a different view of the enterprise as it receives only specific data sets. To work successfully, the groups must bring these data together.

Furthermore, each role is given a role-specific characteristic or ratio, which must be optimised in the course of the simulation game. The different characteristics or ratios were

¹ Debriefing is an important phase in using simulation games. See also Peters et. al. (2004), 70 pp.

² See Tjie (2002), 486 p.

selected such that they are contrary and generate conflicts of goals in the case of different action options.

3.4 Experience After the First Games

The simulation game was tested in two runs with students of business administration and logistics. In both cases a high appreciation of material efficiency as well as of the technical processes in the enterprise were noted in the final meeting. Furthermore, it was noticed that almost all students took part in the simulation game with great commitment and worked out essential knowledge about optimisation possibilities of technical systems self-reliantly. The learning success can therefore be assessed as very high.

4 Conclusion

The practice test showed that the simulation game developed is very suitable for transferring both the theoretical background and the application of methods from the material efficiency environment. It turned out that such contents can also be transferred successfully via a simulation game in study courses that have not dealt with the topic and do not show any proximity to technical questions either.

It is now necessary to professionalize the simulation game developed more strongly and to bring it to further applications in the university environment. Furthermore, the transferability to on-the-job training in manufacturing enterprises must be checked.

References

- Arthur D. Little GmbH; Fraunhofer Institut für System- und Innovationsforschung, Wuppertal-Institut (2005): Konzeption eines Programms für die Steigerung der Materialeffizienz in mittelständischen Unternehmen. Bericht. Berlin.
- Buddensiek, Wilfried (1992): Entscheidungstraining im Methodenverbund - Didaktische Begründung für die Verbindung von Fallstudie und Simulationsspiel, in: Keim, Helmut (1992); Planspiel, Rollenspiel, Fallstudie, 9-24.
- Dominik, J., Loizeau, J.-L., Thomas, R.L. (2003): Bridging the gaps between environmental engineering and environmental natural science education, *International Journal of Sustainability in Higher Education* 4/1, 17-24.
- Jensen, Bjarne B., Schnack, Karsten (1997): The action competence approach in environmental education, *Environmental Education Research*, 163-178.
- Kayes, Anna B., Kayes, D. Christopher, Kolb, David A. (2005): Experiential learning in teams, *Simulation & Gaming* 36, 330-354.
- Martin, Maria J., Rigola, Miquel (2001): Incorporating cleaner production and environmental management systems in environmental science education at the University of Girona, *International Journal of Sustainability in Higher Education* 2/4, 329-339.
- Peters, Vincent A. M., Vissers, Geert A. N. (2004): A Simple Classification Model for Debriefing Simulation Games, *Simulation & Gaming* 35, 70-84
- Stark, Robin, Graf, Markus, Renkl, Alexander, Gruber, Hans, Mandl, Heinz (1995): Förderung von Handlungskompetenz durch geleitetes Problemlösen und multiple Lernkontexte, *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie* XXVII, 289-312.
- Tjje, Colleen B. (2002): Conflict and Roles in Simulations, *Simulation & Gaming* 33, 486-489.