New Approaches for Training and Education of Engineers by Using Simulation Games

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Key words: simulation game, education, teamwork, distributed co-operation, concurrent engineering

Abstract: The ongoing trend of globalisation and growing world-wide competition of European industries have changed the qualification needs of engineers. Human competencies such as team-work, co-operation, customer orientation, and entrepreneurial thinking are gaining more and more in importance. However, traditional education and training concepts in universities and industries do not fulfil the new requirements. This paper gives a short overview on qualification demands for concurrent engineering (CE) and distributed co-operation. It introduces the concepts of two new approaches, to meet the new requirements on engineering education and training by application of simulation games.

1. INTRODUCTION

The European industry is forced to be more flexible in the choice of their production sites if they want be competitive in the world market. Many companies have already distributed their production of different sites all over the world or have developed a closer co-operation with other companies.

In the engineering area, Concurrent Engineering (CE) was proven as an efficient approach to increase a company's competitiveness. Many tools

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: [10.1007/978-0-387-35506-1_17](https://doi.org/10.1007/978-0-387-35506-1_17)

J. O. Riis et al. (eds.), *Games in Operations Management*

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support the implementation and operation of CE. Among the realisation of organisational changes, the uses of modern telecommunication technologies have been gaining in importance. Telecommunication and data exchange support the creation of distributed production systems and have an increasing importance for the daily work of the employees.

Frequently, the companies and their employees have the necessary technical knowledge about CE, techniques and technologies for efficient working and co-operation in distributed production systems. Engineering courses for engineers and students are constantly extended by that knowledge and many books and articles have been written about these subjects, but there is little room in education and training to apply that knowledge for gaining experiences. Thus, engineers from students up to experienced employees have deficits in practical knowledge and no experiences in making good use of what they have learned.

The adequate qualification has to be given by practice, and the training of the new techniques and actions in a practical manner with consideration of the modified working conditions. Thus, there is a strong need for new training and education approaches, enabling engineers to co-operate with CE principles in a global environment (Hirsch, Thoben, Hoheisel 1996).

Addressing this need, the here suggested approaches are based on the idea to use simulation games for learning how to do CE, how to work in parallel and how to co-operate with others. The authors are currently following two complementary approaches of simulation games for group learning. The first approach uses a model company to provide a realistic environment, the other approach simulates the business environment by a computer simulation.

The rationale to use games is to exploit the potential of gaming, i.e. to experience instead of just to perceive. People can be motivated by gaming more than by listening to presentations or similar training methods, and the learning result can be expected to be higher. Being attractive, novel, entertaining, and a kind of 'adventure', gaming makes curious and can be utilised to impart knowledge in an effective way. It can serve as a positive and productive diversion from daily routine work. In addition, the simulation can also serve to test and verify the learning results achieved.

This paper describes the authors' motivation, the initial concepts and first results of the simulation game approaches. The development is subject of two European research projects, partly funded by the European Commission (GLOTRAIN, Leonardo da Vinci project no. D/96/2/0788/PI/IL.1.1a/FPC and COSIGA – A Concurrent Engineering Simulation Game, Multimedia Task Force project no. MM1003).

2. EDUCATIONAL NEEDS

Students entering a university engineering course usually have very little understanding of industrial and business practices. The university teachers, in a relatively short time, have to equip them with the required skills, engineering principles, techniques and practices and simultaneously maintain academic excellence. A brief survey of different engineering courses shows that a typical engineering course initially focuses on engineering principles, mathematics and computing. These disciplines are further developed in detail. In higher semesters, focus shifts to specific techniques and technologies like e.g. Rapid Prototyping, CAD/CAM or TQM. Group projects and exercises are normally used to illustrate the inter-relations between various tools and techniques.

Similar situation applies to further education and vocational training, where fast and cost-effective courses address the imparting of facts and focussing on knowledge that is required for general tasks or to solve exemplary problems. Usually, the courses deal with new technologies, new techniques or aim human capabilities and management, but they miss to consider the overall engineering context.

But engineers do not only need specialised knowledge, they need to know how to apply the knowledge and they need experiences on effects and interactions of their actions. The capability for a proper use of available knowledge requires qualifications, which are different from knowledge itself.

An essential qualification demand of employees is the capability for co-operation and teamwork. Since team members are physically separated in distributed manufacturing and due to frequently changing compositions of partnerships, the requirements are even harder. Furthermore close co-operation between different companies demand empathy and social competencies of the employees and within international partnerships intercultural competencies becomes more important. (Stifterverband 1993; BMBF 1996; VDI 1995; Windhoff, Hoheisel, Hirsch 98).

Since the daily work within a distributed environment requires new approaches for thinking and acting in networks, the employees need to know how to use the technical equipment for the co-operation in networks, especially the handling and experienced use of modern co-operation tools.

In summary a major requirement is that engineering students can experience working in a utmost realistic area. Effective education for future industries needs a learning-by-doing approach characterised by moving from passive perception to *active experience*. However, there are not enough real life situations that can be used for education or training, since in many real life cases the occurrence of errors – which are natural in learning situations –

is not acceptable. Simulation games (Riis, 1995) using advanced information and communication technology can be used as a substitute in order to meet this need.

3. NEW APPROACHES FOR EDUCATION AND TRAINING

Two new approaches, currently under development with participation of Universität Bremen, aim to meet the new requirements on engineering education and training by application of simulation games. Both try to simulate a real working environment, where students and employees are urged to use tools and techniques and to experience co-operation and teamwork (sometimes at separate places) without being afraid of expensive mistakes. Simulations allow us to train and practice skills and knowledge without the risks or costs involved with real life situations. Since distributed work environments becomes more and more important, profitable use of modern information and communication technologies is largely included into the here presented simulations.

The simulations will be implemented as games. Learners will play in groups to solve challenges in co-operation. On the one hand, it is fun to play games and it is always a strong interest to manage the challenge, especially when group dynamics come up, the ambition to reach the goal is sometimes more important than in real business. On the other hand the team idea is better known for games than for business. The approaches may help to transfer the team spirit of games into engineering.

Both approaches are based on scenarios. Each player takes over a specific role in the simulated business environment and changes from a passive consumer of knowledge into an active member of a (simulated) company. For every role, the scenarios prescribe a starting point and a goal and hinder the process of problem solving by obstacles and contradictory individual goals. The player will learn in co-operation and self-directed by gathering and sharing experiences and practice.

Both approaches make intensive use of computers. However, only the COSIGA approach is a computer based simulation game. The GLOTRAIN approach tries to simulate reality in a real environment.

4. THE GLOTRAIN APPROACH

The Leonardo da Vinci project GLOTRAIN (“Training engineers for mastering new requirements in globally distributed manufacturing”) aims to develop, to apply and to evaluate qualification and training modules for engineering activities in distributed environments. Based on the approach of business games, the modules allow to experience and to practice distributed team-work by use of modern tools and methods for communication and production.

Basis of the GLOTRAIN qualification modules is the almost real model of a distributed production environment, that allows to manufacture real products and that needs active work of learners in varying roles and situations.

All modules make intensive use of communication technologies and computers, adopted to the needs of distributed work. In detail, telephone, fax, e-mail, video-conferencing and application sharing have been used so far. Integrated CAD/CAM systems are used as well, but an adaptation to the needs of distributed work is still in process.

There are three qualification modules with different targets under development so far (Figure 1). The first module, called “organisation and teamwork” illustrates the change of the model enterprise from a traditional, formalised and tayloristic company into a modern, process oriented company. Each learner takes over a certain role in the company, e.g. sales representative or manager. The “employees” try to process incoming orders, while changing the organisation of their company e.g. by introduction of group work.

Figure 1. Qualification modules of GLOTRAIN

The second module is called “distributed co-operation”. Three groups of players in a remote set-up, each representing an independent company have to co-operate in three simultaneous game scenarios by using different information and communication technologies (Figure 2). The emphasis is on the application and comparison of adequate tools and techniques for communication and their impact on team-work. Problems and structures of the game scenarios produce stress and ambition. The players get into a conflict between their individual goals, the team goals and a common goal of the three co-operating “companies”.

Figure 2. The GLOTRAIN module "distributed co-operation"

Unlike the previous two GLOTRAIN modules, the third module “customer focus and co-operative product development” targets the product. Several groups of players have to develop and produce a product within a given specification. Time and resources to produce the products is very low. Especially machine-time has to be reserved well ahead of time and leads to competition between the groups.

All three modules are based on each other and tell a coherent story of the model company. The degree of freedom and responsibility increases from module to module, to support eagerness and capability for self-directed and co-operative learning.

Each of the three modules is divided into five phases and embeds the actual game module into a sequence of preparation, implementation and review (Figure 3). The training phases are:

- Learning of specialised knowledge
Short lectures of specialised knowledge that is needed to understand the game module and to solve the concerning problem.
- Preparation of the game
Introduction of participants into the game. Explanation of rules, roles and goals of the game as well as learning goals of the module.
- Implementation of the game
Player become “employees” of the model company. Positive and negative impressions of the model company will be learned by experience.
- Discussion
The overall course and different stages of the game will be discussed together with all participants.
- Presentation
Individual presentation of results by each group, using various methods and tools for presentation. Assessment of results.

The organisation of an educational approach like GLOTRAIN requires a great deal of preparation. The game is limited to groups from 10 – 20 participants and takes 3-5 full days for playing all the three modules.

Figure 3. Phases of a GLOTRAIN module

5. THE COSIGA APPROACH

The second approach is covered by the just started European research project COSIGA ("A Concurrent Engineering Simulation Game – Using Advanced Multimedia and Telecommunication for Education of European Engineering Students") (Barson, Hoheisel, Kasvi, Pawar, Weber 97). COSIGA aims to be more flexible in time and group size than the GLOTRAIN approach. While GLOTRAIN considers general aspects of human requirements and experiences of engineers, the COSIGA focus is closer to experiences and human requirements for CE.

The objective of the COSIGA project is to develop a multimedia simulation game for the education and training of European engineers and engineering students in CE with the purpose to promote parallel, foresighted and co-operative working in a distributed environment. The game can be played by individuals, using the computer as the gaming partner, or in a distributed group, using (e.g.) the Internet as a communication means. The users will interact in a product development scenario where they have to carry out specific tasks and will experience direct feedback as a results of their actions.

The major learning goals that will be supported with the simulation game are:

- to understand and to apply CE practises and principles
- to identify and solve potential problems
- to be able to communicate and collaborate within a CE group
- to have knowledge of the most common tools

In order to meet the game's learning goals a major starting point of the development is the definition of CE principles and processes and especially the development of a corresponding simulation model. This model specifies the logical reactions of the simulation game to the actions of the user. Further, it defines the events and conflict situations with which the user will be confronted when playing the game.

The simulation model defines the roles and actors in the game, simulated actors as well as roles of active players. It also defines the reproduction of the reality into game symbols that have to be transformed into computer representations. This transformation has to melt with utmost perfection the didactic concept, the CE environment and the multimedia user interface into an attractive and ergonomic gaming environment. The faithful and attractive reproduction of the CE environment is a key challenge and requires a careful development of the multimedia user interface.

Finally, the simulation module is required for allowing the users to measure and to evaluate the impact of their actions along with the product design and development process. Unlike the majority of business simulation

games, the assessment is not based on numbers and diagrams, but on realistic feedback mechanism such as the (verbal) respond of colleagues, mail, or the appearance of the product during production. However, the reaction of the simulation module has an essential impact on the quality of players' experiences during the game and defines highest requirements for intuitive and realistic user interfaces.

A further key element of the game is the communication module. The game will allow individual and group gaming in a multi-disciplinary, multi-national, multi-cultural, multi-functional, distributed environment. Playing the game all alone is a special case where all other roles of the game are simulated by the computer, the usual utilisation of the game is group playing. Several clients of the game can link into a network providing a common state of the simulated world. A separate server is responsible to trigger events for the overall co-ordination of the game to manage several coexistent games and to provide a lasting address to join new games.

The communication between groups of players will be realised by the communication module, integrating several information and communication technologies from e-mail to video-conferencing into the game.

The content of the game is much more simple than reality. There is no need to use e.g. real CAD or to consider complete dependencies of decisions. The simulated reality will be reduced to speed up the game, to focus on learning goals as described above and to restrict the game to the most interesting and most important elements of CE.

6. CONCLUSION

First applications of the GLOTRAIN approach encourage the further development and application of educational games for engineers. Exemplary results of a first case study were:

- Interest and activity of the participants were constantly above average and apparently amusing.
- Typical problems of co-operation, especially problems of distributed co-operation were arisen and experienced by the participants
- Experiences with effects of reorganisation and introduction of new technologies have been made impressively.
- Participants were able to realise the connection between their theoretical knowledge and their experiences during the game. (Windhoff, Hoheisel, Hirsch 98)

The paper has introduced two complementary approaches of simulation games for education and training of engineers. Both approaches will be completed and ready to use by the end of 1999. The authors aim to set up

European wide training groups by using the network functionality of the games.

7. REFERENCES

- Barson, R.; Hoheisel, J.; Kasvi, J.; Pawar, K. S.; Weber, F. (1997) A Concurrent Engineering Simulation Game - Initial concepts for new means for the education and training of engineers for concurrent engineering. International conference on concurrent enterprising; University of Nottingham, 8 - 10 October 1997
- BMBF (Hrsg.) (1997) Zur technologischen Leistungsfähigkeit Deutschlands. Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie - Referat Öffentlichkeitsarbeit; Bonn, 1997
- Hirsch B E, Thoben K-D, Hoheisel J. (1996) From Local to Globally Distributed Manufacturing: Consequences and Proposals for a Reorientation in the Education of Engineers. In: Krause, F.-L.; Shtub, A.; Shpitalni, M. (Eds.): CIEME. Israel-Germany Bi-National Conference on Computer Integrated Extended Manufacturing Enterprise. February 28-29, 1996, Dan Accadia Hotel, Herzliyah, Israel.; Deutsche Forschungsgemeinschaft - DFG; The Israeli Ministry of Science and the Arts - MOSA; 1996.
- Riis J O (1995) (Ed.): Simulation Games and Learning in Production Management. Chapman & Hall, London, 1995.
- Stifterverband für die Deutsche Wissenschaft (1993) Qualifikationsanforderungen an Hochschulabsolventen - Empfehlungen aus der Sicht der Wirtschaft, Essen
- Windhoff, G.; Hoheisel, J. Hirsch, B.E. (1998) Training zur Bewältigung neuer Anforderungen in global verteilter Industrieproduktion, Europäisches Planspielforum, Nürnberg, 1998

8. BIOGRAPHY

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Jens Hoheisel holds a degree in Information Science from the University of Bremen. Since 1995 he is employed as research scientist in the Department of Production Engineering at the University of Bremen and works within the Department Manufacturing Systems, Communications and Telematics at BIBA. He is involved in several regional and European research and development projects in the area of learning and training environments for distributed production such as the educational multimedia project COSIGA. His major research interests are in the area of computer supported co-operative work and tele-learning environments.

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Frithjof Weber studied production engineering at the University of Bremen. Prior to that, he gained several years of experience as electro mechanic on the shopfloor level. He joined BIBA in 1995 as a research

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Gert Windhoff

Gert Windhoff received his MSc in production engineering in 1993 at the University of Bremen. In 1993, he started as a research scientist at BIBA. From 1993 to 1995, he worked in the Quality Management Department on projects about new training concepts for employees. Since 1995 he worked as a research scientist in the Department of Production Engineering at the University of Bremen. From 1996 he has been the co-ordinator of the Leonardo da Vinci project GLOTRAIN. He is involved in university courses about organisational structures and organises the course "Games for Production Management". His major research interests are business games, training concepts for engineers and organisational structures for globally distributed manufacturing.