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Education of Engineers by Learning in Networks*

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Tasks of engineers, such as product development, production design, factory operation, etc., are carried out in interdisciplinary teams or in co-operation projects. Therefore, the competence profiles of engineers are characterised by specialised competencies as well as methodological and social competencies. Consequently, networked education concepts are derived for university education and on-the-job training. These concepts require conventional education methods, playing-games, ICT and international corporations to develop the competence profiles needed to accomplish tasks of engineers.

INTRODUCTION

TASKS OF ENGINEERS, as product development, production design, factory operation, etc., are carried out in interdisciplinary teams or in cooperation projects. Therefore, the competence profiles of engineers are characterised by specialised competencies as well as methodological and social competencies. Hence the need for networked education concepts for university education and on-the-job training.

An example for a networked education concept is the one of a two-step course for production design offered at the Institute for Manufacturing Engineering and Production Management at the Kaiserslautern University of Technology. The basic principle of the course is the education of knowledge and skills, and the development of competences with modular learning content supported by several electronic media.

QUALIFICATION AND COMPETENCE

An important aspect of the course is the understanding of the correlation between qualification and competence. Competences are divided into three distinct areas of technical competence, methodological competence and social competence [1]. According to the holistic competence model shown in Fig. 1 [2], it is possible to describe qualifications based on the following components [3]:

- *Qualifications* like knowledge and skills are the basis for competence.
- *Ability* allows the precise application of knowledge and skill.
- Appropriate *skills* are necessary to use knowledge efficiently and effectively. Therefore, skills support the use of knowledge.
- *Mastery* is the efficiency of accomplishing sets of tasks and problems by transferring objectives and requirements to progress and realise results.

The following assumptions substantiate the above-described competence model [4]:

- Competence is only related to accomplishing tasks. Every task might consist of several subtasks.
- Owners of competence are individuals or groups of individuals, teams or company-divisions.
- Team competence is a result of the suitable combination of subject competences. Subject competence is the competence profile of an individual. These individual competences also include parts which are only useful within a team.
- Consequently, competence is the ability to accomplish tasks by an individual, or a group of individuals by establishing an appropriate mix of the qualifications of knowledge, skill, ability, and mastery.

The correlations between competences and qualifications in the above-described holistic competence model leads to the structure of a two-step course to teach technical knowledge and to develop the student's skills as well as their competences. This course is part of the lectures.

THE STRUCTURE OF THE COURSE

In the first step of the course, lectures are offered to teach technical subjects in production design as layout planning, material flow, or quality assurance. This includes a mix of interdisciplinary

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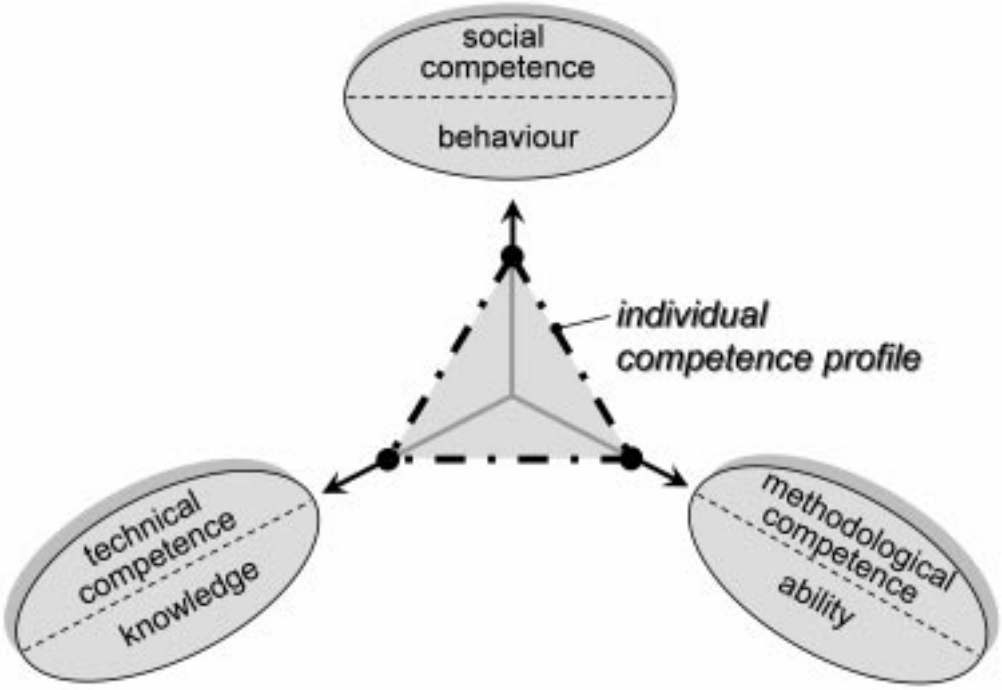

Fig. 1. Holistic competence model.

content necessary for planning a production system like logistics or project management (see Fig. 2).

The first part of the course called 'Production Design—Interaction of work structuring and logistics design' is designed to be held in dual mode lectures. The content of the course includes basic topics and specific topics of work and motivation psychology, work structuring, layout design, work control, production control, personal planning, economic evaluation, transport and warehouse systems as well as logistics systems and supply chain management. A web-based training system (WBT), a computer-based training system (CBT) and an electronic course (EC) are also integrated in the course. They are developed to support the lectures as well as to be used to learn by means of distance learning. Details of these electronic media are described later. During the lectures, also exercises are integrated held. The main target of these exercises like simulating the throughput of a factory is to teach and to deepen the technical knowledge in production design of the students. Teams with 3–4 students do the exercises and they present their solutions during the course. The exercises and the results are also published in the WBT. So, the students have the choice, whether they want to go to the conventional lectures or whether they want to learn by means of distance learning with the support of information and communication technologies (ICT).

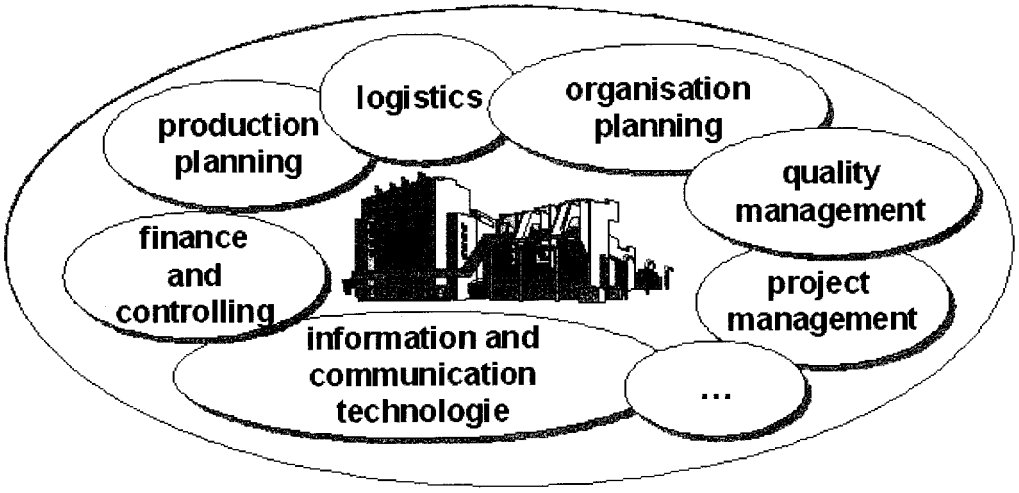

Fig. 2. Tasks for production design.

The main learning targets of the lectures are:

- technical and methodological knowledge for production design;
- skills in new communication media and methods;
- abilities in autonomous learning;
- basic skills in team-work.

With the lectures, students are prepared for the second step of the course. It is a playing game with elements of role-playing to deepen knowledge and skills learned during the lectures as well to develop competences for working in teams. The game named 'FIT2011' is a realistic simulation of a planning task based on a real factory planning project [5]. The participants have to do a rough planning of a factory under great pressure of time. Each team consists, like an internationally distributed planning team, of participants from different countries.

To accomplish the planning task, the participants have to do much cultural and social interaction and they have to cooperate within their teams.

In addition, the participants have to decide under pressure of time and with uncertainty of data and prediction. They have only four days from the beginning of the game until the final presentation. During this presentation, the team members have to present and explain their solutions to the management represented by the tutors of the game. Participants from international universities take part via the Internet.

The main learning targets of the game can be described with the following components [4]:

- ability in selecting and using technical and methodological knowledge in a real application;
- use skills under realistic conditions;
- ability of deciding under pressure of time;
- ability of team-coordination and team-organisation;
- develop skills in using ICT;
- develop social skills;
- technical and social abilities to get information;
- social competence in intercultural teamwork;
- ability of deciding in cases of uncertain conditions;
- presentation techniques and moderation skills;
- and consequently a holistic competence profile in international distributed cooperation.

The integration of lecture and playing game in a two-step course allows the students to deepen the knowledge they learned, as well as to continually

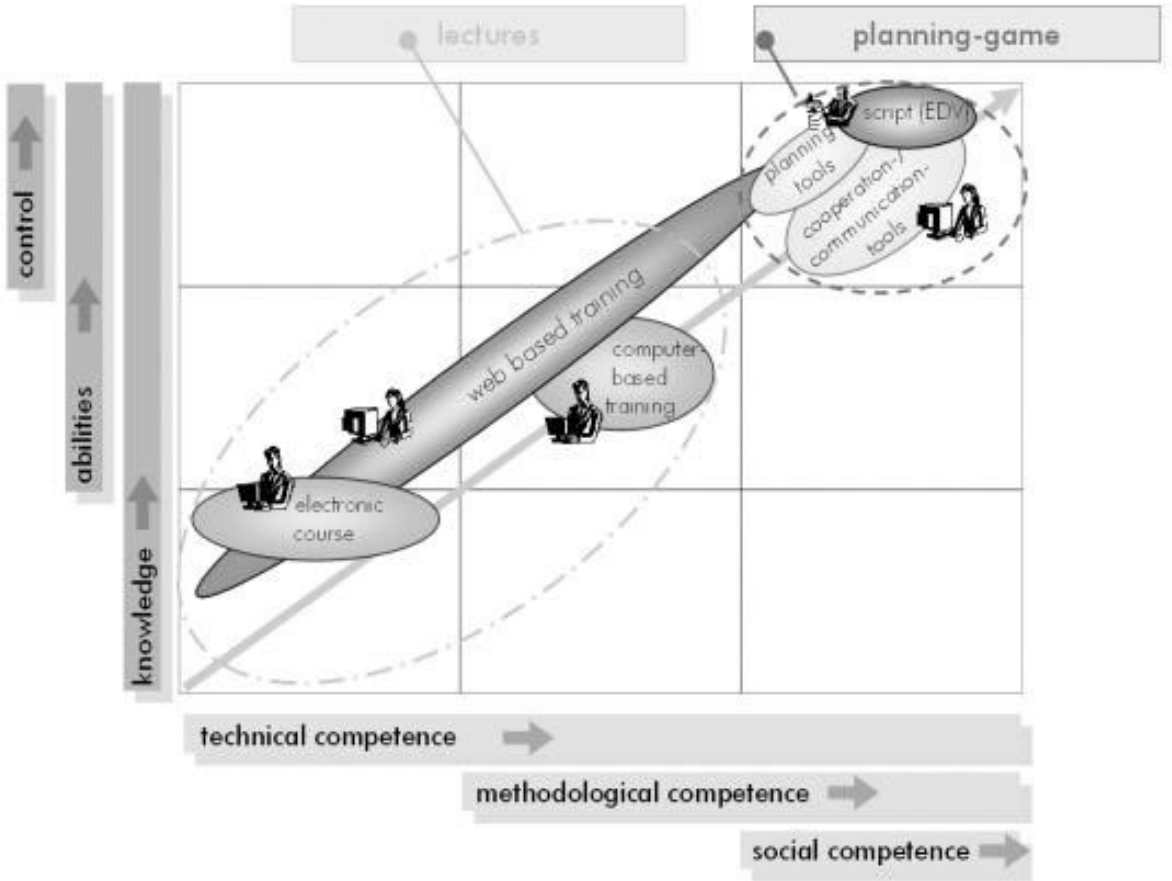

Fig. 3. Media effect matrix.

develop skills and competences. An integral element of the course is the use of certain ICT skills to learn in networks.

LEARNING IN NETWORKS WITH ICT

Within the course, different media like a computer-based training system (CBT), an electronic course (EC) and a web-based training system (WBT) are used to reach different aims (see Fig. 3).

The CBT includes exercise versions of the lectures while the EC offers identical technical content as the lectures. Both media complement the WBT, which is the core of the ICT concept within the course (see Fig. 3)

The WBT is integrated in the first step of the course to enable the students to learn the technical knowledge and to develop skills in using ICT, self-organised learning, etc.

Besides the complete technical knowledge of the lectures, the WBT contains additional information for the students in different media formats like videos. That not only increases the attractiveness of the system, but also gives the students different paths for accessing the learning content.

The content of the WBT is modular to allow the students to determine the speed of learning and the repetition of the content on their own. Functions like self-tests at the end of each content module or records of learning progress support self-organised learning. As a result, students have control over their learning progress.

The success and the acceptance of a system like the WBT also depends on the organised communication between the students and the tutors [6]. Therefore, the WBT contains tools for synchronous and asynchronous communication. Some parts of the course like the consultation hours of the tutors or exercises are held with the communication tools, so the students can participate in the course from different locations via the Internet.

The setting of the course enables also the arrangement of learning networks. The students are used to doing exercises or discussions in groups using the communication tools of the WBT.

In the second step of the course, the WBT integrated as the framework of the playing game. It simulates the intranet of the enterprise. The WBT provides all specific information and data for accomplishing the planning task as number of employees or structure of the building in the existing production system, or the transportation system in the new production system, etc.

Additional functions of the WBT enable the regulation of the access to these data and information. So, the participants have only access to the planning data depending on their specific role and their specific partial task.

Tools for synchronous and asynchronous communication ensure the connection of all participants from the different countries in each team, so they can send e-mails, discuss planning results through a chat or exchange data and information.

As a result, the WBT within the lectures is more than an additional element to teach technical knowledge. It is the key to develop abilities in self-study and skills in Internet-based communication media and methods. Within the game, the WBT enables activities of planning in internationally distributed teams with functions and tools for communication and distributed work.

CONCLUSION

The above described concept points out some characteristics for networked learning concepts. It shows that the combination of conventional lectures, distance learning, game play and role playing opens up ways to teach technical knowledge as well as to develop skills and competences needed for tasks of engineering. The integration of ICT enables new ways of international corporation has shown in the above described game. Networked education concepts help to prepare students for the tasks of engineers in a more realistic way than conventional education concepts can provide.

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