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Project-Oriented Engineering Education to Improve Key Competencies

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It is essential that engineering education meets the demands of industry, and to that end, the so-called key competencies, as well as specialised knowledge, must be taught to students. This paper describes key competencies and the effectiveness of project-oriented education to improve them. The basic requirement is a cross-discipline co-operation to teach specialised knowledge *just-in-time* and *on-the-job*.

INTRODUCTION

The origin of the approach described in this paper is a research project undertaken between 1988 and 1991 [1][2]. The project was funded by the Federal Republic of Germany, the Federal State of Baden-Württemberg and well-known industrial enterprises. Since 1991 the project has been further developed under the guidance of Fachhochschule Mannheim, the University of Applied Sciences, with the resulting development of a tool to improve key competencies and modern skills and to teach knowledge, in this instance, the classical items of engineering. This approach consists of an interactive multimedia computer program, seminars and project-oriented *learning-by-doing*. Target groups are students of engineering, computer science and business administration and employees on the job.

THE NECESSITY OF NEW TEACHING MODELS

It is no longer a secret in western economic systems that traditional tayloristic patterns of working are out of date. These have been replaced by new integrative methods (Figure 1) [3]. These include:

- Fractal factory (eg the German enterprise Mettler Toledo Albstadt, which produces weighing machines).
- Team work.
- Total quality management.
- Synchronous engineering, which is more than simultaneous or concurrent engineering; it expresses the idea of working in parallel, but also intensive interconnectivity.

Workers, employees and nowadays students, who are tomorrow's employees, have to be prepared through their education for these new integrative methods of working. The better that employees are prepared for these new concepts, the more successful they will be; and the more that technology and organisation meet the demands of man, the more sustainable new patterns of working will be.

In accordance with the former situation in most enterprises, traditional education has been tayloristic. Graduates are experts, mechanical engineers, electronic engineers and so on. Much specialised knowledge has to be stored in their brains, but the capability

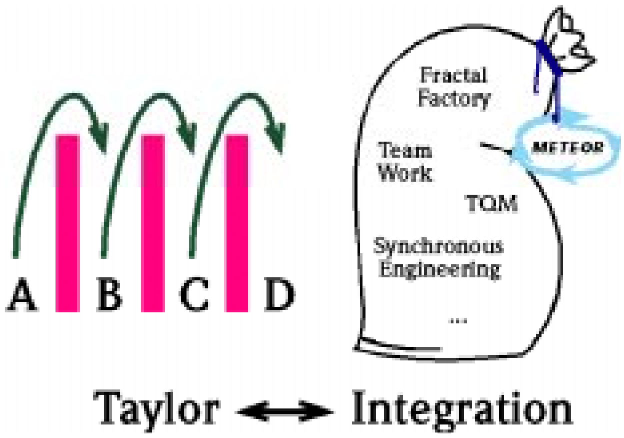

Figure 1: Taylor verses Integration.

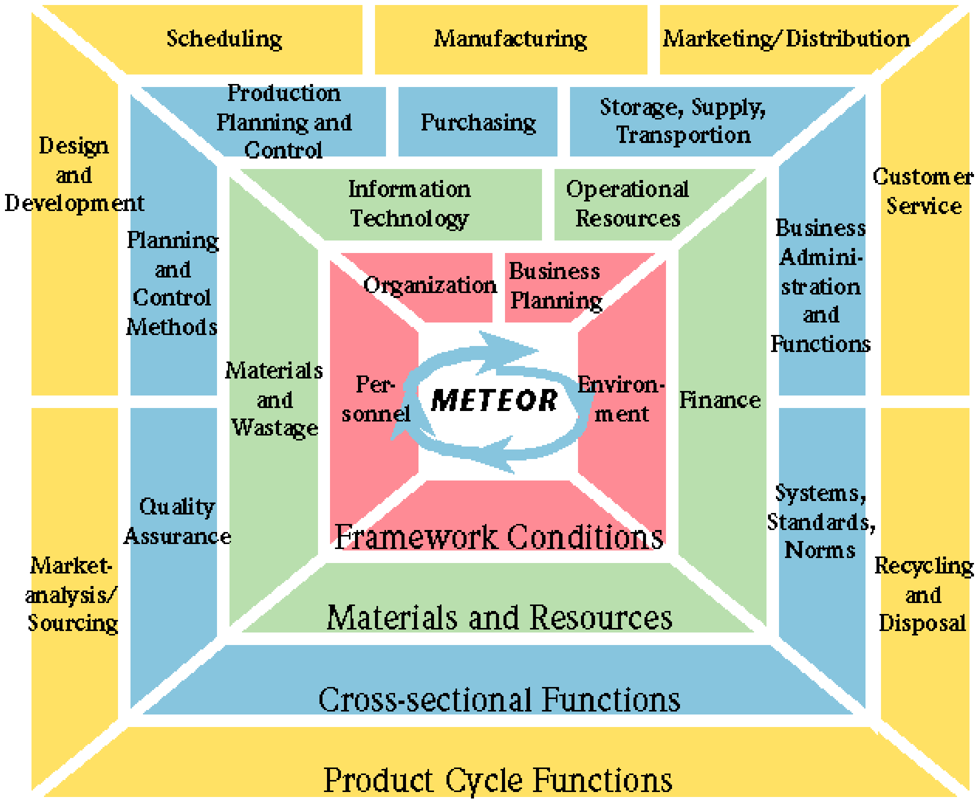

Figure 2: The general METEOR enterprise model.

to know where to get knowledge has not been taught. In contrast to this, modern education should teach necessary knowledge *just-in-time* and *on-the-job*. In a time when knowledge is growing rapidly, know-how management is much more necessary than ever.

Consequently, the approach to modern engineering education described here emphasises:

- the teaching of basic knowledge;
- training know-how management; and
- the integration of man (MEnsch, in German), technology (TEchnik)and organisation (ORganisation), hence the title *METEOR key qualification approach*.

The most efficient way to meet these three demands is project-oriented work during study. It is not necessary to say much about imparting basic knowledge, which is achieved very well by engineering education, only that upper grade students should attend more cross-discipline projects rather than too many courses where specialised knowledge is consolidated and detailed [4].

THE GENERAL METEOR ENTERPRISE MODEL

In an enterprise everyone must know the basic role of all functions. This is the first step to solving common problems and a basic requirement for the development of successful ways of working together. Since it is necessary that employees know a lot about the enterprise, every student - future employee - must know which functions in a modern enterprise have to be considered. Education is much easier if a general enterprise model is used by which the learning matter can be structured for educational purposes. To that end, a general model has been developed that applies to any enterprise in any sector of industry (Figure 2):

- *Product cycle functions* concern product development, product servicing and product disposal (*from the cradle to the grave*).
- *Cross-sectional functions*, such as *quality assurance* or *purchasing*, accompany the *product cycle*.
- *Materials and resources*, such as *materials and wastage* or *finance*, are used for the planning and realisation of a product cycle.
- *Framework conditions* (internal or external to the enterprise), such as *personnel* or *environment*, have a direct impact on all the functions mentioned.

Using this model, the complex dependencies and inter-relationships within an enterprise can be shown in a structured manner and can, thereby, be more easily understood.

KEY COMPETENCIES

Specialised knowledge, which is taught very well in traditional higher education, and acquaintance with the enterprise in which one works are not sufficient, and more skills are necessary. Students, who are tomorrows employees, also need:

- the ability to work in teams;
- communication and creative abilities;
- the ability to recognise and understand problems from different viewpoints, etc.

These so-called key competencies (or soft skills) are important and necessary for any staff member.

Systemic thinking and acting

Whenever we consider a company, we are dealing with a complex and dynamic system. Every system (enterprises, technical universities, administrations, etc) consists of many parts (so-called elements). Examined in isolation, these elements do not provide much information about the system's behaviour, which it is necessary to analyse from a holistic viewpoint because such behaviour is determined by interrelationships between the parts. Thus, the *cross-linking* of all elements has to be known. Only by recognising the linkages can one know how the system will react to stimuli.

Methodical competencies

A lot of key competencies can be described by the term *methodical competencies*. This describes the ability to utilise a *tool box*, which contains different methods, decision making and creativity for example, to solve problems. Both of these examples are basic requirements for working in teams, but beware: the method has to be adapted to the problem. One who has only learned to work with a hammer, will treat every problem like a nail.

Teamwork

In order to solve the most complex problems in modern enterprises, team work is necessary. One has to know that a *living* team is much more than the sum of specialists brought together. Only if the team members have the key competencies to work together, will they achieve a much higher level of knowledge.

Figure 3 shows how the level of team knowledge can increase by the number of team members. The upper line shows the level of team knowledge that will be the best for solving a problem. Theoretically, team knowledge will increase with every new team member, but the larger a team is, the more difficult it is to work in the team. Methodical competencies concerning team work are necessary to reach a higher level of knowledge.

Social competencies and competency of personage

It is unnecessary to explain that social competencies and competencies of personage are necessary for team work. This category describes capabilities and characteristics that determine social interaction with others, eg businesslike arguing, the intention to overcome conflicts and how to deal with them, how one thinks, which talents and preferences one has, and how one uses these talents in teams.

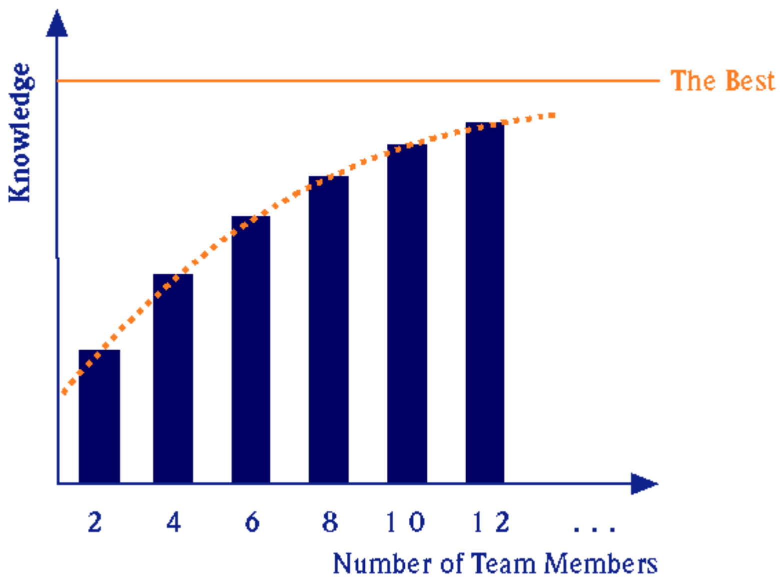

Figure 3: Team knowledge.

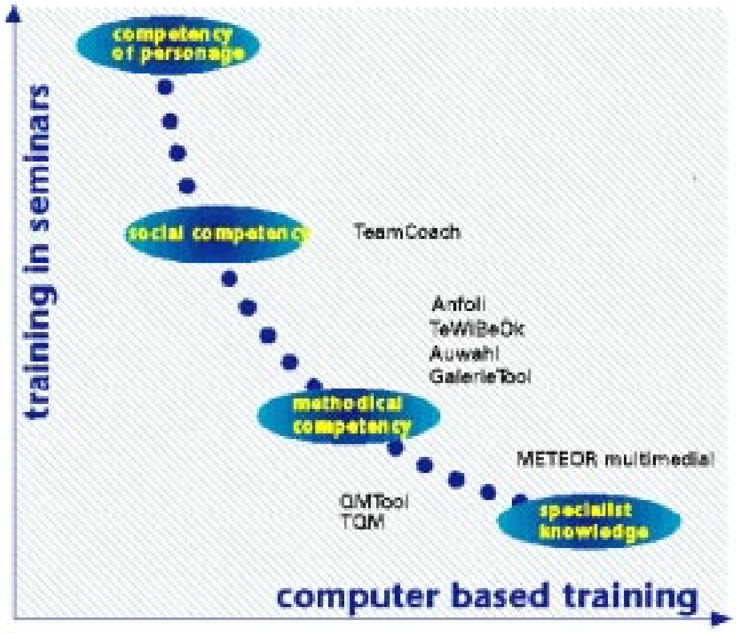

Figure 4: Computer programs used at the Fachhochschule Mannheim.

HOW TO TEACH KEY COMPETENCIES

Fachhochschule Mannheim, the University of Applied Sciences, has developed a seminar structure that integrates *computer-based training* (CBT) based on self-developed software (Figure 4).

Specialised knowledge can be taught by CBT, and the learning matter, structured by the general enterprise model, has been transferred to a multimedia learning program, *METEOR multimedia* [5]. To teach methodical competencies, however, one should use less CBT and more seminars and work on projects. Programs, developed by the University, include *Anfoli* and *Auwahl*. The theoretical knowledge relating to methodical competencies can be taught by CBT, but the abilities, teamwork skills, must be imparted through training on the job. Obviously, social competencies and competencies of personage require more seminar work and less CBT for successful improvement.

The impact of all of this on engineering education is that key competencies can be better improved, the capability of know-how management can be better trained and sustainable know-how can be taught better in projects. In an enterprise, knowledge from different departments and different people must always be combined; education occurs in the same manner (Figure 5), eg it is necessary to have know-how from mechanical engineering and perhaps business administration to solve a problem of low quality on a high cost level. Another advantage of real-life projects in education is that one will learn better to look at a task from different viewpoints.

EDUCATION AT THE UNIVERSITY OF APPLIED SCIENCES MANNHEIM

A basic requirement for successful work in any enterprise is the integration of man, technology and organisation. At the University of Applied Sciences Mannheim, students are taught to use the METEOR strategy, to apply it in all their projects in order to achieve a sustained, high result in their work.

Supported by team working methods, they answer the following three questions when approaching a project:

- *What is bad, what is wrong, what are the difficulties?*

  Followed by:

- *What is good, what is right, what are the advantages?*

  And last, but not least:

- *What is necessary to do this successfully? How should our result/solution look to be successful?*

The following are examples of project-oriented education at Fachhochschule Mannheim, the University of Applied Sciences:

- *Argus* is a scanner for environmental data, such as temperature or air humidity. It is a product that has been developed and built in a real interdisciplinary project by professors, assistant professors and students from all faculties, including the Department of Design.

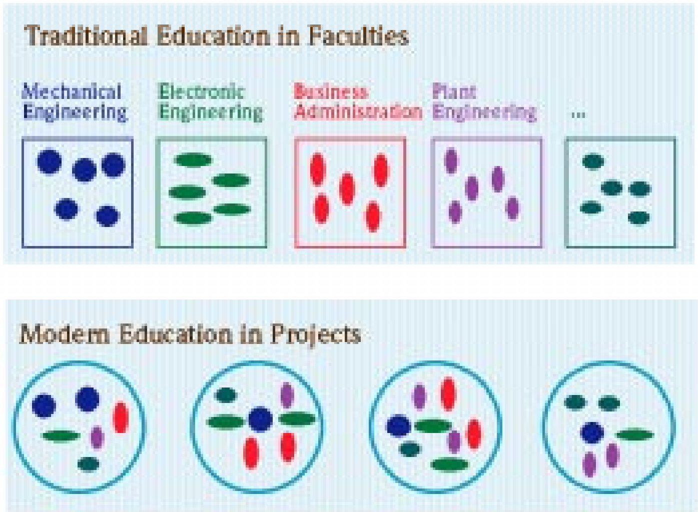

Figure 5: The impact on modern education.

- METEOR seminars last for one week and are attended by ten to twelve students from different faculties. The low number of participants allows for more attention to be given to the students and facilitates teamwork. Some elements within a METEOR seminar include:
  - rhetoric and presentation
  - how to work in teams
  - creativity techniques
  - methods concerning team work
  - games, role plays and so on
- UPM is the abbreviation for *Umweltorientiertes Projektmanagement*, which means project management concerning environmental protection. The work of the students is presented at the end of each term at local exhibitions, for example. A UPM examination about the impact of a planned new road on the environment was presented to the city council of the community in which the road is planned.

CONCLUSIONS

This paper should be completed with an Indian metaphor to show why holistic viewpoints are necessary (Figure 5) [6].

Every *expert* touches the reality with closed eyes: perhaps a mechanical engineer touches a withered leaf. The next one feels a hill; maybe that is the computer scientist. The person who says, that is a twig, is an electronic engineer and so on. Someone even believes they have found a snake. The reality is an elephant, which could only be recognised from a holistic viewpoint.

So why should not experts from all over the world work together to solve worldwide problems? In reference to this metaphor, the purpose of education is to impart the relevant abilities to overcome common difficulties. A holistic viewpoint and key competencies are more necessary than ever.

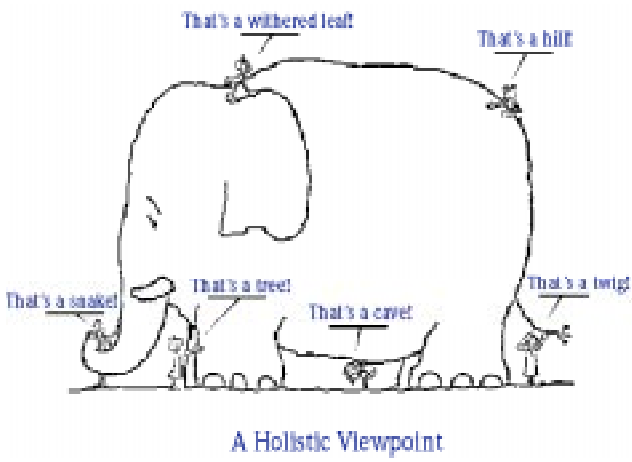

Figure 6: An Indian metaphor.

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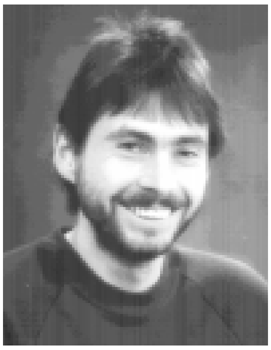
BIOGRAPHIES

Professor Dr-Ing Klaus-Jürgen Peschges studied mechanical engineering in Friedberg and Darmstadt, and subsequently worked for Carl Freudenberg Weinheim in the area of new manufacturing technologies. In 1981 he was appointed Professor at Fachhochschule Mannheim, the University of Applied Sciences, and Head of the Institute for Construction and CAD (Computer-Aided Design). Since 1992 he has been Head of the METEOR Centre for the Improvement of Key Competencies.

He was Head of a Computer Integrated Manufacturing (CIM) research project (1988-1991); Chairman of the Mannheim University of Applied Sciences CIM working group; member of the CIM working group of the Ministry for Science and Research Baden-Württemberg; member of the University of Applied Sciences Baden-Württemberg working groups: *Multimedia, Sustainable Energy-Supply* and *Key Competencies*. He is the author of many national and international publications and lectures, and winner of the 1979 Worthington-Award for his thesis. Since 1981 he has been a consultant to Freudenberg in the area of *central research and development for new technologies and process control in production*. He is working on rapid prototyping and rapid tooling, alternative energy-supply projects, projects on public local traffic and key competencies.



Dipl-Wirtsch-Ing Erich Reindel studied Mechanical Engineering and Business Studies at the University of Kaiserslautern, and is an assistant at the Mannheim University of Applied Sciences METEOR Centre for the Improvement of Key Competencies. His subjects are cross-discipline project-oriented work with students and implementation of the systemic approach of Frederic Vester into engineering education. He is a member of the Universities of Applied Sciences Baden-Württemberg *Key Competencies* working group, and lecturer at the Fachhochschule Ludwigshafen in the subjects of Environmental Analysis and Technology Management.