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How to Structure and Mark Project-Oriented Studies

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Increasingly, it is necessary for engineers to be entrepreneurs as well as specialists. Project-oriented studies, which teach basic knowledge and soft skills, are an appropriate way to prepare students to meet this new demand. Teaching staff also face new demands in conducting projects with students because the trend within the student group and the results cannot be predicted precisely. Moreover, problems of teamwork, social aspects and the personalities of students have to be considered and suitable methods have to be used. A structure for project-oriented work has been developed at the Fachhochschule Mannheim - University of Applied Sciences. Projects are handled in seven steps, beginning with the analysis of a problem and ending with the presentation of results. Students' work is marked through a combination of teaching staff assessment and student self-assessment using criteria concerning the contribution and behaviour of every project group member.

HISTORY

The approach taken by the Fachhochschule Mannheim - University of Applied Sciences to project-oriented engineering education is based on a research project undertaken between 1988 and 1991 [1][2]. The project was funded by the Federal Republic of Germany, its Federal State Baden-Württemberg and well-known industrial enterprises, and had the objective of helping to improve higher education to prepare students to meet the demands of modern enterprises. Since 1991 the project's results have been used by the Mannheim University of Applied Sciences to develop the so-called METEOR approach; the idea behind this approach is that the better the integration of man (MEnsch, in German), technology (TEchnik) and organisation (ORganisation), the better the working results will be. The last decades have shown that human resources could be the most profitable for any enterprise if they are used wisely. This can only occur if *technology* and *organisation* meet the demands of *man*. To stress this the term METEOR has been adopted at the Mannheim University of Applied Sciences [3]. The aim is to teach the classic items of engineering and to improve students' acquisition of *modern* skills, the so-called key competencies, through project-based *learning by doing* in addition to the classic lectures and the use of information technology. This approach consists of an interactive multimedia computer program, seminars and project work.

NECESSITY AND ADVANTAGES OF PROJECT-BASED LEARNING

Workers, employees and students have to be prepared for the demands of today's industry. This does not only mean that they must know about new technologies, they must also possess the so-called soft skills. This is a consequence of the changes in technology and industry during the last decades.

The increasing speed of technological development has created a situation in which it is necessary for education to impart knowledge and the skill to solve problems today and in the future. Factual knowledge changes so quickly that a specialist today will not be a specialist tomorrow if they have not learned how to cope with this new situation. The better an employee is prepared for this, the more successful they and the enterprise they work for will be. Therefore modern engineering education has to deal with:

- teaching the basic and expert knowledge of technical disciplines (eg mechanical engineering);
- teaching basic knowledge of other non-technical

disciplines; that is, the engineer of today must have basic knowledge of disciplines such as business administration, management and law;

- training know-how management, the capability to learn (*life-long learning*); and
- improvement of the so-called key competencies, which are summarised as methodical and social competencies and the competency of personage. These competencies are very important because in industry everyone has to work in teams and projects.

To avoid any misunderstanding, it is necessary to stress that although little has been mentioned about teaching basic knowledge, such knowledge is central to engineering education; it is not to be replaced but extended by further skills. The key issue is that traditional education is insufficient for today's environment. The old mode of education produces experts: mechanical engineers, electronic engineers, process engineers or business administrators, etc. Much specialised knowledge must be stored in their brains, but knowledge management is not taught, even though it is much more necessary than ever.

Project work on actual problems and internships is a very efficient way to prepare students for industry. But it has to be stressed that the project groups should consist of students as well as teaching staff from different faculties to reflect the situation in modern enterprises. The difference between traditional and interdisciplinary education in projects is shown in Figure 1. Upper grade students should attend more cross-discipline projects instead of too many courses where primarily specialised knowledge is consolidated and detailed [4].

Project studies have the following advantages:

- Learning by doing (*on-the-job*).
- Practice in working closely together with professors and other students from different disciplines. This is a necessary requirement to improve a number of key competencies.
- High motivation because students know that all they do during their work is necessary for the result of the projects. They may strongly identify themselves with their task.
- During the project work students are forced to learn new things from other disciplines, thus training their capability to learn.
- Learning just in time: students do not have to store a lot of knowledge in their brains, but rather learn where to get knowledge from when they need it. This leads to the ability of knowledge management. Relevant information has to be separated from ballast. *Sources* of knowledge (other students, professors, books, internet, etc) have to be identified and used.
- Students can use their fortes during project work.
- Working on projects, especially those with direct industry participation, means working very closely with actual problems and modern technology.

All these items lead to a sustainable way of learning.

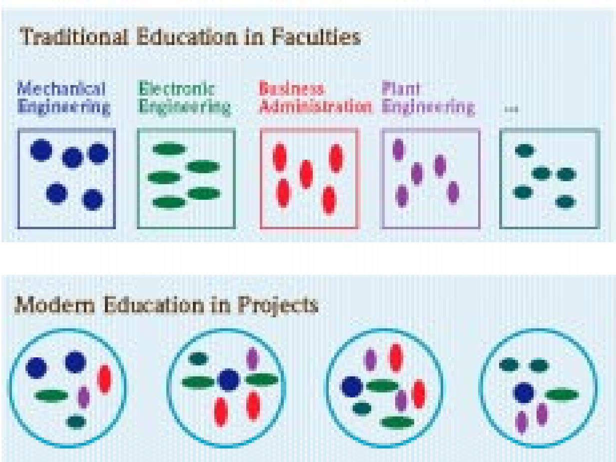

Figure 1: Interdisciplinary education in projects.

PROBLEMS OF PROJECT-BASED LEARNING

There are several problems in this new approach that are unknown in the traditional mode of education:

- The teaching staff is faced with a totally new situation. They have to accept that factual knowledge is only a part of competencies for the future. Teaching in the traditional *classroom style* allows one to hide behind prepared exercises. In project work the professor has to be as flexible as the students. One has to realise that social competencies and competencies of personage, of students and teaching staff, have a huge impact on the project and its results.
- Another problem of project-oriented work is its complexity: what has to be considered? The *METEOR General Enterprise Model*, which has been developed in the previously mentioned research project, can be used for this (see below) [1].
- The scheduling of the project to get a successful result: where and how to start and which steps must be considered to complete the project. Based on the authors' experiences, seven steps of project management have been pointed out to allow structured work within a project (see below).
- The professor has to conduct a project group. Therefore he has to be able to use a variety of

methods for different situations during the project, eg creativity techniques, decision techniques or several instruments of project control and management.

- In accordance with most study and examination regulations, teamwork in projects has to be marked individually, but referring to the contribution of every group member.

THE STRUCTURING OF PROJECTS

The *METEOR General Enterprise Model* can be used to structure project contents. Originally this model was developed by taking into account all tasks and functions within an enterprise in order to structure the learning matter, especially for interdisciplinary education. However, experience has shown that a single model is sufficient to apply to all projects because all the tasks that an enterprise has to fulfil to manufacture and sell products or to perform services are the same for each project.

The *METEOR General Enterprise Model* 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* accompany the *product cycle*, such as *quality assurance* or *purchasing*.
- *Materials and resources* used for the planning and realisation of a product cycle, such as *materials and wastage* or *finance*.
- *Framework conditions* (internal or external to the enterprise), such as *personnel* or *environment*, which have direct impact on all the mentioned functions.

Through this model the complex dependencies and interrelationships within every project can be shown in a structured manner.

Every project needs a schedule by which the work can be temporally structured. There is a lot of literature available concerning project management and a lot of computer-based tools can be used for project management objectives. But, on the whole, these books and tools are as complex as the project itself and require special lectures to teach students how to use them. Although the use of such complex tools makes sense in large projects, time restrictions forced the authors to develop a scheme by which students can see very quickly what it is they have to do. The seven steps of project management are introduced to the students through a game. This is a further development of a similar game that the authors got to know in a different context at Freudenberg.

These seven simple, but sufficient steps, which are the essence of every project management, have been developed at the Mannheim University of Applied Sciences to structure projects successfully:

1. Problem description and analysis: describing and analysing the problem/task.
2. Development of the approach to how to solve the problem.
3. Dispensation of the tasks: delegation of the various tasks among the members of the project group.
4. Working synchronously: means working on the solution simultaneously but interconnected intensively.
5. Combination of the results: the contributions/results of the project group members have to be combined.
6. Presentation of the results.
7. Implementation of the results.

The last step is mentioned because the project results should be implemented. One example can be given: UPM, which is the German abbreviation for *Environmental Project Management*. The work of the students is presented at the end of each term in local exhibitions or elsewhere. For example, one UPM examination about the impact of a planned new road on the environment was presented to the town council of the community in which the road was to be built.

These seven steps of project management seem to be very easy, but the traps are hidden in the detail. Everyone should be aware that changes due to new information are possible at any time. These steps can not be compared to a schedule where, for example, phase four follows phase three.

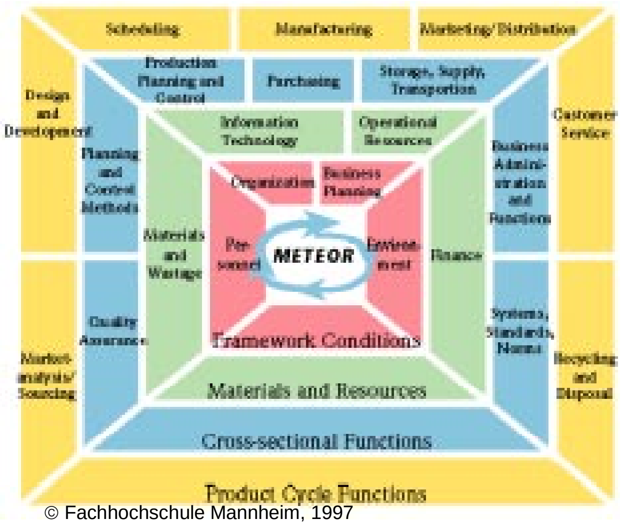

Figure 2: Tasks within every project which have to be considered, shown by the METEOR General Enterprise Model.

A SURVEY OF THE METHODS

The authors' experience in recent years has shown that there are methods which can and should be used in every project. Originally those methods were well-known among people involved in industrial projects. Nevertheless, most of the methods have been improved during ten years of project-oriented work at the University of Applied Sciences Mannheim to meet the demands of the students and teaching staff. Figure 3 presents a survey of preferred methods according to each of the seven project phases [4].

In the following the methods mentioned in Figure 3 are briefly described:

- *Team idea gallery*: a paper-based creativity-technique to elicit new ideas from participants.
- *Team decision*: a procedure which avoids winner-looser situations and leads to a winner-winner situation.
- *Systemic thinking*: a holistic approach to describing a system.
- *Project management*: structuring a task according to the seven steps mentioned above. Additional use of a process chart on a pin board with four sections (*future*, *to do*, *in work* and *done*) and cards (with the items *what?, who?* and *when?*) to be placed in the different sections.
- *METEOR-strategy*: an efficient strategy to solve problems.
- *Team organisation*: structuring work in a very efficient way.
- *Team idea gyroscope*: a paper-based creativity-technique to get new and detailed ideas from the participants.

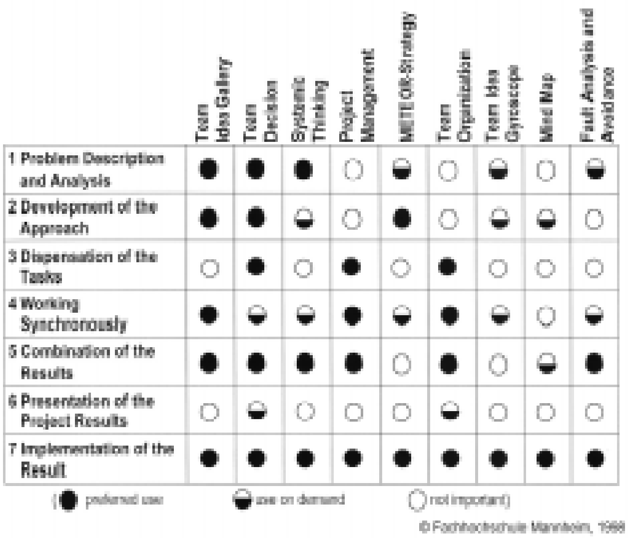

Figure 3: Methods in a project.

- *Mind map*: a graph to show different aspects of a question.
- *Fault analysis and avoidance*: strategies are developed to avoid faults based on the question of why a concept or a product may not work.

HOW TO MARK PROJECT-ORIENTED WORK

Study and examination regulations generally demand that each student has to be individually assessed according to his contribution to project work. At the University of Applied Sciences Mannheim the mark of each student consists of three components with different weighting:

- The project result is marked by the professor. This is the base for every student's mark (more than 80%).
- The student's method of working is marked by the teaching staff in accordance with the impression that the student made during the project. This is a small part of the mark (less than 20%).
- Nobody can estimate the contribution of a student better than the students themselves because they worked together intensively for several months. At the end of every project the students are asked to estimate each other. The result may change the mark in the range of one to three tenths to a better one (1.0 is the best mark one can get; 5.0 is the worst).

How students estimate each other

To get successful results, team-oriented project work has to distinguish the contributions of the students. To equalise the achievements would kill a lot of commitment. Therefore students are informed at the beginning of the project how their mark will be calculated. Through several attempts, a scheme has been developed which is accepted by the students. According to several criteria (shown in Table 1 with their weighting) they are asked to estimate their fellow students in comparison to themselves.

The students are given the questionnaire shown in Figure 4. There are only three possibilities for an answer: *as good as me*, *better than me* or *much better than me*. Students are not asked who was worse than others because it is intended that they will learn to commend (people usually prefer to tell others what they disapprove of, but if fortes of students are commended by others, it may be a base for strengthening them in the future). Qualities that are not commended may be clues for necessary improvement.

Table 1: Criteria and weighting by which the students estimate each other.

No	Criteria	Weighting
1	knowledge, know-how	20%
2	creativity, new ideas	20%
3	helpful	15%
4	consensus oriented	12.5%
5	reliable	10%
6	tolerant	10%
7	communicative	7.5%
8	on time, duly	5%
		100%

Moreover, experience shows that students do not like to criticise the behaviour of others.

Those criteria and the weightings are the result of several sessions where different student groups were asked *which criteria are important for successful team work?* The methods which were used are *team idea gallery* and *team decision* (see Figure 3).

CONCLUSION

The results of project-oriented engineering education are that key competencies can be more easily improved; the capability of know-how management can be better trained; and sustainable knowledge can be more intensely taught in projects because in an enterprise knowledge from different departments and different people has to be combined always and everywhere.

Project-oriented work can be structured very well by using the *METEOR General Enterprise Model* and the seven steps of project management. During the last years the scheme for marking project work has been developed with participation of the students. Because the students have to estimate each other, only a scheme can be used which is accepted by both students and teaching staff.

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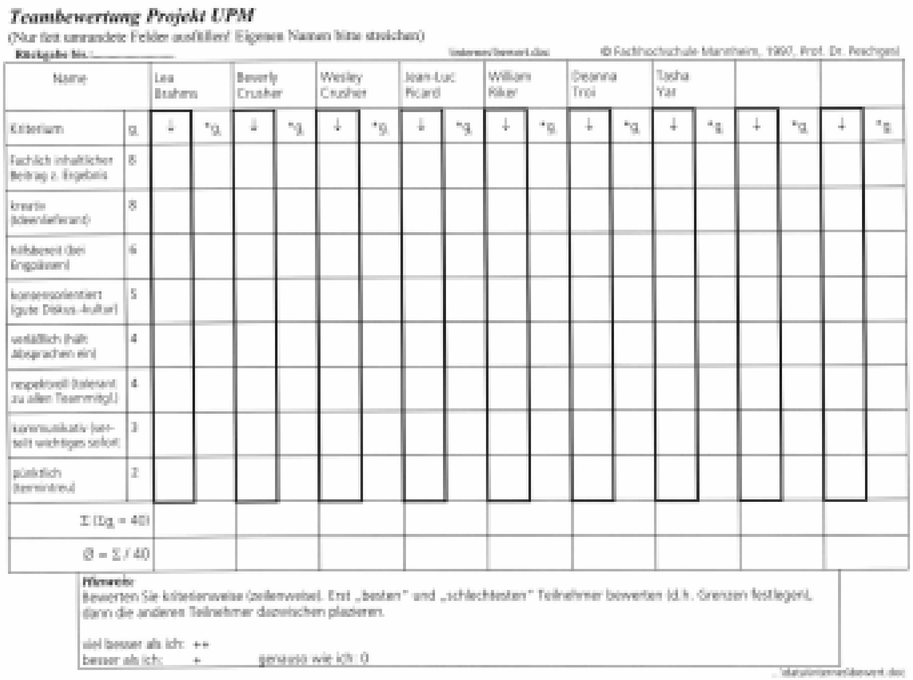
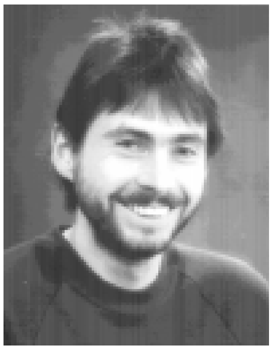


Figure 4: Questionnaire.

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.



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