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The Reformation of Technical Education through Project-Orientated Education (TheoPrax®)

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A network of schools, universities and engineering schools has been built together with the industry for the higher practical orientation of technical education. Within the network, industrial problems of a low priority, a time schedule of less than six months and with a financial volume of between 500 and 5000 Euro, are solved by interdisciplinary and interfaculty groups of pupils and/or students. To involve project-orientated teaching at the universities, frontal lectures have been reformed to team-orientated group work exercises. Students and industrial partners are very satisfied with the project-orientated learning and with the results of the project groups. However, after establishing the network, there is a need for the further education of teachers at schools and universities concerning project work and project management. New projects in this field are in preparation or have already started. This paper presents the TheoPrax-network, as well as the first results and experiences with project-orientated education. The authors demonstrate the importance of project work as an element of the learning organisation, as well as how project work can form the basis for life long learning.

INTRODUCTION

The strength of engineering education in Germany undoubtedly lies in the depth and range of fundamental knowledge the students learn during study. But practicing abilities like taking initiative, taking risks, creativity, communication and conflict management, and especially teamwork, are not trained. Although these are the abilities which are necessary for the job in industrial life, our students are more likely to be educated to work alone; they *know everything, but they can do nothing.* As a consequence, most students encounter a huge practical shock on entering the workforce.

However, there is a further problem in German engineering education. For centuries, teachers at schools and universities have imparted knowledge primarily by means of lectures to the pupils and students mostly without making any connection to the passive audience.

How can this unsatisfactory situation be reformed? Neef and Hamann give some answers to this question [1]. The central answer is: project work. From this has sprung TheoPrax, which focuses on the reformation of technical education through a stronger interlinking of schools and universities with the industry. This can be achieved through the integration of project work in education, particularly in the field of engineering.

The stated goal of TheoPrax is that the pupils and students work together on industrial problems as part of an interdisciplinary group. The name TheoPrax is derived from the combination of Theory and Practice and this is exactly the aim of TheoPrax: the combination

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of learned theoretical know-how with the training of abilities by using the knowledge in project work solving industrial problems [2].

THEOPRAX: THE CONCEPT

For a better practical orientation of education and for the training of abilities, industrial problems are solved by student teams during their current education. This ensures that the basic theory that has already been taught is put into practice. The project work should therefore be integrated into the normal education at the university or the school. Otherwise the project work is an additional work for the students, and they already have enough to learn.

However, as changing curricula can be very difficult and needs a long time, it should also be possible for student teams to work on an industrial project as an *add-on* to their normal education. Be that as it may, the decision to work out an industrial problem with the students or pupils is only made by the teachers at the universities or schools.

The industrial problems must fit the following conditions:

- The problems should be of lower priority and should not be day-to-day problems of the company.
- The time needed to complete the project work should be in the range of three to five months.
- The project costs should have a volume between 500 and 5000 Euro.

In many cases, the problems will have a very high need for creativity and they should go together well with the actual standard of education of the students and/or pupils. The company must be open for creative and innovative solutions, because in many cases the students present solutions far beyond the normal thinking in the companies. If possible, the problems should be solved by more than one independent group to offer multiple solutions to the industry [3].

How Does TheoPrax Work?

During the last months, a network has been built consisting of the TheoPrax centre at the Fraunhofer Institute for Chemical Technology in Pfinztal, Germany, and different TheoPrax communication centres located all over Germany.

First of all, the company gives the problem to the TheoPrax centre or communication centre. Together with the company and competent institutes at universities or with teachers at schools, the problem is analysed and put in concrete terms in order to bring together the didactical needs, actual knowhow of the students and expectations of the industry.

When the teacher or the institute decides to work at the problem with student groups, either during normal course of education or as an additional project, the second step is the making of a written offer to the company, including a detailed project plan. This plan includes at minimum the exact aims of the project and the definition of the work that will be done by the project team.

The plan also defines the project time schedule and the project costs, which for example pay for professional project management by retired project managers from the industry or by highly educated women during or at the end of maternity leave. It is also possible to pay students further in degree, so called tutors, to lead project groups of younger students and/or pupils. Thus the need to work at subject unrelated jobs falls away; students can earn money with their knowledge and train their skills at the same time.

Project work of the teams starts with the written order of the company on the basis of the project plan. During the course of project work, pupils and students encounter the reality of a working environment. Through real-life contracts the students come to grips the serious side of the contract, which in turn helps to strengthen the project work. In simulated projects, which have no real contract, this would not be possible. Here, pupils and students exercise skills that are necessary for future career choices. They acquire self-motivation and personal responsibility skills that are acquired over and above the normal curriculum on offer. Career decisions are improved by this hands-on practical experience gained from a real job. TheoPrax centre or TheoPrax communication centre assists all communications between the university or school and the company.

At the end of the project, the project team has to write a report and there is a final presentation at the company. Figure 1 shows the communications in the TheoPrax network.

PROJECT-ORIENTATED EDUCATION

First experiences with the project work at universities and schools revealed satisfying project results for the industry. Additionally, a very high interest from the industry to work together with schools and universities was observed. There are enough real problems from industry suitable for grammar schools and students of the first semesters. Experience also demonstrated the need for an intermediate didactical process.

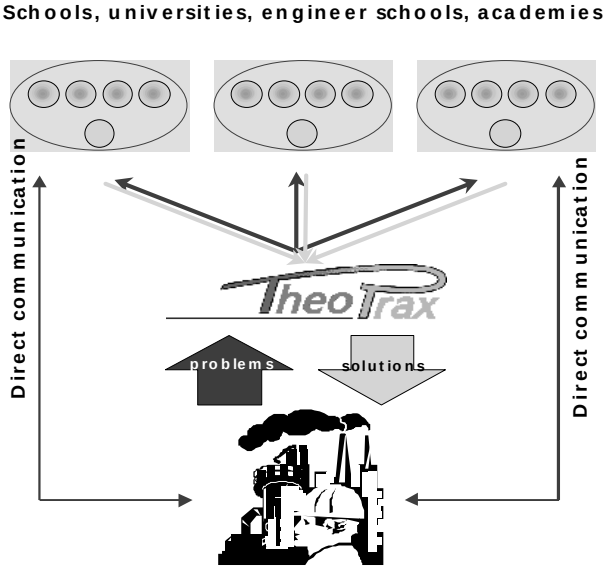

Figure 1: Communications in the TheoPrax network.

The change from lectures to teamwork within an industrial project is currently too great. Because project work is not integrated into the timetables of education at the moment, the students have to do a lot of additional work.

As such, the first author decided to change his lectures in the subject choice of polymer technology [4]. As a first step, an industrial problem was divided into smaller parts and the students had to solve these problems during a lecture of 90 minutes in groups of four to five. Students were assisted by the professor and his assistants. The students found solutions with an astonishing high quality. As it stands, this observation could be made in nearly all TheoPrax projects. Motivated by the general approval of the students, the lecturer integrated more and more project-orientated exercises, until finally 50% of the lecture time is done as project-oriented group work, solving TheoPrax problems from the industry.

The students were very satisfied with this form of education. Figure 2 demonstrates the results of a survey on this matter.

Furthermore, the number of students increased from 35 students during the winter semester of 1996 to 85 students two years later. This demonstrates the interest of the students in project work during study.

THEOPRAX: THE NETWORK

The TheoPrax network began with the TheoPrax centre at the Fraunhofer Institute for Chemical Technology in the summer of 1997. Since then, eight TheoPrax communication centres have been founded in Stuttgart, Saarbrücken, Aachen, Oberhausen, Berlin, Freising Ellwangen and Golm.

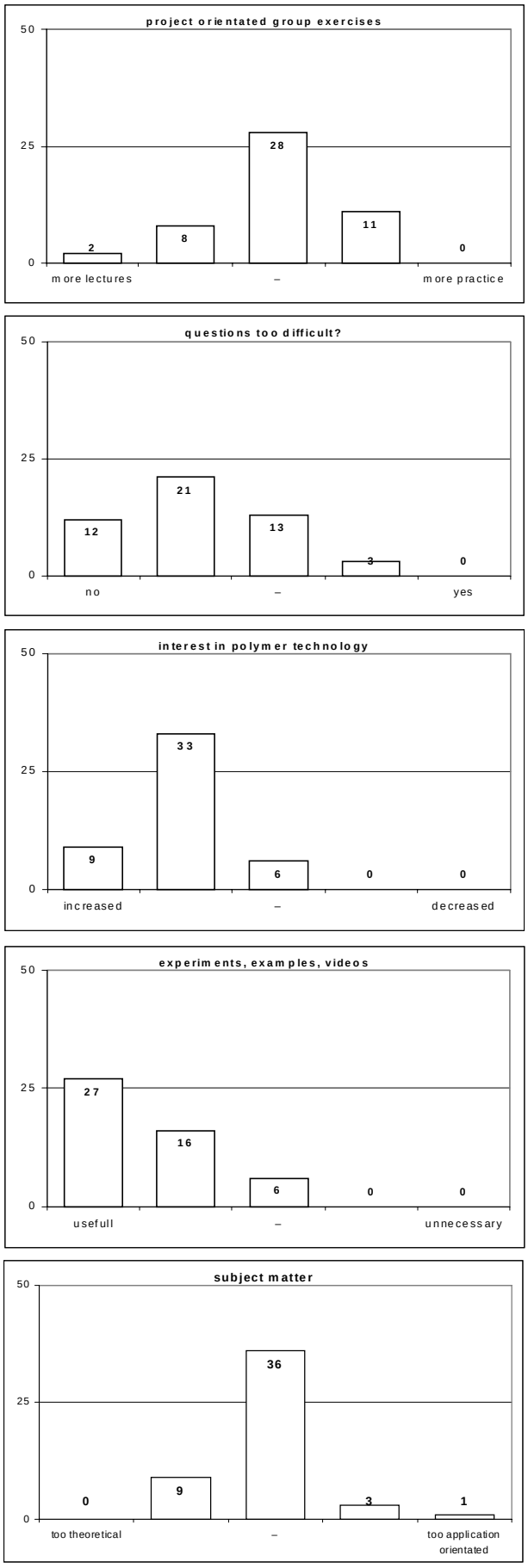

Figure 2: Evaluation by students in the subject choice of polymer technology.

The TheoPrax centre and the communication centres are responsible for the communication between universities, schools and the industrial partners in their region. They are also responsible for the acquisition of new partners and projects from the industry as well as for the acquisition of new partners at schools and universities. The TheoPrax institutions support the project teams and take care of the quality management within TheoPrax.

Along with the TheoPrax communication centres, more than 40 professors from four universities and nine Fraunhofer institutes, 14 professors from five engineering schools and 29 schools are members in the TheoPrax network. About 50 companies from global firms to small companies are partners in the network and their number continues to grow. Figures 3 and 4 illustrate the branches and competence in the network. It is the aim of TheoPrax to match competence and branches in the network by expanding the network to new disciplines and branches.

EXPERIENCES IN THEOPRAX

More than 110 industrial problems are available in the network. Thirty of these projects are already finished, with 33 in progress. Table 1 gives detailed information about the actual numbers and the distribution of the projects to schools and universities.

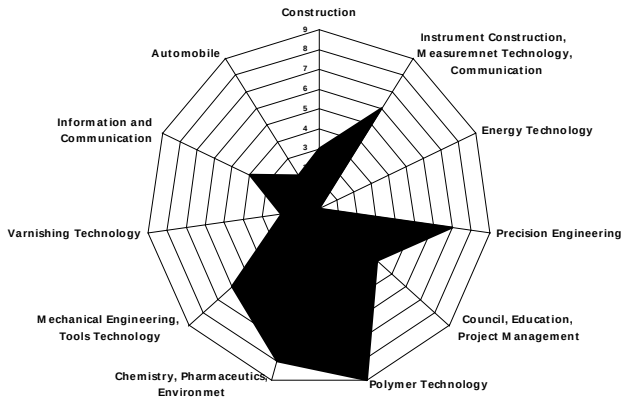

Figure 3: Branches in the TheoPrax network.

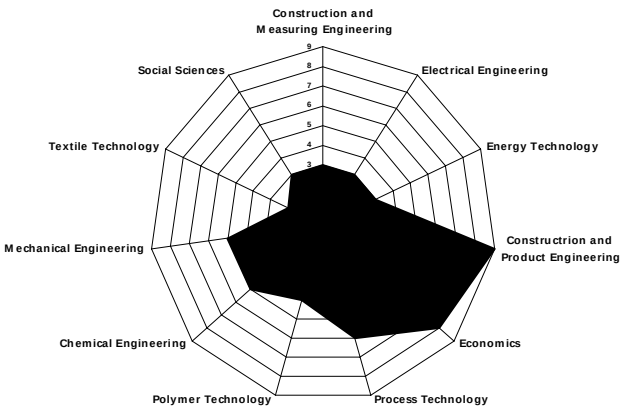

Figure 4: Competence in the TheoPrax network.

The main problem in finding a team of students and/or pupils that wants to work on the project is often the modest definition of the projects by the industrial partners. In most cases, the problem is defined only by a few sentences. The students do not recognise the chance to define the project work on the problem by themselves in close communication with the industry. Over and above that, the pupils and students have problems with the formulation of the project plan. They need help for the calculation of the time schedule and the project costs. Of course, the responsible TheoPrax institution offers this help.

Further, the present experience in TheoPrax shows the need for education of the teachers at schools and universities in the field of project management, particularly team management and conflict management. The teachers are in a new teaching situation. The methods have to change from classical teaching methods to project-orientated exercises. Therefore, projects for teaching the teachers are in preparation.

One example of such a project is a one-week seminar for young teachers. After an introduction into project management by a professional project manager, a short project work of one day on a fictive problem has been done by the groups. The last three days of the seminar the young teachers worked in project groups of three to four people on a real-life problem given and financed by a company from the TheoPrax network. A professional team manager has coached the project groups. The evaluation showed that the students have been very satisfied with the seminar. The company will try to realise the three solutions from the three project teams.

Although all project teams did the project work with great engagement and enthusiasm and the results are normally satisfying for the industry, students and teachers complain about the high amount of time that is necessary for the project work. This demonstrates the need for better integration of the project work in the timetables of education in universities and schools.

First steps in this direction involve the integration of TheoPrax project work in the seminar course at the high schools in Baden-Württemberg, as well as

Table 1: Project statistics in TheoPrax.

	Projects finished	Projects in progress	Projects not started
Schools	16	7	54
Universities	27	7	
Total	43	14	54

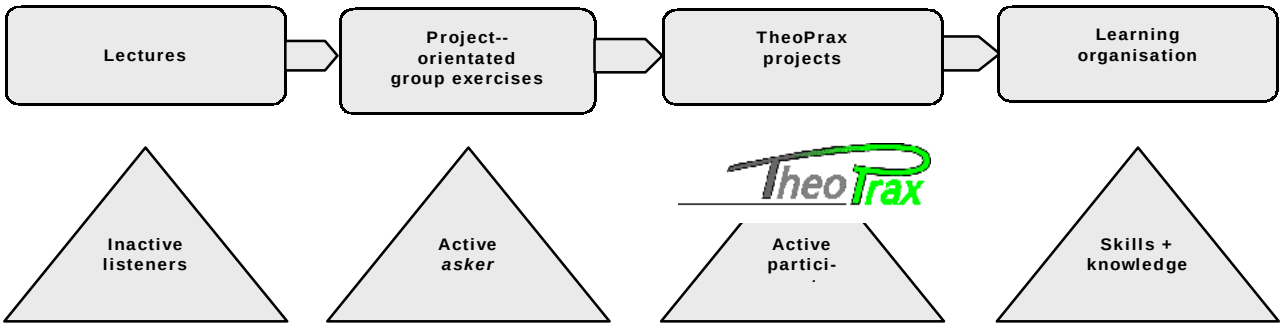

Figure 5: From passive listeners to the learning organisation.

the integration into the teachers' education in Germany. Additionally, the change from lectures to project-orientated group exercises as described above is a good way to integrate project work in the normal course of education.

ON THE WAY TO A LEARNING ORGANISATION

Project-orientated education, not just in the field of engineering education; it is the first step on the path to becoming a learning organisation. Figure 5 demonstrates how the behaviour of the students, and the interaction between them and the teacher during education, changes from inactive listeners in lectures to active askers in project-orientated group exercises.

With the next step of implementing TheoPrax projects into the education, both teachers and students are active participants – a main step on the way to a learning organisation.

According to P.M. Senge, a team is the nucleus of a learning organisation – a group of people developing the capacity to obtain exactly the results they want to have [5]. In order to become a learning organisation, it is first necessary to overcome the following learning hindrances:

- Egocentric: the daily routine in the individual (small) personal sphere blocks the view to a larger field of activities.
- Error analysis: most people tend to search for guilt everywhere but themselves, even though they are a part of the same system as others.
- Actionism: action is determined by emotions, but rational thinking recognises personal contribution to a solution.
- Modernity: action is shaped by a short lifespan, and slowly creeping processes are not recognised.
- Short-term memory: people learn most from short-term experiences, but do not examine these effects on important decisions.
- Lack of self-confidence: people are ashamed by the admission of incompetence.

In many cases, these learning hindrances are typical for strongly hierarchical organisations and it is a yearlong process of change to overcome such hindrances.

In the authors' opinion, project work and therefore project-orientated education is an excellent basis to overcame the learning hindrances. Most important in this field are not the direct project results – although in most cases they are very good, there will be failures - but the connection between industry, pupils, students, professors and teachers reached by project-orientated education and the working on TheoPrax projects. By this connection a mutual awareness is formed and mutual changes of thinking and behaviour may be initiated.

Figure 6 demonstrates the significance of project-orientated education in the formation of learning organisations and the subsequent influence on all humankind. This leads to greater community spirit,

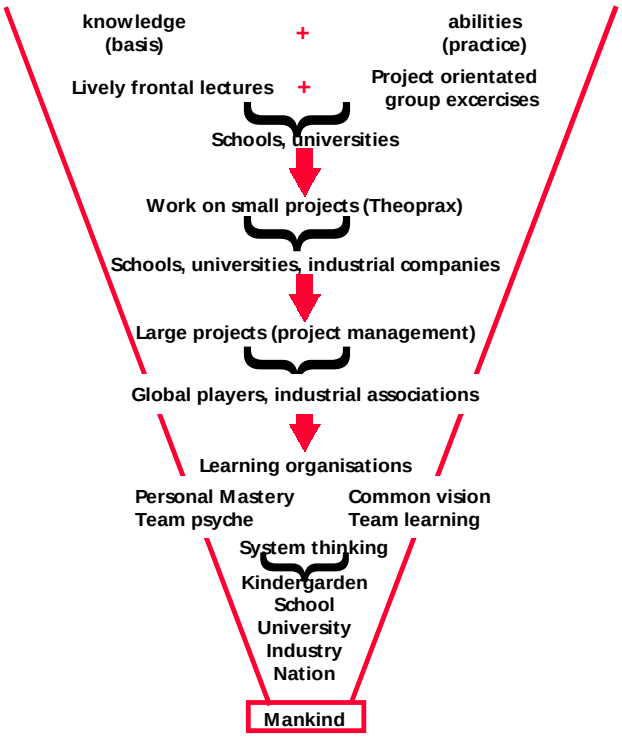

Figure 6: Project work as the basis for life long learning.

more self-motivation, increased motivation of others and finally improved quality of life.

SUMMARY AND CONCLUSION

The practical orientation and necessary training of abilities can be integrated into the education at schools and universities by project work on industrial problems of a lower priority. A network of industrial partners, schools and universities has been built to bring education and industry closer together. Students and pupils are very interested in project work and the results have been to everyone's satisfaction. Changes in teaching methods from lectures to project work are necessary, but there is a need for the further education of the teachers themselves.

Furthermore, project work during education is the first step to overcoming the learning hindrances on the way to becoming a learning organisation.

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BIOGRAPHIES

Peter Eyerer is the Director of the Institute for Polymer Testing and Polymer Science (IKP) at the University of Stuttgart since 1979. During a sabbatical leave from 1985 to 1988, he was the departmental leader of engineering and member of the management board at Pebra Paul Braun GmbH, in order to push ahead the development of painted car body parts made from polyurethane. In addition, since 1994, Peter Eyerer has been the Head of the Fraunhofer Institute for Chemical Technology in Pfinztal near Karlsruhe, Germany. The main interests of his scientific and engineering work cover polymer and product engineering, composite materials, Life Cycle Engineering as well as integrated balancing of industrial projects, economy in cycles, sustainability, and environmental technology. Together with his co-workers from both institutes, Peter Eyerer is working in the field of practical education and practical orientation of education at schools and universities.

Bernd Hefer graduated from the University of Regensburg as a chemist in 1989 and received a doctorate in chemistry in 1993. His main research field is in applied electrochemistry, especially lithium batteries. Since 1994, he has been a scientific co-worker at the Fraunhofer Institute for Chemical Technology. Since 1997, Bernd Hefer has been the Head of personal, finances and administration at the institute. Together with Peter Eyerer and Dörthe Krause, he is one of the founders of the TheoPrax idea involving the reformation of technical education by the integration of industrial projects.

Dörthe Krause is working at the Fraunhofer Institute for Chemical Technology since 1990. She started her career in the field of material investigations and was the Head of the Electron Microscope Group in the Institute. Due to rising recruitment problems, she started her activities in the field of education and cooperation with schools and universities in 1994 together with Peter Eyerer. Starting with a partnership with schools, today she is the leader of the TheoPrax-Project and many subsequent projects in the field of practical orientation of engineering education.

Dörthe Krause finished her education as medical assistant in 1971. Currently, she is studying social sciences and education at the University of Hagen.