A PRACTICE-BASED MODEL FOR CONTINUED ENGINEERING EDUCATION

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Abstract - A pedagogical training approach will be presented based on an engineering degree and oriented towards the tasks and the expected job profile of an engineer in a companys´ research and development department. The pedagogical approach is based on two different types of learning: self-controlled individual learning right on the job while fulfilling project tasks and pedagogical systematic learning while attending job-oriented accompanying training courses. The curricular structure of this training program is presented together with the results of this cooperative, industry-related approach and its importance for the training and engineering studies at universities are shown

Initial situation

In spring 1991 a new training program for unemployed engineers has been developed, which is being put into practice today in cooperation with several partners.[1] It was necessary to develop the program because at that time the unemployment rate of engineers had reached a never known extent which is up to now a great problem (fig. 1). Therefore, the target of this new pedagogical program was to achieve a better reintegration of unemployed engineers as it was the case with former training offers.

In the year 1997, according to an official statement of the Federal Employment Office, in the whole Federal Republic of Germany 50,000 engineers were unemployed. As a reaction to the surplus of engineers, the personnel departments required quickly employment conditions according to the qualification requirements of the companies to solve the relevant projects. In order to achieve a successful reintegration by means of a training program, it was necessary that the program met the „specific qualification requirements of the companies“ as well as the requirements of the regions in question. A prerequisite for this was a close cooperation with the future potential employers.

Not only junior engineers with little practice suffer from unemployment, but also experienced senior engineers. Both groups differ from each other for example by the degree of their professional specialization. When a suitable individual training or coaching program has to be chosen, each single case has to be examined whether it is necessary to conserve or to deepen the acquired specialist knowledge or, due to alterations of the employment market, only a new professional orientation can be offered. Contrary to engineers with little practical experience, for whom the first priority it is to broaden their professional knowledge, experienced engineers intend to conserve and refine their individual special field. Both groups correspond in their wish to get a practice-related task, in order to participate as effectively as possible in the training program.

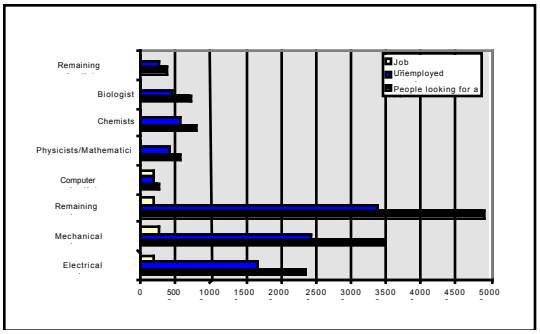

Fig. 1: Employment of engineers (Source: Federal German Employment Office, 22.12.97)

Pedagogical Approach

In order to achieve the highest degree of reintegration of the participants into the employment market it is indispensable to meet the short-term job profile of the companies as well as the long-term development of the employment market and the related required qualifications.

Therefore, the persons in charge of training programs are making regular inquiries on the importance of employment criteria with members of the personnel departments of regional companies and are analyzing nationwide employment offers. These results correspond to those achieved for the whole Federal Republic by the German Engineer Associations VDI and VDE. Here, it must be pointed out that the regional inquiries were mainly concentrated on me-

[1] The training programme was developed and is being practised by the Institute for Applied Electrical Engineering and Engineering Pedagogics of the University of Hildesheim, the Centre for Continued Education of the Technical University of Braunschweig, the Teutloff Gemeinnützige Weiterbildungsgesellschaft mbH (a training institution), the Institute for Applied Microelectronic F&E GmbH. and the Braunschweig-based employment agency.

dium-sized companies, where a future demand for engineers will become visible.

Considering the most important employment criteria one can see on the one hand behavior-related criteria of personality development and on the other hand professional mobility which requires interdisciplinary thinking and independent knowledge acquisition.

In order to consider also the long-term development of qualification requirements, analyses of renowned national and international institutes for economics and social sciences were taken into account. With reference to the national employment market it must be said that „the historical weakness of the German economy lies in its inability to create positions in new branches. Nevertheless, to be innovatively and internationally competitive in the future, it is necessary, to have qualified employees for future technologies such as information technology or biological technology“ [1]. The expected transformation process related to the proportion of employed persons is transparently shown in the „Four-Sector-Model“ (fig. 3).

For the economist Reich, the future type of specialist in high industrialized nations is the „symbol analyst“ [2]. This type is to be understood as a knowledge engineer which tasks are problem solving and identification processes. For Reich, such basic abilities as „abstraction, systemic thinking and cooperation“ are important, not only to get access to fields which become more and more complex and interconnected, but also to be capable to develop it further on by means of professional team work.

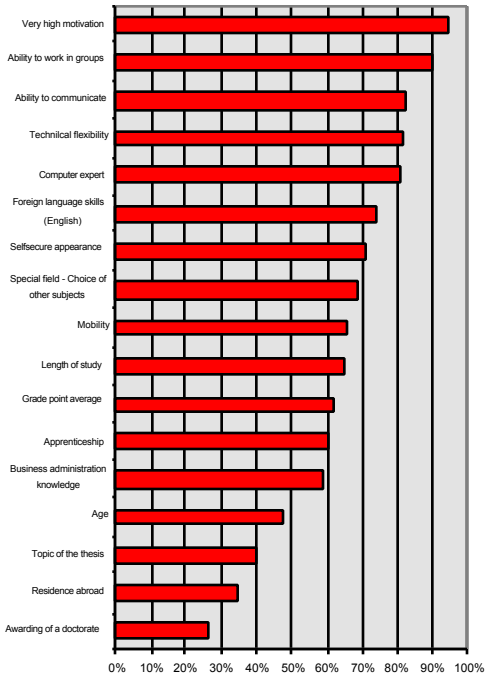

Fig. 2. Order of the employment criteria

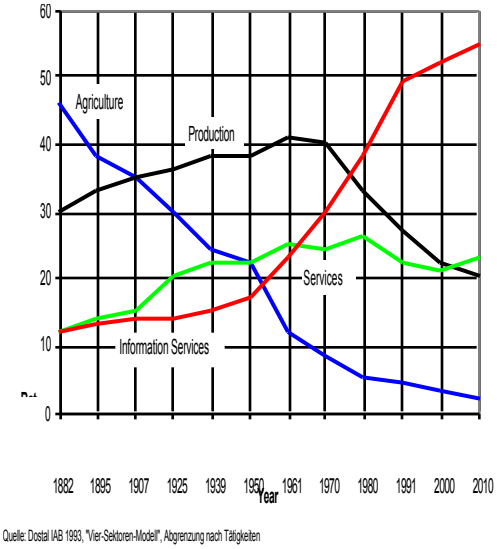

Fig. 3. Proportion of employed persons according to the „Four-Sector-Model“

In order to meet all these requirements which correlate with the term holistic capacity of acting in a single training program, „project-related training“ was chosen. It offers the participant the following possibilities:

1. The development of new and practicable project solutions under consideration of new key technologies which will be successfully applied in future,
2. Interdisciplinary working methods and the ability to teamwork on projects with group members of different technical fields,
3. Interdisciplinary thinking, achieved by forming small teams with the typical structure of integrative or interdisciplinary and technical work at the same time,
4. High flexibility achieved by means of task-related methods of learning as well as acquiring experience knowledge with the group and the participation of experts,

5. The development of job guaranteeing key qualifications [3, 4].

When the participants of a learning process develop transfer abilities it can be assumed that the contents to be transferred as well as the methods are generated during the training program as identical elements / characteristics of the field of action, the work place. The more authentic the working and learning situations are, the higher is the probability of transfer [5]. As consequence follows that training programs have to be carried out directly on the job, as close as possible to the job or related to the job. The pedagogical efficiency of the close relation between practice-oriented acting and theoretical knowledge is shown by the example of the dual system carried out in the German professional training / apprenticeship and especially by the high quality of the training of specialist workers.

Therefore, practical learning circumstances are closely related to the success of the curricular targets of a training program. If the aim is to develop process competence and systemic thinking and acting under complex technical circumstances, processes must be given as a concrete and under curricular aspects optimized training field. This encloses for example situations which employees will find when their job organization is altered, such as into cost centers [6]. If holistic understanding is required as an essential target in training programs, holistic / complex learning circumstances should be given.

Due to this it was just consequent to integrate the potential buyers of training programs, the companies, into the training. Thus, projects are given and supervised by the companies. The company-related project task ensures that the working conditions correspond to those in a development department or an engineer office and that the achieved results are visibly put into practice. The psychological importance of this learning organization for the participants is their integration into „practice-related working conditions“, emphasized by the contact with the project-giving company. Moreover, this ensures the not negligible importance of technical knowledge exchange with company experts and participants among themselves as a „community of practice“ [7]. At the same time a learning culture for training programs was tested which correlates with the company culture.

In order to achieve the necessary acting competence of the participants, which means to increase their chance to get employed, the projects have to be chosen carefully. The projects[2] should correspond to the following criteria:

1. The degree of difficulty and the duration of the program must be individually adequate.
2. Relevant projects which will open for the participant the chance to be taken over by the company.
3. The projects must be designed in such a way that the participant is able to develop technical, methodical and social competence in order to achieve qualifications for the European employment market.
4. A broad technical field of application which requires self-controlled learning with multimedia teaching tools.

These criteria also show that the project-giving companies have a certain responsibility. On the one hand, they get a solution for a problem as a result of the training. But on the other hand the project giving companies have the responsibility towards the participant and the training institution, to provide professional and technical resources.

Structure of the training program

The training program offers each participant a learning place as a work place, where he can work on industry-oriented tasks under typical conditions for a longer period of time. The organization can be characterized as follows:

1. At the beginning of the training, a group of experts analyzes the potential of the participant, based on his studies and his professional practice. Afterwards, the trainer develops an individual training program together with the participant to improve his technical, methodical and social skills.
2. The duration of the training is one year. The time to work on a project will last between six and twelve months. If the company is going to employ the participant, he can leave the training at short notice. In case of inadequate performance of a participant, the training will be stopped immediately.
3. A project group consists of one to four participants, according to the task. Members of the group are not exclusively engineers but also scientists and economists. The participant can also be a member of a company-own project group. The participants have to organize a lot of things on their own, such as keeping contact to the project-giving company and to the partners of the participating companies.
4. Participants, trainers and the persons in charge of the project-giving company define together the task description.
5. In most cases, the training institution supplies the location where the project is being carried out during 40 hours per week. If these locations are not suitable, the participants work with the project-giving company.
6. The participating partners have installed a strategic acting group of managers of both the training institutions and the project-giving companies which presents the technical and

[2] Here are some typical project subjects: development of a fuzzy controlled transportation system, preparing a quality audit according to ISO 9000ff., optimizing a lifting device by simulating meat processing machines, implementing field bus systems using Touch Screens, exposure measurement for µC-controlled medium-format cameras, development of a code-converter from Intel 8085-assembler to Intel 80486-assembler.

pedagogical guidelines and supervises their fulfillment.

7. A group of experts of different technical fields looks after the project groups which are spread on the different training institutions. Here, these experts/ assistants act mainly as moderators. Their task is it to accompany the process, helping to develop competence but not to act as a lecturer. The experts are managing the learning process and are opening information channels. Moreover, they have to arrange clear project targets together with the project-giving companies, to look for adequate group compositions and the appropriate applications of methods and resources.

In figure 4 the structure of the training program is made transparent, pointing out that the focus lies on the companies project as source of learning. By presenting papers on the results of his project, the participant trains presentation methods. Here, an exchange of ideas takes place within a larger group and facing experts. The participant has this opportunity two or three times during the training. Presenting his results, the participant is forced to answer critical questions related to the solutions achieved.

During the training program, courses are offered which vary in subject and duration. According to the individual training plan a decision is made whether the subject of the course is relevant for the participant or not. By the integration of courses into the training program a concentration on just one project or working field is avoided. In order to ensure a high technical level of the courses, only those training institutions are chosen which are leading on the relevant field.

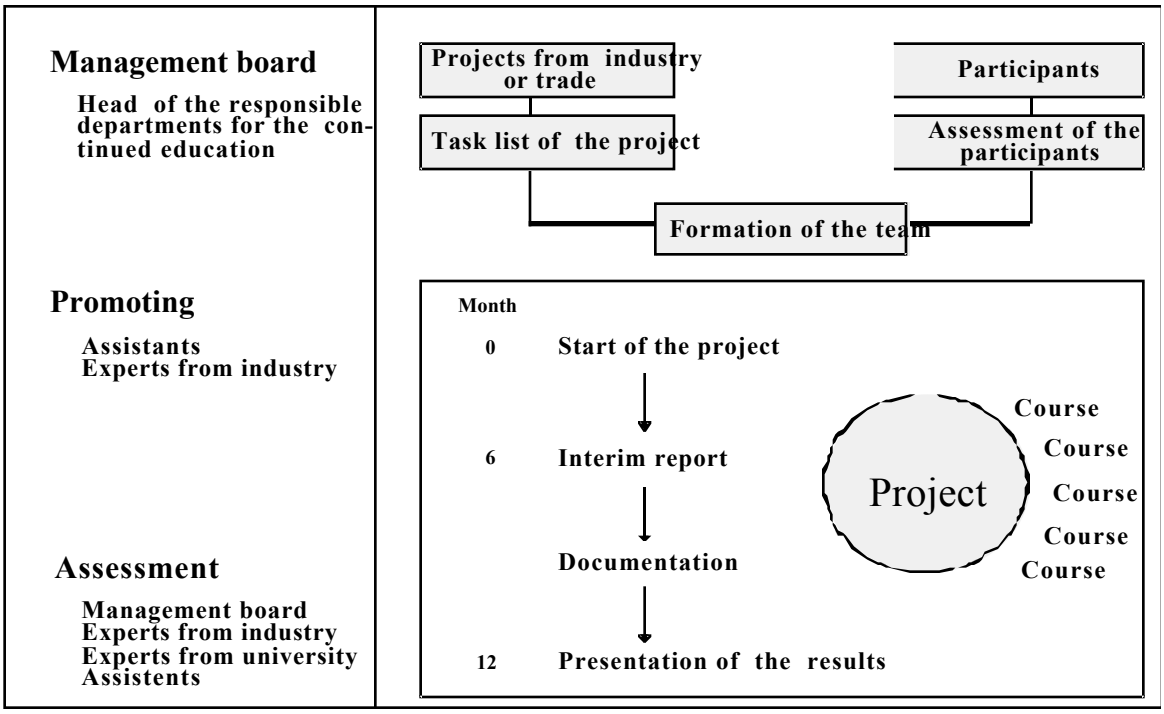

Fig. 4. Structure of the training program

The duration of all technical and interdisciplinary courses which are offered to support the project work, is about 500 hours. The system and the realization of these courses correspond to the typical company-own training management of large enterprises (such as the Volkswagen AG). Table 1 shows some subjects.

A prerequisite for successful project work is the willingness to apply knowledge and to acquire new qualifications and abilities. Both, the individual person as well as the project group are learning by exchanging experience knowledge. In order to deepen methodical competence, all participants are obliged to attend the course „Project Management“, as a prerequisite to ensure high-level project results. The command of foreign languages can be ensured by a stay abroad.

Table 1. Survey on training courses

Courses with examination, certificate carried out by external institutions	Quality Assurance Environmental Protection Technology Cost Management

Courses with external and internal lecturers with certificate of participation	Project Management Communication Training Technical English / Spanish Job Application Training
Technical, special courses, with internal or external lecturers and institutions	CAD-Systems, CATIA/, Pro Engineer e.g. Field Bus Systems, Profibus /Interbus
Programming courses	programming languages, . for high level & automating tasks S7

Evaluation of the program

When evaluating the effectivity of a training program, success factors and evaluation methods are needed to obtain valid results. If an evaluation of success factors has to be carried out, it must be embedded into the working conditions or otherwise at least a direct relation to them has to be established [8]. A positive change of proven results after a training course can serve as an indicator for the quality of the training. The project-related training meets the requirements for such an evaluation by its project-orientation as well as by the suitable working conditions. Assuming an evaluation related to the results of the project and the working condition, the success factors for evaluating individual or group-related learning results correspond to the results of personnel evaluations in companies.

This effectivity evaluation of the training program, based on concrete project results such as calculations, programs, drawings and meeting records can be described as follows.

The efficiency profile of the participant can be observed during his work on the project task under the given working conditions. The quality of the training program can be evaluated concerning two aspects. On the one hand, experts of the project-giving company evaluate the quality of the participant's engineering abilities by a „job report". This ncludes the level of the task and the way, how the task had been solved. On the other hand, the project task is evaluated by the trainers of the training institution, who have worked over a longer period of time together with the participant. They also write such a „job report". Due to the project-oriented task, the participant finds himself in a „competitive situation", so that the trainers can state changes in the affective behavior (soft skills) of the participants.

Finally, the decisive factor for the efficiency evaluation is the proportion of the participants employed. Thus, the quality of the training program becomes transparent, for the participant as well as for potential participants and the customers of the program.

The continuous dialogue with the customer of the training program leads to a direct feedback on the effects of the training, so that the program of the learning process is not only improved but optimized. The evaluation of success can be understood as process evaluation, as the training program is aiming at improvements concerning processes in companies. Therefore, the evaluation carried out in the training program is a permanent evaluation.

The effectivity and the success of this training method are proven by its application not only in Germany but also in Greece, where the same pedagogical approach is used.

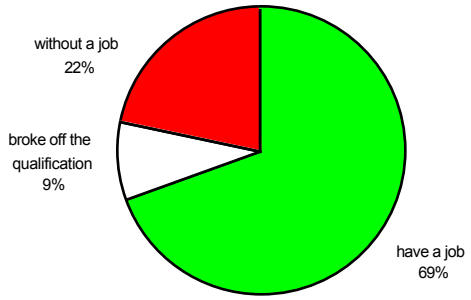

Fig. 5. Proportion of the employed participants of the training program[3]

Consequences for basic studies and training programs

In Germany, training programs are based on the different stages of basic studies. In an analysis on human resources Porter holds the view that German employees are „not only trained better in special fields compared to other countries but have also a well-founded theoretical knowledge. Thus, the preconditions for high-quality training programs are given, to be able to develop and produce professional goods of rising quality." [9]

Therefore, universities offer short training courses where the latest research results are presented, in order to support the employed participants to find solutions for their practical work. Contrary to this, new continuation courses of study for training purposes were not launched, although they are urgently needed for a new job orientation. The practice shows that the job, somebody originally was trained for, frequently does not correspond to the actual work he is doing. Facing high unemployment rates (see fig. 1) universities have also the social task to conserve human resources for society.

The continuation courses, organized as day or evening courses, could correspond to the project-oriented structure of the training program presented in this paper, a typical characteristic being the close relation to industry. With the highly qualified and experienced participants a completely new learning culture

[3] Insert statistic / number of participants, etc.

would be created and the special fields of the universities could benefit from the knowledge potential.

Positive experience have been made with the continuation course „personnel development in companies“ which is a course of study at the Technical University of Braunschweig and is organized and supported together by the Volkswagen AG and the University [10]. As around 50% of the lecturers came from regional companies, not only a close relation between theory and practice was given but a close long-term cooperation between partners in industry and research was ensured. Perhaps universities have not recognized that continuation courses of study are at the same time a field of competence and experiment. Here, innovative and creative learning conditions are opened which contribute to a better understanding of the problems of university and industry.

The change of the paradigm „work and study“ in professional training programs has found new fields of application as it is shown by theses and reports, already carried out during basic studies at universities:

1. Establishment of joint courses of study between technical colleges and companies for the subject mechanical engineering with the concentration on manufacturing and automotive technology (automo- tive industry).In a company linked to the University of Witten Herdecke, students of economy, who have passed their mid-course qualifying examination, work together with their lecturers on industry orders.
2. In Dortmund, a manager training meeting the requirements of the European market is carried out by Goeudevert[4]. The training comprises theoretical knowledge which is put into practice afterwards in companies linked to the training institution. (see also John M. Olin School of Business, Washington University St. Louis)

Thus, efficiency centers are created as entrepreneurial unities which serve as entrepreneurial and knowledge centers. This is also the basis for the foundation of new companies.

Positive learning results in training programs have shown that after an initial phase of study, in which basic knowledge must be taught, enough room for industry-related projects should be created, where students of different subjects can participate. Only by interactive project-cooperation, in which students of not-technical subjects like sociology and pedagogics are participating, practical experience and mutual understanding can grow.

In order to put into practice the presented strategies and structures, universities have to create the relevant conditions, such as the necessary structure of the courses and the examination rules [11]. Nevertheless, adjustments concerning the whole education system are necessary to train engineers as well as graduates of other subjects who meet the requirements of global competition.

[4] Goeudevert was board member of the German Ford Corporation and of the Volkswagen AG

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