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Restructuring engineering education for the 21st Century

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ABSTRACT: The article describes ongoing research and development work in Finland aimed at developing and implementing a new solution for Engineering Education (EE). This development is undertaken as a systems engineering endeavour by combining theoretical and experimental work. It is driven by the fundamental changes created by globalisation on the global, national and institutional education system levels that force organisations and people participating in the global market to make a qualitative transition from the maintaining (routine) mode of operation to the development (creative) mode of operation. In global companies, this transition is almost completed. However, in professional and academic education organisations, this transition is still in its infancy. The results obtained show that the new requirements of EE in the global environment can only be met by re-engineering the current EE to incorporate a new structure. The new model was developed during work tested since 2001 in the programme of industrial management at Helsinki Polytechnic, Helsinki, Finland. The new way of doing things removes the structural discrepancy between EE organisations and their customers in professional and work life, and offers potential advantages to students, faculty members, EE organisations, industry and other nations.

INTRODUCTION

Globalisation Effects that Influence Engineering Education

The study described in this article is driven by the fundamental changes in Finland and in the societies of the world created by globalisation. At the beginning of the 21st Century, the economic and cultural evolution of the world continues at an accelerating rate. Driven by continuing market liberalisation, most of the world is moving rapidly towards a global, market-oriented, real-time economy.

This accelerating transition has led to dramatically rising levels of know-how and use of technology in most parts of the world and increasing competition between companies. It also forces routine manufacturing to be transferred to countries of low labour costs and to the adoption of modern Information and Communication Technology (ICT) tools in order to automate routine (repetitive) work. At the same time, global development is progressing towards the fulfilment of basic human needs and to the rising emphasis of the higher individual needs.

The new requirements created by changes of the societies and increase in global competition can no longer be met by present sporadic development. The situation forces the organisations and people of the industrialised countries to make a fundamental transition: they must move from the routine (repetitive) operating mode to the systematic development (creative) mode.

Such a transition demands a qualitative change in attitudes, organisation, work methods and management. In most of the global companies, the transition to the development/creative mode is being completed. In the field of education, this transition is still at its infancy.

The Role and Importance of Engineering and Engineering Education in the Global Transformation

The transition also has a direct impact on the engineering profession. Engineers play a central role in the social transformation by being instrumental in transferring human routine work over to synthetic machines and systems. Meeting the needs of societies in the global competition of the early 21st Century emphasises the role of engineering and increases the requirements for engineers.

High-quality Engineering Education (EE) is very important to all nations, particularly small countries such as Finland, which have a strong focus on high-tech industries. These industries depend on the excellence of their engineers in the global competition. For the same reasons, high-quality EE is essential to the future of developing countries. During this decade, the developing countries have an opportunity to bypass old EE, in the same way as adopting the latest technology, eg in the field of wireless communications.

The present situation places new demands on EE organisations for deeper, long-term learning, more efficient and innovative teaching, greater responsibility for student employment and career success, as well as a general influence on society.

Changes in the Societies and Higher Education of Industrialised Countries

Social changes during the past decade have also directly influenced higher education, including EE. During the 1990s, the education systems of industrialised countries have undergone great changes, which have also affected EE. The first is the shift of higher education and EE from elite to mass education. In Finland, for example, national plans call for almost 70% of the annual age group to be educated to the tertiary college level. At the same time, the marketisation of higher education has led to continuous assessment of the educational organisations by government and accreditation institutions. These trends have led to the competition between EE organisations for high-quality students and faculty/staff.

The expansion of higher education raises the average know-how level of the country and also affects the characteristics of its students. The changes have had a distinct effect on the know-how level and heterogeneity of students entering EE. Present-day youth no longer follow the classical ideologies or conventions of societies. At the same time, students are strongly influenced by advertising, media and trends in society. This has also changed the status of education: the youth do not see it as the only way through which to succeed in life.

The combined effects of modern society and the old education system are also manifested in a large percentage of unfinished studies in higher education, particularly in EE. At the same time, the resources available for EE are decreasing. In Finland, large funding cuts have taken place during the 1990s. Therefore, increased funding cannot be used to solve problems. A large increase in efficiency is needed in order to meet EE requirements during this decade.

STRUCTURE OF CURRENT ENGINEERING EDUCATION

The present EE model is based on the classical education structure, which has evolved (not systematically developed) for a slowly changing society over a number of centuries. The curriculum used in most EE institutions in the world (including Finland) goes back to the curriculum implemented in the USA during the late 1940s.

Predominantly, the structure of the current system is based on the mode where a single teacher presents written material produced by another person to a group of pupils gathered for listening and copying the material. The structure is also intrinsically based on the division of the world into specialised disciplines and subjects. The content is partitioned into a collection of separate courses and the learning is controlled by means of individual written tests. Most of the content presented is based on the *model world*, eg textbooks and separate theories.

However, the structure and mode of operation of the present model has run into trouble. It has led to a fragmentation of the content, the work of people and their use of time. It has also separated the learning from the real world (eg the work of an engineer). A comparison of the week of an engineering student to the workweek of a modern engineer illustrates the fundamental differences.

Yet, from a student's point of view, the present way of doing things has resulted in a study overload, has created incoherence and resulted in uncertainty about EE objectives. The resulting lack in the ability to combine knowledge into functioning wholes for the real world is the fundamental deficit of the present educational system. For teachers, the need for change has spawned many additional tasks, such as continuous development of the work, cooperation with industry and internationalisation. Because these tasks have been introduced as additions to basic teaching, the situation has resulted in overload and confusion. These deficiencies and problems are common to most of professional and higher academic education.

It is important to realise that the inherent obsolete structure is not due to deficiencies in the educators or teachers. The present model has, in fact, turned into a barrier for individual teachers in improving their work. It makes it impossible, even for a perfect teacher, to meet these new demands within the present mode of operation.

Originally used for a small group of students, the structure was sustained when education was expanded to mass education during the late 1800s. The structure has also been maintained during the whole 20^{th} Century, when the complexity of the world has continued to increase at an accelerating pace.

The operation of EE institutions still corresponds to the industrial era (assembly line) mode, which concentrates on routine (repetitive/maintaining) tasks. This type of work is driven from outside and fragmented into small repetitive parts. People are treated as objects or machines, using only a small part of their capacity as human beings. In the development (creative) mode, the emphasis is on methods and forms of cooperation in flat organisations where people are treated as individual humans.

Strong Need for Restructuring Current Engineering Education

National education systems have the responsibility to support, if not also drive, fundamental transitions in industry and society. They have to take into account changes that affect society over a long period of time. For example, students entering EE institutions in 2003 will be professionally active in the 2040s and the early 2050s.

Until now, profound changes in societies and dramatic developments of technology have had relatively little effect on the structure and mode of the operation of EE. The emphasis of the present EE is on quantity, still aiming at including and presenting everything the EE student needs during his/her career. The increase in the complexity of the world, the rise of the expectations for the required knowledge and an increase in the level of know-how have made this approach impossible.

The basic structure of the present EE can be summarised as outside-driven fragmented mass teaching in the model world. This inherent structure inhibits change in EE institutions in order to meet the demands imposed by industry and society. The disparity between the increasing new requirements and deficiencies has created a strong need for the restructuring of EE. During the 1990s, it has been widely recognised that present EE, particularly during the first and second undergraduate years, has severe deficiencies. During the 1990s, the need for a major change in EE has also been emphasised in Europe and the USA [1].

DEVELOPMENT OF NEW EE IN FINLAND

Background of the Work in Finland

The ongoing work in Finland is based on the ideas and initial work done in project-based entrepreneurial education and continuing EE at the University of Oulu, Oulu, Finland, in the 1970s. A structure of student-driven real-world education was developed at this University in the early 1980s [2]. The adoption of the polytechnic system on the national level during the 1990s has created an opportunity to reform higher professional education. The R&D work towards developing the new solution has been undertaken as an engineering endeavour since 1993.

Systems Engineering Approach in Finland

During the 1990s, it became clear that the discrepancy between education organisations and their corporate customers in business life could no longer be solved by means of partial solutions (eg adding separate subjects/courses/projects/work practice, adopting new teaching methods or exploiting new technology) within the present operating mode. The situation can only be remedied by reengineering the present EE to incorporate a new structure. At the same time, dramatic advances in ICT offer great possibilities.

The goal of the work in Finland is to develop and implement a new solution that meets the requirements of a complex global environment. The work has been executed as an engineering endeavour, utilising a new approach based on hierarchical systems and model thinking [3-5]. It has been carried out as a parallel combination of theoretical and experimental work. The work has required going back to the basics of EE.

The classical scientific approach divides the world surrounding human beings into a large number of separate scientific disciplines and sub-disciplines. The systems approach tries to cope with the extreme complexity of the world by treating the world as a collection of functional entities (dynamical systems), which consist of material, energy and information.

In systems engineering, complex real-world systems are usually described as hierarchical (multilevel) systems. Systems are separated into subsystems. Accordingly, the structure and operation of systems can be separated to the operational level (how), the tactical level (who, what, where, when), and the strategic level (why), which is connected with the goals of the system.

Human life is based on using models (representations or *information packages* located in the brain) for describing and responding to events in the real world. In addition to mental models, humans also use a number of external models for influencing behaviour and exchanging information. Examples of the categories of external models used by humans are verbal models (eg spoken languages), visual models (eg symbols, characters, graphics, still and moving 2-D and 3-D pictures), analogue models (one system as a model for another system), mathematical models (information presented in an unambiguous, universal and artificial language), and computer models (a collection of the previous external models stored and processed in an effective electronic form).

Science, Engineering and Technology

For the purpose of developing the new EE model, science, engineering and technology have been defined. Science is a human activity (work of people) that extracts knowledge from the world surrounding humankind and packages it into useful external models. It is driven by inherent human curiosity and the need to make the world a better place in which to live.

Engineering is a human activity (work of people) that improves (mainly) the physical world for humans. It is driven by inherent human creativity and the need to make the world a better place to live in.

Technology is a combination of visible and invisible tools that are available to the human beings (mainly engineers) in their work. Comparing meteorology to (almost non-existent) weather engineering clarifies the closely intertwined but different nature and orientation of science and engineering.

Routine Work and Development Work

There are inherent differences between routine work and development work (and destructive work). The main purpose of routine (operative) work is to maintain a system in its present state. Usually, routine work is repetitive and driven from the outside. Routine work uses existing knowledge and skills, but lacks the tactical and strategic choices essential in development work. Much of routine mental work can be automated by means of modern ICT networks.

Development work means bringing a system into a better state through a path that is usually unknown in advance. Further, development work in the real world involves differences of opinion, conflicts of interest, unexpected problems, errors and temporary defeats. It is possible to have a routine (maintaining) attitude or a development (creative solution-oriented) attitude in all types of professions and vocations.

The proven means for successful development work is a goal-directed, systematic and creative, long-term cooperation of selected, personally committed people, who possess the required knowledge, skills and sufficient resources. The work must be done within physical, human, economical, legal, ethical and environmental constraints. Development work requires continuous learning of new knowledge and skills. Forms of cooperation include close personal relations, teamwork in small groups (teams), teamwork in larger groups and project organisations, mentoring relationships and personal and professional networking. The success of development work depends decisively on the positive feelings of the people involved, such as enthusiasm, the joy of learning, pride, faith, self-confidence, respect, trust, hope, love, excitement and humour. This recipe has been used for the demanding task of sending 12 persons to the moon and returning them safely to Earth or winning world championships in sports. It is the best-known method for realising the personal dreams of human beings, succeeding in business and solving social problems.

The basic idea of the work in Finland is that real learning is development work. Writing down part of the material presented by a teacher on paper during an examination is routine work. Analogously, real teaching is development work. Presenting prepared material to a class of students is routine work. These types of routine work are done much faster and easier by a computer network.

The modes of operation of humans and organisations correspond to the three fundamental methods of human survival, which are as follows:

- Maintaining the existing situation and environment (repeating).
- Improving the situation and the environment (developing).
- Removing the threat in the environment (destroying).

Analogies and Tools Used in the Development Work

The mode of operation and organisation of large, medium-sized and small global customer-driven corporations has been used as a main analogue model in the development of the new EE model. The methods of doing things in these development organisations (learning organisations) have been used as analogue models and tools in the development and optimisation of the new EE solution. Examples include Just-In-Time (JIT), Total Quality Management (TQM) and lean production methods, which have greatly improved the efficiency of mass-producing manufacturing development work. The ideas and experiences of mass customisation are also important for the optimisation of the new EE solution. The term *learning organisation*, generally used for these organisations, refers only to a part of the structure and function of the organisations. *Development organisation*, which describes the general operating mode, would be a more appropriate term.

For the purpose of developing a new EE solution, an EE organisation can be regarded as a customer-driven service company and the EE provided by the organisation as a service product. The company has multiple customers. Students can be regarded as the first customers and companies employing the engineers (industry) as the second customers.

However, analogies of EE organisations to companies have deficiencies. Physical products are entirely passive. Many service products also require little activity from the part of the customer. Yet learning depends decisively on the active long-term participation of the student in the learning process. Therefore, students can be considered as clients (active long-term customers). However, they do not pay the price of the services personally. Society, which is the owner of public EE institutions, pays for the services of these EE institutions instead of the students. Industry also pays for the services by paying engineers' salaries. Industry can be thought of as the second customer/client of EE organisations.

The theories and ways of thinking of modern education science (eg constructivism, project learning, Problem-Based Learning (PBL), cooperative learning, active learning) have also been used as important tools and analogue models.

The Role of Modern ICT in the Development Work

Modern ICT is used as a central tool in the development of the new solution. Using modern ICT networks for the automation of the operation of the companies is one of the main methods of improving the performance of modern companies. The networks are used to automate the routine part of work by utilising the earlier results of repetitive work. The automation of routine work allows people to concentrate the available resources on the development component. The ICT networks also make it possible for a large number of people to work effectively together and to minimise the effect of geographic locations.

MODELS FOR A HUMAN BEING AS THE BASIS OF EE

Model of a Human Being in a Current EE System

One of the fundamental explanations for deficiencies in the present EE is the underlying conscious or unconscious model for a human being, most importantly: the student. In the current EE solution, the model for a human being is a physical (nonliving) object. A student is regarded as a vessel (eg a partially filled cup), simple machine or a computer. The goal of the present EE model is to fill all students with a similar knowledge to last for their whole lifetime. The teachers are understood mainly as dispensers for filling the vessels (cups).

Model for a Human Being of the New Engineering Education

According to systems modelling and thinking, human beings involved in EE (students, teachers, specialists, etc) are modelled as complex dynamical, parallel and hierarchical systems that have a genetically programmed internal control system. This system operates according to the genetic program under a continuous strong influence of the environment. The system continuously manages the survival of a human and grows/develops towards the achievement of internal personal goals.

The inner system consists of a non-conceptual part that controls the behaviour of a human by means of positive and negative feelings. This part operates in parallel and close interaction with a part that uses a hierarchy of conceptual mental models. The systems utilise the similarity of information (analogy) to create emergent models on higher levels. This leads to a hierarchical structure and function for a human being.

The mental models (information stored in the brain in different forms) are crucial to life and education. Learning can be described as the development of the desired mental models in the brain. EE is the activity directed towards constructing an optimum set of mental models into the brains of individual students in the most effective manner. The deep learning needed inherently involves positive and negative feelings during the learning process. The basic mental models needed for the engineering profession can only be created by doing engineering-type work.

According to this approach, education and teaching is development work aimed at producing the desired changes in the function of the human students (behaviour of the learner). The aim of modern education/teaching is to support, guide and accelerate the individual learning and developing processes of each student towards the learning goals needed for a personal career as an engineering professional. The most effective methods of successful development work can be used in teaching and learning.

The adoption of the new thinking forces educators to abandon the idea of charging a young student with all the knowledge needed during his/her professional life during the first half of the 21st Century. The new thinking also naturally leads to the transformation of the structure of EE. It concentrates on learning the basic knowledge and skills and the effective use of general models. An important part is the know-how and skills of the development mode of work and life.

Practical Development of Modern Engineering Education

In terms of the new thinking, the work in Finland can be described as a transformation of an EE organisation from the routine mode of operation to a systematic (customer-driven) development mode of operation. This change requires qualitative changes in work methods, organisation and management of EE organisations. This transition also requires qualitative changes in the attitudes and work methods of the people participating in the process.

The transformation is deeper and more difficult than generally understood. The complexity of this development task requires a systematic theoretical approach, which must be closely integrated with continuous experimental work. Therefore, the work in Finland uses the engineering approach, which is based on systems and model thinking.

Learning Goals of New Engineering Education

The new EE model developed in Finland is based on the definition of the competence requirements for the modern engineer working in the global environment. These requirements can be summarised as the capability to do efficient engineering work (in a selected engineering field) by using modern concrete and abstract tools within global economical, environmental, legal and human constraints. This level of professional competence can only be achieved through a life-long process of learning and professional development. The new EE is designed to be a natural first part of the life-long engineering work process. The four-to-five-year learning period makes it possible to learn the basics of these skills.

These ideas have been used to derive the detailed overall learning goals for EE students. This work has been done by the faculty of EE organisation in cooperation with industrial partners. In accordance with this new approach, the goals have been divided into knowledge and skills on the levels of physical, biological, human and economical systems (object and environment of engineering), engineering (work of engineers) and technology (concrete and abstract tools of engineering), as follows:

- Physical nature: the basic physical and chemical phenomena, use of models for describing physical and chemical phenomena, use of general models and structures for describing physical and chemical systems and their functions.
- Biological nature: the basic structure of life, ecosystems, the environment and sustainable development.
- Human: structure and function, groups of people, organisations, society and the world.
- Engineering: systems approach, market-driven processes from idea to product, the use of mathematical and ICT tools, engineering ethics and the history of engineering.
- Technology: mathematics, ICT tools, basic technologies of the chosen field (eg electronic engineering, mechanical engineering).
- International business: product, product lifecycle, market economy, principles of business, customer-focused business and marketing.
- Personal skills and specialisation: continuous learning, verbal and written communications in the native language and in an international language such as English, creativity, teamwork, project work, control of personal life, time management, specialties in engineering and technology, capability to specialise, team management, knowledge of foreign cultures and languages, and personal networks and goals.

Mathematics is included as an important abstract tool for using mathematical models. Modern ICT is also included as a central concrete tool. The goals' emphasis is on learning an engineer's systematic and creative way of thinking and doing things in the real world.

The learning goals for the knowledge and skill areas (learning goal components) are defined as comprehensive lists to cover all the overall learning requirements. In addition to this static definition, the areas are also divided into a number of basic dynamic learning processes (learning process components). These processes are formulated to correspond to natural human learning using theoretical knowledge about human beings and the accumulated experience from experimental work. The progress of these processes corresponds to the development of mental models: from simple concrete models towards the more general and abstract higher-level models, which are very important in modern engineering. This approach forms the basis for the systems design of the new type of a learning environment. During the development phase, this work is done in an iterative way in close interaction with the design and optimisation of the learning projects and the overall learning project sequence.

Basic Ideas for the Realisation of the New EE Model

The new EE model is based on achieving the learning goals for engineers derived by the EE organisation in cooperation with industrial partners. This is done by means of systematic and creative long-term cooperation of students and teachers/ specialists, who are on an equal human level. It requires a change of focus on individual student learning processes. The mode of learning can be described as *learning by doing and experiencing*. The implementation of the new EE model can be summarised as a shift to inside-driven, individual total learning in the real world.

Structure of the New Engineering Education

The new EE model described in this article is based on the overall learning goals. The main building block of the new model is a real-world learning project. It is a task performed by a student and is designed to produce a required learning result.

A learning project is divided into leaning tasks. A sequence of learning projects connected with the real world is used as a vehicle for achieving a continuous effective learning environment in order to support and guide the individual learning processes of students during the whole four-to-five-year study period. The themes and contents of the projects are selected, formulated and coordinated to meet the learning goals, which are imbedded in the learning projects. Individual learning projects are included in a project sequence during the whole learning period.

This new model offers a flexible way to select and formulate learning projects in order to optimise the learning process. The sequence starts with relatively small-scale learning projects and approaches real-time projects from industry/society during the study period. Participation in real engineering work during the first year forms an important foundation for the following years.

The basic knowledge needed in a project is made available to students in compact and effective forms. Continuous real-time measuring of the individual learning processes of students is integrated into the model as a fundamental component. Continuous feedback forms a foundation for the real-time cooperation between students and faculty, making it possible to deliver teaching and support for the learning projects to students on demand.

Details of the New Engineering Education Model

During the design and implementation, a project sequence is continuously optimised on both the project and sequence levels by selecting, formulating and coordinating the themes and contents of the projects. Examples of projects include those connected with the personal lives of students, media events, engineering achievements, development projects of teachers and faculty members, projects from industry (from cooperating companies and organisations), practice/internship, study periods abroad, personal specialisation, entrepreneurial projects and thesis work. During the second semester, students use approximately half of their time to carry through an industrial project from a partner company.

This new kind of EE model provides the needed flexibility to select and formulate the learning project sequence together with local industry. This optimisation is based on direct feedback from students, teachers and industry, processed by combining the information with the systems and model thinking approach. This method is consistent with the *meet in the middle* approach in systems engineering, which combines the details (operational level) with the whole (strategic level) in the middle (tactical level).

One process of learning projects running throughout the total learning period concentrates on the whole of the work of an engineer. It helps students to grow into engineers by describing the fundamentals of the engineering profession and providing real-world examples. The aim is to provide a model of the engineering profession from the first year to facilitate a personal development process towards an engineer. Seeing a picture of a jigsaw puzzle greatly contributes to the success of the assembling task. Experience shows that the first year is the most important year, requiring the best teachers with human skills and a deep understanding of engineering and technology.

The continuous process also contains a personal mentoring system. Selected teachers of the student group, who are interested in the human being, function as a team of mentors. Mentoring is based on personal contact with students and on real-time feedback through the measuring system. This arrangement allows the mentor to support a student in case of difficulties and temporary defeats. The mentoring effort is concentrated in the first and last years, when the need for personal support is greatest.

All of the practical forms of cooperation used in successful development work are used in the learning and cooperation between students and faculty. As an example, students may start their work in groups of three students during the first semester, and start working in larger groups and project organisations during the industrial project during the second semester. Experience has shown that a continuous change of groups and group characteristics is needed during the whole study period.

In a similar way, team and project organisation is used for the cooperation between teachers. Each learning project has a project manager who directs and coordinates the work of those faculty and staff assigned to the project within the resources allocated.

To facilitate near-real-time teaching, the basic knowledge needed in a project is made available to students in a compact and effective form. Some information is presented by faculty members to the whole student group or a smaller group. These concise information presentations (*information flashes*) include simple examples and exercises that facilitate understanding and project performance. In addition to the knowledge delivered personally by faculty members, selected material in books and on the Internet are also used as project material.

Modern ICT is systematically used for automating the routine part of the work. This includes the delivery of basic material to students, weekly and daily scheduling, and the practical arrangements for the personal feedback and grading of students. Experience has demonstrated that ICT is the only way to control and coordinate a complex network of cooperating people. The effective utilisation of ICT makes it possible for all of the people involved to concentrate on the most important functions, which maximise individual learning.

Integrated Assessment System

Continuous real-time measurement of the individual learning processes of students is integrated into the model as a fundamental component. One example of performance is by means of small tests included in the learning tasks and the *information flashes*.

The assessment system integrated into the new structure is divided into two components: the system for facilitating and learning self-assessment and the system for grading. Self-assessment has been selected as the central method for continuously evaluating the learning processes of individual students. The first component is designed to facilitate and learn self-assessment by providing direct feedback from teachers and fellow students as a natural element of cooperation. Continuous personal contacts with teachers are also an important part of feedback.

The second component is used for the individual grading of students. It is based on the evaluation of the individual outcomes of the learning projects. Students present the outcomes of the learning project to a teacher as a justification for their grades. The evaluation is mainly carried out during private and public personal discussions between teachers and students. These meetings take place at specified times during the learning tasks and at the end of the learning projects. They also provide personal feedback, which has been found to be very important to students.

Comparison with the Present EE Model

According to the systems approach, there are no divisions to subjects and courses, or to theoretical or professional subjects. Because the world is inherently interdisciplinary, the use of learning projects connected with the real world virtually removes the need for integration, as the projects are not differentiated into disciplines or subjects. The content needed for obtaining the learning goals can be embedded into the learning projects in a natural way by selecting and formulating project themes and contents.

This new thinking converts the basic task of teachers from presenting their subject matter to making students learn the required knowledge and skills in cooperation with other teachers. Learning projects common to a number of existing subjects makes it natural to teach a student group as a cooperation of several teachers. This new method affects the work of teachers in a natural way, freeing them from the routine presentation of information and making them coaches/mentors/leaders to students.

The change from routine to development mode eliminates many of the present problems of teachers by making the new tasks a natural part of the work. Examples are continuous development of the work in cooperation with other teachers, cooperation with industry through real projects from companies, and internationalisation through international learning projects. Importantly, the model allows greater flexibility for faculty members to use their personal skills and interests. In particular, the model allows the tasks of teachers, faculty members and specialists from within or outside the EE organisation (eg industry) to be chosen according to their personal skills and interests.

An interesting result of the work is that the use of other approaches (eg in educational science) seems to lead to same kinds of solutions, indicating that different approaches and experiments seem to converge towards a similar structure.

IMPLEMENTATION OF THE NEW EE MODEL

The reform of an EE organisation would start by a preparation phase involving a relatively small team of teachers dedicated to the development work. During this phase, the generic ideas, learning goals and learning project material would be made available to the team. Also, the learning projects would be selected and optimised to meet local needs.

According to the experience gained in Finland, it is impossible to use the current and the new model in parallel. The actual implementation, therefore, requires a decision of the whole EE programme or the whole faculty to make the transition simultaneously. During the preparation phase, some of the new methods and materials would be tested within the existing curriculum. During that time also, the new type of curriculum would be prepared for students and teachers. It would consist of a description of the overall and annual learning goals and a description and schedule of the learning project sequence (themes, learning goals, content, outcome requirements and schedule).

After the preparation phase, the implementation could be made in two phases:

- Implementing the solution within a limited part of the organisation (eg single EE programme): The courses of this programme would be replaced with a sequence of learning projects and ICT networks would be used to implement the basic functions of the operation.
- Completing the transition within the whole organisation: During this phase, computer networks would be extended to handle all of the functions.

Facilitating the Implementation Process

During the development of the new EE model, special emphasis has been placed on solving the implementation problems associated with the qualitative transformation needed. The design and implementation phases must have the direct support of the senior management and ownership of the institution. Management must reserve resources for a small team of experienced people to lead and carry out the project work. Furthermore, resources are needed to free time for participating faculty members so that they can undertake the additional development work required during the whole design and implementation period.

To facilitate the transition, the structure of the reengineered EE programmes must be kept as simple as possible. Modern ICT (wireless computer networks) must be used from the start to minimise the unproductive work of teachers and to make the basic material available to teachers in a compact form. The new model also provides flexibility in selecting and formulating a learning project sequence together with local industry.

For faculty and staff members, the preparation phase and the implementation phase form a long-term learning process. The new model must include education and training for teachers as an integral part of the model in order to facilitate the continuous learning process and support the practice of doing tasks in a new manner. During the transition, faculty members would have the opportunity to specialise, for example, in becoming learning project managers, teachers, mentors or specialists in engineering and technology.

Incentives for the Restructuring of EE

Until now in Finland, the competition between EE organisations has not been real in the sense that it had forced institutions to make real adjustments. The situation may change during this decade, as the transformation of the higher education system continues. Companies in international markets are driven by direct feedback, which forces a change in their operation when the environment changes. This mechanism is based on the personal effects of the environment on the individual people within the organisation. EE institutions are examples of organisations (typically in the public sector) that lack this kind of mechanism. Therefore, in order to accelerate the adoption of new EE solutions during this decade, pressure and influences from companies, professional engineering organisations, accreditation institutions and governments are needed.

POTENTIAL ADVANTAGES OF THE NEW EE MODEL

Ongoing work in Finland suggests that the new model would provide several advantages. To EE organisations adopting the model, it would provide benefits in the competition for high-quality students, faculty and staff and lead to more efficient utilisation of resources, including the know-how and creativity of faculty. It would also naturally bring about systematic long-term cooperation between education organisations and industry and direct EE institutions towards producing active and innovative people for the benefit of regions and nations in the future global competition.

To industry, the new model promises to produce higher-quality engineers: *young engineers with the latest know-how and long experience in industry*. These engineers are particularly valuable for companies operating in international markets.

To students, the new EE model offers more effective and rewarding learning and real personal electiveness. The internally-driven process naturally enhances the self-knowledge and personal strengths of students, directing them towards employment or an entrepreneurial career, improving their employment opportunities and forming a natural start for a successful career in engineering.

For teachers/faculty members, the model makes work more rewarding and enjoyable. It naturally directs teachers towards cooperation and becoming coaches/mentors/leaders, while also enhancing continuous professional development.

Cooperation between EE Institutions and Industry

The main result of this restructuring is that the operation and organisation of new EE organisations would correspond to those of a modern company in international competition. The main difference would be that corporations concentrate on business operations, while education organisations concentrate on effective learning. The change would considerably lower the barrier between EE institutions and industry and eliminate the discrepancy between education and modern work life.

The new model is also applicable to continuing EE, continuous professional development and other fields of technical education. This restructured EE represents an example of the fundamental reengineering of professional and academic education to meet the new needs of societies in the global environment. The change of the structure of education would also be important for developing countries of the world.

DEVELOPMENT WORK OF EE IN FINLAND

The work described in this article is based on the ideas and initial work undertaken in project-based adult education and engineering education at the University of Oulu in Finland in the 1970s. The ideas described in the paper by Miles et al decisively contributed to this initial work [1]. The structure of student-driven real-world education has been developed and tested in the continuing EE and entrepreneurial education of the University of Oulu in the early 1980s [2].

The new approach to EE has been developed in 1993-1997 at Kymenlaakso Polytechnic in south-eastern Finland. During 1998-1999, the structure of the new model was developed in an R&D project funded by the Ministry of Education in Finland and the European Union [6]. Parts of the model have been pilot-tested during 1997-1999 at the Department of Mechanical Engineering at Kymenlaakso Polytechnic. The theoretical and experimental work during the 1990s also confirmed the feasibility and potential advantages of the new EE solution.

Since 2000, the development and implementation of the new EE model has been continued at Helsinki Polytechnic, Helsinki, Finland. Since August 2001, the new EE model has been pilot-tested with two groups of students in the programme of industrial management [7]. The new four-year BSc programme leads to the MSc degree as part of European cooperation [8]. The work is being carried out by a team of approximately 25 dedicated faculty members and specialists.

Future Work in Finland

During 2003-2005, the testing and implementation of the new solution will be continued at Helsinki Polytechnic in the EE programme in industrial management. Present plans call for the new model to be extended to a new EE programme in autumn 2004. The theoretical and experimental work will be carried out as a systematic long-term R&D effort with partners from industry and EE organisations.

The work has also manifested a need for a new student selection system/process to minimise the problem of students who drop out of programmes in EE and other professional and higher education on the national level. The new system would be based on implementation of the new operating mode during the first study year, adapted to the special engineering fields by means of selecting and formulating the themes and contents of a portion of the learning projects. The new solution would facilitate and support individual choices based on the personal plans and goals of students.

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