E4 Thematic Network:
Enhancing Engineering
Education in Europe

VOLUME C

Innovative Curricula in Engineering Education

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with contributions of
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Preface

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From the constitution in Louvain (February 2000) throughout 3 years of activities (until October 2003) the SOCRATES Thematic Network E4[1] (Enhancing Engineering Education in Europe), with its Activity 1 "Employability through Innovative Curricula", contributed in various ways to current discussions on curriculum development in Engineering Education (EE) in Europe.

Immediately after the Bologna Declaration and the ongoing Bologna Process the adaptation of curricula to the envisaged two and three cycle system of the European Higher Education Area (EHEA) ranked high on the agenda. The roughly 15 active participants of Activity 1 therefore concentrated on urgent questions of two tier curricula in the first year of their work. In a sub group chaired by Oddvin Arne, Professor at Vestfold College in Norway, a proposal for core qualifications of two tier curricula was elaborated and presented to the Network. The document has been also discussed during a conference on two tier curricula drafted in cooperation with the Curriculum Development Working Group of SEFI[2], hosted by the Vilnius Technical University, Lithuania, and organised by Professor Algirdas Valiulis, Vice Rector International and member of A1. That proposal is now also a significant part of this publication.

The day by day work of Activity 1 concentrated on topics of quality standards and outcome orientation of curricula, an issue highly relevant not only for curriculum development but also for transparency of programmes and readability of degrees, for quality assurance and accreditation. A workshop on Outcome Orientation and Output Standards, organised by the A1 promoter Günter Heitmann at Imperial College (London) in April 2002, provided a good opportunity to confront the A1 discussions with an ongoing debate on these issues in the UK. To the workshop contributed some invited speakers from the Engineering Professors Council (EPC), the Quality Assurance Agency (QAA) and the Engineering Council (EC). The results have been presented meanwhile to various workshops and conferences on accreditation and quality assurance, partly organised together with Activity 2 of E4, and also to the first International Colloquium on Global Changes in Engineering Education, organised by the A1 promoter together with the American Society of Engineering Education (ASEE) and SEFI and hosted by the Technical University Berlin in October 2002. Outcomes of these discussions are also reported in this volume.

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[1] www.ing.unifi.it/tne4/
[2] Societé Européenne pour la Formation des Ingénieurs (www.sefi.be).

Recent debates within Activity 1 were focused on the question of outcome assessment and its contribution to continuous improvement of curricula and of teaching and learning. These topics were highlighted at a conference of A1 in cooperation again with the Curriculum Development Working Group of SEFI, hosted in May 2003 by the University of Valladolid and organised by Urbano Dominguez, Professor of this University and member of Activity 1.

Activity 1, mainly through its promoter, disseminated the outcomes of the current work by contributions to various activities and events, namely the Engineering Synergy Group of the Project "Tuning Educational Structures in Europe", the Thematic Network of Civil Engineering (EUCEET), ESOEPE Conferences, the Helsinki Conference of SEFI and CESAER in preparation of the Bologna-Berlin 2003 Conference, the Bologna Process Seminar at Villa Vigoni, the World Conference on Engineering Education 2003, organised by the World Federation of Engineering Organisation (WFEO) and the American Society of Engineering Engineering (ASEE), last but not least the Glossary of Terms Group of E4 (see Volume B of this publication).

Unfortunately, due to the small group of active participants and to the limited and decreasing amount of time which they were able to invest, Activity 1 did not cover all the topics originally intended. Moreover, from the very beginning, curriculum issues of special subject areas of engineering and of emerging branches, besides our proposal of qualification profiles (Chapter 7 of this publication), have not been taken into account and left to the respective specialised networks. However, this report covers many issues of curriculum development based on the experiences of Activity 1 members and the previous work done in the same field (e.g. in the frame of SEFI and its Curriculum Development Working Group as well as on examples of good practice presented in Journals of Engineering Education or on SEFI Annual Conferences)

Thanks to all members of Activity 1 for active participation and continuous interest during the time of existence of the working group. In particular a special acknowledgement goes to all those members of A1 who spent a lot of additional time for the organisation of conferences like Algirdas Valiulis, Urbano Dominguez and Otto Rompelman (TU Delft and chairman of the SEFI Curriculum Development Working Group), for the preparation of special reports like the Guidelines for Core Profiles of two tier Curricula, drafted by Oddvin Arne, Urbano Dominguez and Jan Nadziakiewicz (Silesian University of Technology, Gliwice) or contributing to seminars and to this final report, namely Oddvin Arne (Vestfold College, Norway) with the Guidelines on Core Profiles (Chapter 7) and Aris Avdelas (Aristotele University of Technology Thessaloniki the Demands part (Chapter 3).

This report is not an edition of various individual contributions but covers in a systematic way different topics with regard to curriculum development and innovative curricula based on work, discussions and experiences of A1 members. It should invite and stimulate discussions in the dissemination year of E4 started in October 2003.

The hope is that interesting reference points for future development of curricula in EE in Europe are provided and can thus function as kind of a guideline.

1. Introduction

1.1 Enhancing Engineering Education in Europe and Curriculum Development

Enhancing Engineering Education in Europe requires to a major extent a focused and continuous revision of existing programmes and the creation of new programmes of study based on the development of innovative curricula and the improvement of teaching and learning. This was the reason why within E4 Thematic Network, differently from the previous Thematic Network H3E, curriculum development has been explicitly addressed by establishing Activity 1 “Employability through Innovative Curricula”.

Promoting or ensuring employability is certainly an important driving force for curriculum revision and development. As a consequence of the Bologna Declaration it gained actual attention as the implementation of a two-tier system of higher education in Europe was and is coupled with the explicit expectation that at the end of the first cycle and a minimum of three years of study a certain degree of employability should be achieved. Programmes of EE in Europe so far tended to take at least 4 years or even 5 to 6 years, as long as research-oriented university programmes were concerned. A lack of employability in the traditional, and often binary, not consecutive system of EE in Europe was not really perceived as a crucial problem. It appeared that one of the greatest challenges for curriculum development was to find the way to attract enough, and not primarily male, students to study engineering. This was identified in strict connection with the rapid expansion of the body of knowledge in science and engineering and the new ICT[3] media, which contribute creatively to the solution of environmental, technological and societal problems and foster entrepreneurship and economic development. But in addition, since some years, there has been a loud call for changes from the increasing complaints of employers. This referred mainly to a lack of basic economic knowledge and management skills and of so called “soft skills”, namely having learned how to learn and obtain communication and teamwork skills.

1.2 Aims, Themes and Working Methods of Activity 1

The Activity 1 group – discussing a work schedule – felt that the relation of employability and innovative curricula is a necessary but by far a too narrow approach with regard to curriculum development and the enhancement of EE in Europe. It was decided that the European dimension should be placed on top of the agenda, in particular

[3] Information and Communication Technologies.

- how changing frame conditions caused e.g. by the Bologna Process,
- how the facilitation of mobility by different means of harmonisation and increasing transparency, and
- how the improvement of international orientation and quality assurance

can be tackled by innovative curricula.
Apart from issues of internationalisation and curriculum development some more general aspects of innovative curricula should be approached.

The Activity 1 working methods have been e-mail corresponding, reports, thematically focused seminars, workshops and meetings. With particular reference to the seminars and conferences which Activity 1 organised, or was involved in, an attempt has been made – besides collecting informations about the state of the art – to stimulate discussions on innovations in curriculum development and to disseminate results already achieved.

It turned out that the Thematic Network, as a cooperation platform, offers at best an active forum for state of the art descriptions, systematisation and structuring of knowledge gained, sharing experiences and disseminating good practice examples between higher education institutions. On the other hand, it was observed that the lack of time and of inappropriate financial support, particularly in terms of money for staff or work contracts for necessary research and for time consuming and more representative investigations, definitely limited the outcomes and diminished the interest in networking and working on such a project. However, taking these limitations into account, Activity 1 has tried to contribute to the European process of developing and enhancing engineering curricula in the frame of Bologna by focusing on crucial issues of this process.

2. Criteria of Innovative Curricula

2.1 Responsive to New Demands, Creative Towards New Offers

The continuous development of curricula and of teaching and learning strategies is emphasised in the Higher Education Law of some European countries as a central responsibility and duty of the Higher Education Institutions. In the frame of growing autonomy of universities on one side and the corresponding call for accountability on the other, it explicitly became a focus of quality evaluation and quality management. Even more recently it turns out to be a powerful and necessary approach towards competitiveness on a national or transnational, if not global, educational market. In EE, because of additional, reasons it seems even more evident than in some other academic branches that continuous innovation is essential in order to adapt to the fast growing body of knowledge and new scientific and problem-solving approaches and to demands from society, students and employers.

Adapting to new contents and methods is by far not the only criteria for innovative curricula. In general "innovative curricula" in this context are understood as curricula, which show responsiveness to new demands and possibilities. In order not to restrict changes to only demand driven reactions the development of curricula should also try to create and provide new offers with regard to modern subject areas and promising qualification profiles, using the potentials of innovative teaching/learning arrangements as well as ICT.

2.2 Specific Criteria of Innovative Curricula

More specifically and besides responding to:

- new developments in science and technology,
- changing demands of employers, and
- governmental calls for internationalisation,

innovative curricula in EE should address the following aspects:

- a shift from a teaching to a learning-centred approach,
- a move towards an explicit competence and outcomes orientation,
- the adoption of a comprehensive and holistic concept of curriculum development aligning competence oriented learning objectives, provision of appropriate learning arrangements and assessment procedures, finally, continuous feedback and quality improvement,
- flexibility to address different learning styles, student interests and abilities and barriers of underrepresented groups of students like e.g. female students,

- an appropriate and effective use of modern teaching and learning technology,
- a support of life-long learning by explicitly educating “reflective” learners.

Most probably many curricula will not deal with all the aspect mentioned. The extent to which they refer to the listed aspects thus can also determine diversity and profiles as well as good practise within European EE, apart from well known attempts to distinguish between e.g. application and research oriented qualifications and levels.

3. New Demands

3.1 Reacting to Changing Working Environments

One of the major challenges for the curricula is that they should provide capabilities to face the new and / or changing economic and cultural working environments. The internationalisation of trade and industry, the introduction of new materials and processes and the fast expansion of the information technology have changed many aspects of the engineering practice. New demands are often conflicting between themselves. It has to be decided to which ones precedence should be given.

The engineers of tomorrow have to acquire much more and more diversified skills than their predecessors did. They will have to take into account the human dimensions of technology, to be sensitive to cultural diversity, and know how to communicate effectively in a global level.
In addition to a solid basic engineering knowledge, they will also need the ability to face and solve problems together with other scientists. The understanding of subjects such as economics, marketing and management will be required.

So tomorrow's EE will need to be focused not only on technical knowledge but also on providing the students with the ability to learn, to analyse, to synthesise, and to creatively apply fundamental engineering principles to new problems.
In addition to all that, the next generations of engineers will have to have an aptitude for life-long learning.

3.2 New Teaching and Learning Technology

Another challenge for engineering curricula is the incorporation of ICT and ODL[4]. They both rely on long distance communication, an aspect of modern life that will become a very useful tool for future engineers.
The possibilities offered by ICT together with the next generation of engineering software will dramatically change the engineering classroom and will help the students, by improving accessibility to education and training, to more easily understand and solve real life engineering problems. On the other hand, it will be a very important issue for the teachers to balance this new way of learning with the traditional student-teacher and student-student interaction.
In ODL, the design and the implementation of the appropriate environment (considering pedagogical aspects) is very important for high quality EE. The

[4] Open and Distance Learning.

advantages and disadvantages of the different ODL systems (e.g. Computer Based Education, Knowledge Robots, Intelligent Tutoring Systems, Pedagogical Agents etc.) have to be evaluated in each case.
ODL further raises another class of challenges, not technological but “administrative”. They refer to the way ODL courses are graded and by whom, how these courses can be accredited and, most important, who teaches and who follows these courses.

3.3 Interdisciplinarity and Working in Teams

Engineers have always worked in teams. Yet this old fact tends to become an unavoidable necessity, since working on very complex systems with close interaction and interdependence of various components and aspects makes ever more necessary for engineering students to become accustomed to think along interdisciplinary lines in their approach to problem-solving. In the following two points such subjects will be briefly outlined.

New Materials

It is now well accepted that materials are crucial to the quality of life, and to economic security and competitiveness. New materials will play a key role in solving many technical problems facing society, improving the design and development of modern devices, structural products etc, increasing the efficiency of energy utilisation, achieving major breakthroughs in future technologies, such as the ones associated with telecommunication, medicine, nanostructures and intelligent materials and helping industry maintain and improve international competitiveness.
The introduction of new materials courses calls for interdisciplinary coordinated curricula cutting across departmental lines. Faculty from various departments and with different backgrounds will have to participate in integrated and interdisciplinary programmes of study encompassing both the necessary scientific fundamentals of chemistry, physics, and mathematics and their technological and engineering applications.

Intelligent Buildings

Another subject that calls for interdisciplinary coordinated curricula is intelligent buildings. An intelligent building is defined as the one that maximizes the efficiency of its occupants while at the same time allowing effective management of resources with minimum lifetime costs. The complex interdependencies of the systems, required for an intelligent building to function, calls again for faculty from various departments that will have to cooperate in the framework of integrated and interdisciplinary programmes.

3.4 Environmental Issues

EE must enhance the environmental sensitivity of the students. Design methodologies incorporating the principles of sustainable development and must be utilised throughout the education of engineers. Furthermore, standards for environmental protection should be highlighted during the formative period of engineers, so that their use becomes a natural part of the later practice of the engineer after graduation.

3.5 Engineering Ethics

The understanding of the rising role of the engineer as a policy maker whose decisions have a wide impact to society has created an increasing need for special courses to help engineers to develop a better understanding of the role of technology in shaping public policy and developing a moral-reasoning process. Courses in ethics and pubic policy in the engineering curricula will instill in graduates a greater sensitivity to risks, societal values, and the will to resist management decisions not adequately technically supported. They will also give the students a broader understanding of the nature, side effects and societal aspects of technology, of the ethical issues at stake in their professional practice, of their legal and moral responsibility and of the levels of responsibility (individual, corporate and profession, society) induced by the technology they contribute to develop.

3.6 Research versus Application Demands

Research and educational partnerships between universities and industry improve the quality of EE and strengthen the competitiveness of industry. This can be achieved by providing a technology-focused, industry-informed, interdisciplinary educational environment in which students are educated by, through and in conjunction with active participation in the performance of cutting-edge engineering research and technology innovation. The integration of research and education can produce both new technology and curriculum innovations. Faculty members can play an important role in this process by developing teaching material based on their research results, bringing in this way their students in contact with engineering research and by encouraging the innovation capabilities of the students.

Yet, the golden rule is to be found. Although the trend is to train students on how to work in research projects, it must be remembered that engineers are closely related to practice. For this reason, engineering curricula should include an early exposure of the students to practice. In addition, increasing activities should be taken towards entrepreneurship education in the context of EE.

3.7 Attracting Students

Because of various reasons, in many countries the interest in enrolling in engineering programmes of study has dramatically decreased. Consequently the demand for improving the attractiveness of these kind of studies by providing innovative programmes and challenging learning environments has been expressed. In particular it is hoped that innovative curricula could help to interest female students and raise their share on the engineering students and graduates, which, in some engineering branches, is below 10%. Even if it is obvious that the curricula itself are not the main reason for this unsatisfactory state of the art, we know from some experiences that innovative curricula can contribute significantly to better the situation.

3.8 Interests of Students and Graduates

Responding to demands of employers and trying to achieve employability does not necessarily cover all the interests of the students and future graduates, in particular when only short term interests are satisfied in employer-oriented qualification profiles. Graduates need to be prepared for life long learning and for competing successfully on an ever changing labour market. In addition, students as learners with different abilities and learning styles want to find a certain diversity of offers and challenging learning situations addressing the increasing heterogeneity of the student body. They do no appreciate to be threatened by inappropriate assessment and selectivity patterns. They also expect programmes with a certain degree of flexibility in terms of individual options, recognition of prior learning and the opportunity to profit from part time and distant learning.

4. Internationalisation[5]

4.1 Internationalisation as a Key Strategic Goal in Higher Education

Besides of what has been previously described, internationalisation has become a main challenge and driving force of curriculum development in EE and in due course a key strategic goal on various levels of higher education (EUA 2003). It covers a broad range of approaches and activities, which in different ways affect the development of curricula:

- internationalisation on the higher education systems level through adapting to common reference structures, credit and grading systems, accreditation and quality assurance standards;
- internationalisation at the higher education institution level through transnational cooperation in education and research based on bilateral agreements or multilateral networks; offering programmes of study on a global educational market by attracting foreign students to leave their home country or addressing them in their home country by ODL, Virtual University offers or establishing university extensions abroad;
- internationalisation at the department and programme level offering programmes or courses/modules in foreign languages, incorporating intercultural modules, integrating study or internship abroad phases, creating joint and double degree programmes, facilitating the recognition of modules and outcomes gained in foreign countries;
- internationalisation at the staff and student level by promoting the idea of studying or working part time abroad, encouraging student driven international activities like transnational student bodies, mixed international teamwork and summer courses, funding student and staff exchange through various sources, providing international experiences for students at home and increasing virtual transnational cooperation.

Internationalisation is facing many obstacles namely in the area of national law and institutional traditions and regulations. And by far the majority of staff and students still hesitates or is reluctant to be involved in any kind of international activity. However, governments and Higher Education Institutions through different means are on their way towards internationalisation trying to make it a significant feature of their research and educational offers. Europe with regard to the 15 EU member countries and the associated countries supported internationalisation increasingly through various cooperation and exchange programs like ERASMUS, Tempus, Leonardo, SOCRATES and Alfa.

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[5] This topic has been treated also by Activity 4 Working Group which dealt with “Enhancing the European Dimension” (cfr. Volume E of this publication).

A tremendous drive was caused by the Sorbonne (1998) and Bologna (1999) Declarations and the subsequent and ongoing Bologna Process – meanwhile signed and supported by 40 European countries – aiming at the creation of a common European Higher Education Area (EHEA) by 2010 and linking it increasingly to the European Research Area (ERA). Also the Lisbon Convention (2000) contributes remarkably to the process of internationalisation. This is mainly due to the fact that it comprises even more countries as signatories. It addresses and facilitates mutual recognition and introduces the Diploma Supplement as a tool of increasing the transparency of qualifications.
Comparable initiatives and activities are to be registered globally, partly based on values which traditionally characterized university research and education but more and more driven by the strive for economical competitiveness.

4.2 The European Approach: Harmonisation and Diversity

Europe's claim for becoming the most competitive economy by 2010 is to great extent based on the improvement of higher education and research and the achievement of excellence. It is widely accepted that one of the central aims will be the improvement of the quality and comparability of degrees and outcomes. Thereby the international attractiveness of higher education will be increased and the mobility of students and staff, of graduates and finally the work force in general will be facilitated.

Harmonisation of structures and curricula in higher and vocational education could be a means to achieve this aim more or less easily as far as other obstacles are not hindering mobility and exchange of ideas and people. Not surprisingly harmonisation of educational structures as a central goal was already stated during the fifties of last century in the Treaties of Rome at the beginning of the process of European integration and cooperation. But soon it turned out that this aim could only be achieved by a long-term bottom up process due to significant differences and traditions in the European education systems and the lack of power devoted to European bodies with regard to educational and cultural affairs. It also became more and more evident that keeping the cultural heritage and developing diversity could contribute positively to an integrated and competitive Europe. The tension between the conflicting aims of harmonisation and developing diversity thus characterized the European development since decades. Consequently the current move to convergency through a common reference structure of two, respectively three cycles of higher education based on the Bologna Process is still and should continue to be accompanied by the improvement of transparency of divergent degrees and approaches in order to facilitate mutual recognition and the fruitful development and competition of good practice. National recommendations and laws implementing the Bologna Declaration aims thus should not be too rigid and prescriptive to not threaten creative and innovative solutions to emerge.

Besides of common reference structures the development of a “European Dimension” within the programmes offered (or even a “European Curricularisation” in terms of developing transnational modules and joint programmes), as well as agreeing on common core qualifications or curricula, is one of the challenges for innovative curricula and was the focus of the E4 Activity 1 considerations.

4.3 “Global” Education

In EE a strategy of “Europeanisation” tends to be far too limited when answers to the question of necessary international competences of graduates are to be found. What is needed is a kind of “global” education.

To the extent that engineers will be involved in the management of technology in a global context, their education should prepare them for this role. In the years to come, more and more of the engineering projects will be performed by ad hoc combinations of specialist firms that come together from different parts of the world to tackle a single project and disband upon its completion. The modern engineer must learn to perform teamwork in an ethnically diverse and geographically distributed global environment. Engineering students must get this ability at least basically already through their programme of study. With regard to changing needs on the local, national but also global labour market engineering graduates will have to achieve a far higher flexibility than they were used to up to previous times.

A significant part of this education should address professional ethics and code of practise and refer to global demands on sustainability and societal demands.

5. The Overall Frame Conditions and Structures of Engineering Curricula

5.1 Diversity of National Systems and Traditions and the Challenge of the Bologna Process

Since systematic education of engineers emerged and became part of either the vocational or the higher education system in the 19th century the basic approaches and the main structures of the programmes followed different lines according to national traditions and needs. With a growing number of students requiring university education and an uprising demand of differently qualified engineering graduates by a big range of employers the diversity of systems, degrees and programmes increased dramatically. In European countries to a different extent – besides of 4 to 6 years long university programmes often linked to or based on research – a remarkable variety of 3 to 4 years programmes aiming at a more application oriented and professional engineering qualification came into existence. In addition, on a sub degree level different types of technician education were established, mostly based on 2 years programmes.

This parallel system of long and short programmes in EE, either provided within the Universities or Universities of Technology or by different types of additional institutions like Polytechnics, Technical Colleges, higher education Engineering Schools or Fachhochschulen – despite of some problems of mutual recognition on national and international level – in general proved to be quite functional with regard to the needs of employers and society. A certain degree of comparability and transparency of the diverse EE and degrees has been achieved throughout Europe permitting international exchange of students and cooperation of staff to happen. Also the recognition of degrees by the EU General Directive of 1988 and other means like the FEANI register of EurIngs was somehow settled in Europe. Challenges in EE derived primarily from changing demands from employers and the development of science and technology than from recognition and mobility issues. The Thematic Network H3E as a predecessor of E4 therefore tried to contribute to the achievement of issues of improving quality and transparency in European EE rather than proposing new structures.

The Bologna Declaration aims to implement a two cycle sequential system as a general feature for all disciplines of higher education. In many European countries this was perceived more as a threat than a promising frame for future developments and the improvement of quality in EE. In Europe only UK and Ireland had this kind of sequential system with bachelor and master degrees in existence and by transforming the Polytechnics to Universities in 1993 the UK skipped the binary structure and strengthened a 3 plus 2 system. This structure was – at least according to the formal length of studies – also not comparable to the 4 plus 1 bachelor / master system of the

USA. Partly in order to avoid potential problems of international recognition and in addition to raise the quality in EE higher education institutions in the UK, following the so called SARTOR III recommendations of the Professional Institutions, four years programmes have been implemented. They do not provide a bachelor degree like in USA but claim to arrive at a level of quality worth to award a master degree. The MEng degree is now the required educational standard for becoming a Professional Engineer, known as Chartered Engineer, after additional three years of respective Initial Professional Development and registration with an Engineering Institution. In addition a route to a so-called Incorporated Engineer (IEng) was established based on a three years bachelor degree plus Initial Professional Development and registration.

SEFI, as well as CESAER[6] and many national academic and professional bodies of engineering educators and engineers have repeatedly published their support to the general aims of the Bologna Declaration and the creation of a European Higher Education Area (see http://www.sefi.be). In due course they expressed their concern that a too rigid application of a two tier structure with three years of study as the frame for achieving a first cycle degree and additional two years for a second cycle degree may diminish the quality, the typical features and the international competitiveness of the European Engineering Education. In particular this seems to concern the achievement of satisfactory employability and of Trans-European international recognition for three-year programmes and degrees. It also applies to the maintenance of research and theory orientation of long integrated university programmes leading directly to a second cycle respectively master degree level.

CESAER and SEFI, supported by E4 Thematic Network, contributed recently, with the outcomes of their 2003 Helsinki Seminar, to the Bologna-Berlin Summit of the signatories and further shaping of the Bologna process (see Annex 1 of this volume). The recommendation regarding the overall structure is a confirmed support of a two, including a doctoral phase three-cycle structure in general but a strong plea to provide open frames. Options for diversity must be offered e.g. for the conservation of long integrated programmes leading directly to a second cycle respectively master degree.

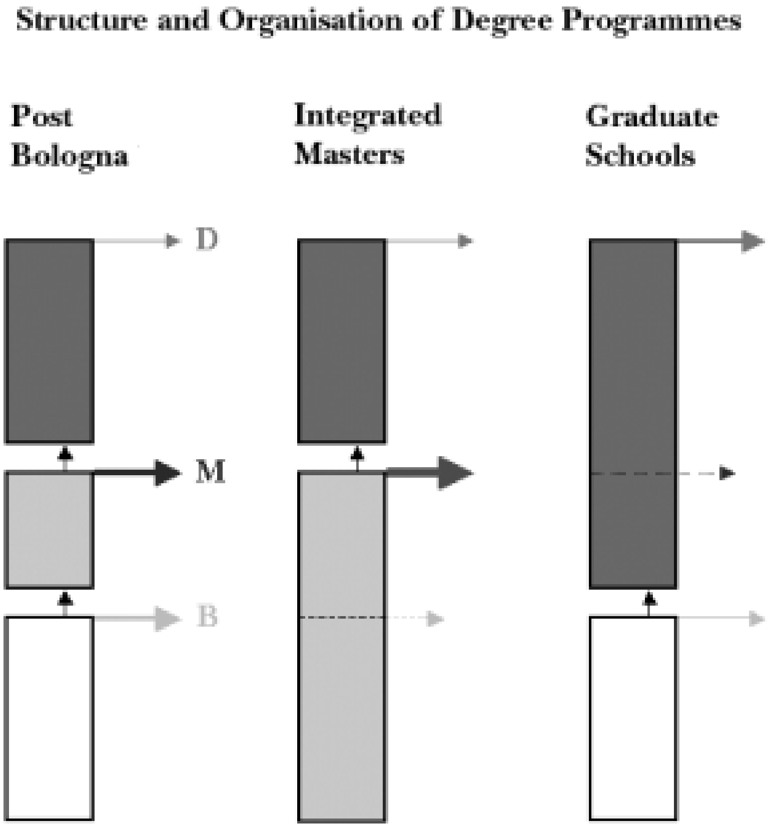
In addition the successful application oriented programmes towards a first degree in many European countries should be maintained. It is hoped that a time frame will be found, possibly exceeding three years of study, where typical features like internships, semesters in industry, various projects and final thesis work can be kept. Recent recommendations based on stakeholders, signatory countries seminars and discussions in the wake of the Bologna Process, seem to allow these options by stating that the programmes towards a first cycle degree should comprise 180 to 240 ECTS credits. With 60 credits connotated to one year of full time study and with an overall workload of 25 to 30 hours per credit this amounts to three respectively four years of study. Second cycle programmes should comprise 90 to 120 credits with at least 60 credits at

[6] Conference of European Schools for Advanced Engineering Education and Research.

advanced level. As far as integrated 240 to 300 credit programmes are also possible, this frame would provide enough options and flexibility for EE to maintain quality and to develop innovative curricula.

During the Helsinki Seminar the following structure was presented as a possible general "post Bologna" frame encompassing also the doctoral cycle (Gareth Jones, Imperial College London: "Beyond the Bachelors"). This structure would offer enough options with still the crucial question on which role a three years bachelor in EE can play in the future.

For the time being it is not quite clear how the various national authorities will act



in the future and whether a flexible approach to different professions and academic disciplines will be taken. Throughout Europe a high degree of diversity, if not confusion, still persists. There are however some indications that a majority of governments would prefer a rigid 3+2 solution with a tendency to let the majority of students finish higher education after a first cycle degree. This is mainly due to financial reasons. The higher education systems in Europe are still predominantly state funded and are facing new challenges if the political goal of increasing the number of students or providing higher education for higher percentage of an age group would be implemented.

Not only for EE it can be questioned whether by a superficial convergence of time frames the envisaged compatibility and recognition can be achieved as long as different intake levels, selectivity patterns, assessment and grading approaches and professional development schemes are not taken into account.

E4 Activity 1 at its 2002 Vilnius Conference on two tier curricula and also by its state of the art investigations has monitored the process of implementation of new curricula and degrees.
(SEFI Document: Bologna Spirit in Two Tier Engineering Education Curricula Development) As far a the Bologna structures have been implemented in EE different types of programmes of 3 and 4 years but also 3 and a half year duration to a first cycle degree can be observed, in some countries like Germany even all of them, in Italy a rigid 3+2 frame (see the SEFI Portfolio on the Bologna Process at http://www.sefi.be). The main challenges for curriculum development obviously concerns the 3 years programmes, in particular when in due course employability and satisfactory professional education and training, as well as a profound scientific foundation for a continuing advanced study in the second cycle, must be provided.

Activity 1 has therefore reacted to this challenge and attempted to design a kind of core curriculum for the 3+2 frame as points of reference, not in the traditional approach of content lists but in an outcome oriented approach as a set of ability statements with regard to core subjects. These cores express minimum standards and have to be enhanced by additional requirements and curricular and educational provisions to arrive at certain qualification profiles (see chapter 7 of this volume). By additional requirements with regard to typical profiles or labels, national conditions and traditions or with regard to problems of international recognition for academic and professional qualifications these enhancements may well exceed the notional time frames for each cycle or the relation between the two cycles up to a frame of 4+1.

5.2 Levels and Profiles

Generalised determinations of levels and profiles in terms of duration of cycles or programmes of study or in terms of credits respectively calculated student workload do not provide a satisfactory frame for curriculum development, quality assurance, for comparability and readable degrees, as e.g. the Bologna Declaration aims at. Besides quantitative and qualitative criteria have to be stated and taken into account. To be operational and assessable these criteria should be focused on outcomes and not on inputs. As long as they are just general statements they have to be specified for different disciplines and professional orientations, as, for instance, the engineering field.
Some countries in Europe like the UK, France and to a certain extent the Netherlands

since the 90ties have tried to develop comprehensive qualifications frameworks encompassing all levels of their educational system including higher education. Particularly the UK has tried to follow an explicitly outcome oriented approach. In addition, for higher education the Qualification Assurance Agency (QAA) has undertaken the initiative to specify the bachelor with honours level with regard to different disciplines by subject benchmarking. Following a generalized format for each of the subjects chosen, in EE the outcomes and threshold standards have been specified with regard to knowledge and understanding, intellectual abilities, practical skills and general transferable skills. Different bodies have undertaken other attempts and we shall refer to it in some detail in chapter 5.3.

Based on UK experiences and with regard to the two cycles aimed at in the Bologna process the so called "Joint Quality Initiative", a group formed by representatives of some national Quality Assurance Agency which at the same time are members of the European Network of Quality Assurance Agencies (ENQUA) have tried to define certain generalized level descriptors. These so called "Dublin Descriptors" are meant to provide reference points for the necessary qualitative dimension and convergence with regard to the two Bologna Declaration cycles:

Bachelor	Master
Have demonstrated knowledge and understanding in a field of study that builds upon and supersedes their general secondary education, and is typical at a level that whilst supported by advanced textbooks includes some aspects that will be informed by knowledge of the forefront of their field of study	Have demonstrated knowledge and understanding that is founded upon and/or enhances that typically associated with Bachelors level and that provides a basis or opportunity for originality in developing and/or applying ideas, often within a research context
Can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study	Can apply their knowledge and understanding and problem solving abilities in new and or unfamiliar environments within broader (or multidisciplinary) contexts related on their filed of study
Have the ability to gather and interpret data to inform judgements that include reflection on relevant social, scientific or ethical issues	Have the ability to integrate knowledge and handle complexity and formulate judgements with incomplete or limited information, but that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgements
Can communicate information, ideas, problems and solutions to both specialist and non- specialist audiences	Can communicate their conclusions and the knowledge and rationale underpinning these, to specialist and non- specialist audiences clearly and unambiguously

Have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy	Have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous

The Joint Quality Initiative also summarised the main differences of the two levels incorporated in this overview.

Besides of representing very basic and general qualitative criteria these kinds of level descriptors do not differentiate between threshold and advanced levels and also not between certain profiles on each level. The latter, however, used to be a crucial issue for EE and in general for those countries which had established a higher education system with two or more parallel tracks primarily aiming at different profiles of engineering graduates not necessarily on levels of qualifications. In many European associated countries, even with different types of higher education institutions, who submitted the respective programmes of study, the most prominent distinction is that one between more-application-and-practice and-more-theory-and-research oriented tracks. Examples with long tradition are to be found in Germany, the Netherlands and Denmark, and with quite recently developed Fachhochschule type of institutions also e.g. in Finland, Switzerland and Austria.

In EE the implementation of the two-tier system recommended by the Bologna Declaration did not yet result in a more or less common European approach. The frames and conditions for developing innovative curricula are therefore considerably different.

Italy with the most rigid and top down approach replaced the old system and skipped the binary structure, established within the universities in the early 90ties, and required to develop three year first cycle programmes to a Laurea degree in the different branches of engineering with no distinction in application or research oriented profiles. The ongoing developments of two years second cycle programmes towards a Laurea Specialistica degree may in the future arrive at different profiles. A master degree so far is delivered for special continuing education programmes only.

Germany quite in contrast started to implement bachelor and master programmes already in 1998 and even before the Bologna Declaration. With a revised Higher Education Frame Law Act of August 1998 Germany gave way to a comprehensive experimentation phase whereby the attempt was made to keep the existing system of two different profiles represented by the programmes of Universities and of Fachhochschulen in both cycles. The profiles should be made visible in the denomination of the degrees: application oriented bachelor or master degrees should be called Bachelor or Master of ... Engineering, with the special subject area mentioned in the title, whereas the more theoretical and research oriented profiles should be named Bachelor of Science in ... Engineering or Master of Science in ... Engineering. Thus four different sets of threshold standards for the four different profiles had to be defined by the newly established Accreditation Agencies which have to accredit each one of the newly developed programmes and their delivery and outcomes. The most radical step undertaken by the new law was the cancellation of the previous institutional links: Fachhochschulen (Universities of Applied Sciences) are no longer restricted to offer just first cycle degrees of the application oriented type but can also provide theoretically oriented science bachelor and in addition they can develop and offer master degrees of both types. Vice versa are the Universities encouraged to offer all different kinds of profiles as well?

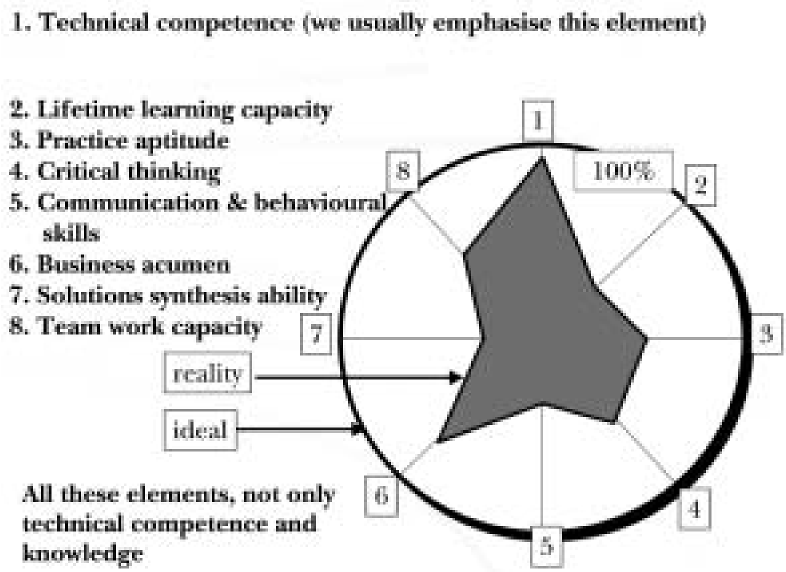
Since 1998 up to 2003 more than 1800 new programmes with bachelor or master degrees have been established. More than 400 are in engineering, mostly in addition to the existing programmes towards the Diplom-Ingenieur (Dipl.-Ing.) degree and with the old system still in place. What makes the situation even more diverse is the fact that bachelor programmes may last from 3 to 4 years, master programmes from 1 to 2 years, in a sequential mode not longer than 5 years. Not surprisingly all variations have been developed. The 16 Federal States (Bundesländer), responsible for educational and higher education affairs, follow partly their own strategies in the implementation of Bologna and executing the options given by the Frame Law Act.

A recent statement (June 2003) of the Conference of the Ministers for Cultural Affairs (KMK) and an envisaged specification aim at joining some kind of simplification but also at increasing the pressure to replace the old system with parallel tracks and degrees until 2010. The simplification is seen in that the distinction between application oriented and research oriented profiles shall no longer exist with the bachelor degree but only with the masters. All bachelor programmes have to strive for employability, and therefore a certain amount of practice and application orientation, and should not be developed as mere preparation for a continuing master programme. However, the Universities of Technologies in Germany continue to argue that the main destination of their educational offers should be the second cycle or master level degree with the bachelor as a pivot point for selecting an individually appropriate if not tailor made (through modularisation and a high amount of optional combinations) master programme. The Fachhochschulen (like similar Higher Education Institutions in many other European countries) may continue to focus on first cycle degrees with strong application orientation but have grasped the new opportunities and offer – at least in Germany – a big variety of master programmes, an increasing number of them of the continuing education type. Degrees now to be used in engineering are preferably Bachelor of Engineering and Master of Engineering or Master of Science. In these cases the specification of the engineering branch or the profile only appears in the Diploma Supplement, but not in the title.

In 2002 France has passed a new Law fostering to implement the Bologna Process type of cycles. But it looks like this will mainly affect the Universities and in Engineering probably the IUT/IUP programmes. The traditional Grandes Ecoles programmes towards an Ingénieur Diplomé based on 5 years of study including one or two years of classes preparatoires at special schools want to continue with their traditional programmes and in addition provide master programmes solely devoted to continuing and special additional education (for a comprehensive overlook of the state-of-the art in EE see the SEFI Portfolio on Bologna at http://www.sefi.be, in particular T. Hedberg (ed.), The implementation of the Bologna Declaration in Higher Engineering Education).

As a conclusion, with regard to various profiles in EE on each of the two levels, it can be stated that a great variety of different profiles (and in addition quality labels) is going to emerge at the second cycle and will leave a lot of options for curriculum development. As far as the first cycle programmes are concerned, a tendency of convergence can be observed throughout Europe with profiling of programmes and outcomes and the quality achieved more implicit and often based on the mission and merits of the respective programme providers. In order to make transparent the profiles and the quality of the programmes it is still necessary to have an appropriate common language of description of outcomes and a valid and reliable practice of assessment. E4 Activity 1 recommends that, for an appropriate description of profiles in certain branches of engineering, more than the usual 2 criteria application and theory orientation should be used.

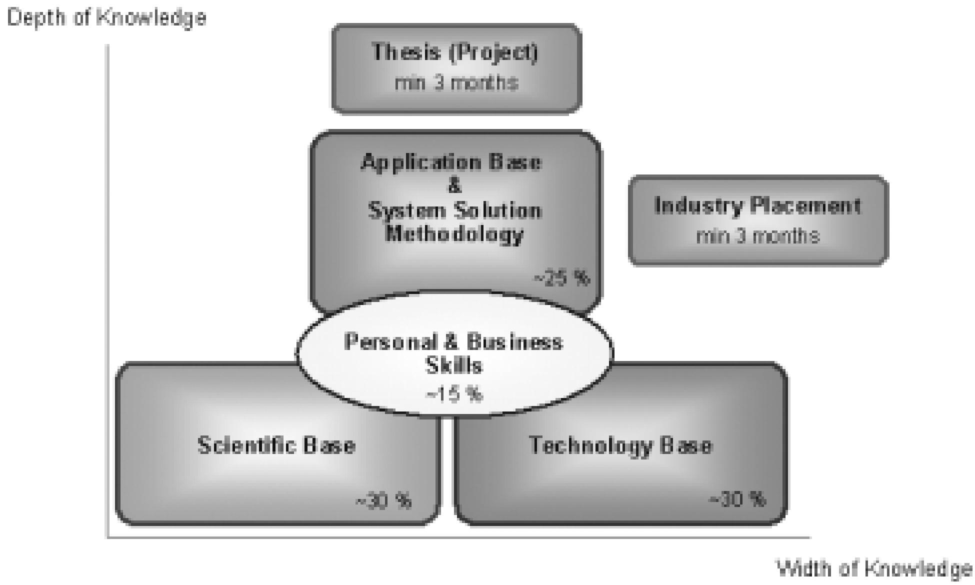
One possible solution which operates with 8 criteria and could be adapted to cover all competences of a certain profile including their intended levels of achievement is given by the following graph:



(Source: Majewski S., Rubinska B., Modernising of educational system at the Civil Engineering Faculty of the SUT in Gliwice, Poland, ppt presentation at a EUCEET seminar at Gliwice, 2002).

For curriculum development itself more detailed competence lists or intended learning outcomes should be used as described in the following chapters.

As profiles are strongly related to the breadth and depth of a programme and are sometimes discussed under the question of generalist versus specialist education a more traditional in-put oriented approach could be based on the different subjects or subject areas involved and the intended level of achievement. This approach is demonstrated e.g. by the Career Space Networkin its curriculum development guidelines for new ICT curricula (source: Careerspace: Curriculum Development Guidelines, New ICT curricula for the 21st century, 2001, for details see http : / / www.careerspace.com.



5.3 The Professional Dimension: Employability, Threshold Standards and the Role of Initial and Continuing Professional Development

Engineering science as an academic discipline with rapidly evolving branches and subject areas is more or less strictly related to engineering as a profession. Achieving a certain kind of employability through the respective programmes of study was thus always a trivial aim of the education and training and the design of the curricula. However, the approaches have to be flexible and can be quite different depending on what kind and level of employability shall be achieved. This does not only apply to the extent employability refers to the demands from employers and society described in chapter 3. It also depends on more legal aspects of employability and of getting access and executing the profession: the right to carry a protected title or to register or get licensed as a professional engineer, the right to execute certain specialities of professional work or to start a business as a freelancer or consultant. Answers to these questions have an influence on the definition of threshold or access standards to the profession, on its application in accreditation or registration procedures and thereby also on the development of programmes and curricula.

The European Union has tried to regulate and to harmonise the access of higher education graduates to the European labour market and to ensure the appropriate recognition by various Special or General Directives and it is currently discussing a new comprehensive Directive. The engineering profession, although heavily striving for a Special Directive, has never succeeded as the architects did. Professional recognition in Europe, but meanwhile even globally, as one aspect of employability continues to be a crucial issue influencing the definition of threshold standards and programme development.

Without going into details here (for this purpose have a look at Volume D of this publication) and focusing only on some conditions for curriculum development, it can be stated that employability, not in the sense of getting a job, but in the sense of getting licensed or getting professional recognition, in more and more countries around the world, is based on achieving an accredited degree in engineering, based on certain standards and often a certain amount of an appropriate practical experience or Initial Professional Development (IPD). Wherever there are, like in the UK or in the USA, a registration, additional requirements on practical experience and additional exams or interviews, towards a professional engineer status, they influence, in some ways, the model of the initial education. For instance: practical experience during the initial education, a practice or research-oriented thesis work are often not required. On the contrary, many continental European countries just rely on the education and training as the only professional qualification, providing, like in Germany, the right to use the title of engineer after having received the appropriate degree. The absence of additional requirements after graduation and the lack of registration patterns have often led to the result that the Higher Education Institutions felt more committed to provide a comprehensive and professionally-oriented EE leading to a master level degree.

For the future, it can be expected that together with the demand for transnational or global professional recognition, registration patterns of professional bodies or chambers will also become a common feature, probably based on experiences already existing (e.g. the Engineering Council in the UK or FEANI in Europe) or on structures currently being established (like the Engineers Mobility Forum). This will at least result in tendencies to refer or agree on global threshold standards for the accreditation of first degree programmes, like already started with discussions in the context of the so called Washington Accord or by referring to existing standards like those of ABET[7]. Europe, with its traditional focus on second cycle or master level qualifications in engineering should contribute to the determination of these standards. Nevertheless, for the time

[7] Accreditation Board for Engineering and Technology.

being, it is hoped that there won't be any problem in surmounting existing standards by the traditional five-years programmes. In due course it should be remarked that also the first cycle qualifications achieve these standards, thus providing not just employability but full recognition and access to the profession. The orientation on comparable outcomes of the programmes now developed and offered under the Bologna scheme, in order to achieve substantial equivalence to internationally recognized programmes, will support this attempt. This seems to be possible even if the duration of studies is not 4 years, as usual at an international level, but 3 years, as often these three-years programmes are based on a more comprehensive and higher level of qualification from secondary school, as the required access level, e.g. compared to the USA.

5.4 Contents of Programmes versus Outcomes Orientation

Traditionally, curriculum development – not only in EE – used to be guided by some fairly vague programme specifications, but an often very detailed list of necessary subjects, contents and associated contact hours. If not totally prescribed by government bodies or fixed through approval or accreditation standards, this in-put driven approaches are at least based on compulsory core curricula with some variety of optional subjects to be developed and offered by a certain Higher Education Institution. It is mostly argued that a high degree of similarity would ensure quality, recognition and, thereby, mobility of students at least on a national level. Also with regard to comparability, on an international level, this approach claimed to be operational but, in the reality, it often failed when it came to detailed comparisons of outcomes and attainment levels. Similarities in the structure of engineering curricula, traditionally often based on two initial years of math and natural science plus foundations in an engineering branch, proved to be superficial with regard to outcomes. This happens as long as access requirements or selectivity of student intake has not been taken into account.

In addition, this kind of in-put related curriculum development, proved to be too much focused on teaching instead of learning. A shift from a so called teaching paradigm to a learning paradigm is sometimes demanded and advocated also for higher education and it is based on respective research results and better understanding of learning and learning styles. It is quite obvious that this orientation towards learning outcomes and performance is partly related to the public call for improved quality and accountability of higher education. But it also corresponds to the fact that with the increase of the number and heterogeneity of students, on one hand, and the differentiation of the demands of employers, on the other hand, different profiles or clusters of qualifications became useful and necessary. They should focus not only on academic knowledge and understanding but on a range of additional attributes and competences. Particularly in EE an emphasis on personal and social competences, or so called transferable or key skills, was claimed for different reasons. Even if implicitly the education of these skills and competences may have taken place to some extent in the traditionally in-put driven programmes, deficiencies were articulated by employers. Only if explicitly addressed in terms of respective learning objectives and intended learning outcomes an improvement of the results seems to be possible. It demands that appropriate teaching/learning arrangements are provided and that the achievement of intended outcomes is properly assessed on a differentiated and regular basis.

Still many countries implementing the two tier Bologna structure of programmes prefer regulations by in-put data as for instance Italy and Spain. Others shifted at least partly to outcomes orientation, manifested in accreditation standards and often combined with specifications of subjects or subject areas like UK and Germany.

CESAER and SEFI in their comments on the Bologna Process (see Annex 1) supported the outcomes-oriented approach towards programme development and specification of qualifications. Activity 1 of E4 strongly recommends to focus curriculum development on student learning and specified outcomes, even when curriculum development or revision starts from subjects or course units. The core profiles developed by A1 as points of reference for an agreement on minimum standards (see chapter 7) try to apply this approach listing the abilities graduates should achieve and demonstrate in certain common and branch related subjects. It was presented and discussed at the A1 workshop on outcomes orientation at Imperial College in 2002 and has been partly revised afterwards. At this workshop and also from discussions in the context of the Tuning Project and ESOEPE it became evident that still quite some differences exist with regard to:

- the respective language terms and the implicit concepts used to specify outcomes,
- the agreement on generic and specific outcomes curricula in EE should be based on,
- the necessity of levels related to specified outcomes, e.g. a distinction between a threshold and an advanced level.

As programme developers and providers should be aware of the respective frames or possible options, some of the approaches shall be quoted here. As regards the terms and concepts the Thematic Network H3E already 1998 has proposed to use a list of qualification attributes which then – in combination with different levels of attainment – can form the basis for describing qualification profiles as a set of intended learning outcomes, but also as record of the knowledge and understanding, the skills and attitudes achieved.

The so called EuroRecord Project financed by the Leonardo da Vinci Programme has determined an elaborated list of outcomes against which an individual graduate or engineer should be able to assess and record his or her personal qualification profile, achieved through initial education as well as work experience, continuing education and informal learning. The Socrates financed Tuning Project (Tuning Educational Structures in Europe) started its outcomes-oriented model from a concept based on competencies, applying somehow the attributes idea.

"By learning outcomes we mean the set of competences including knowledge, understanding and skills a learner is expected to know / understand / demonstrate after completion of a process of learning – short or long. They can be identified and related to whole programmes of study (first or second cycle) and for individual units of study (modules). Competences, can be divided into two types: generic competences, which in principle are independent from a subject, and competences which are specific for a subject. Competences are normally obtained during different course units and can, therefore, not be linked to one unit. It is however very important to identify which units teach the various competences in order to ensure that these are actually assessed and quality standards are met. It goes without saying that competences and learning outcomes should correspond to the final qualifications of a learning programme" (see the full report of the Tuning project, page 23 at www.relint.deusto.es / TuningProject / index.htm or www.let.rug.nl / TuningProject / index.htm).

Tuning has made a distinction between generic and subject specific competences.

"Competences represent a combination of attributes (with respect to knowledge and its application, attitudes, skills and responsibilities) that describe the level or degree to which a person is capable of performing them". (Tuning, open cit., page 255).

Within the generic competences 30 items have been determined and used to identify demands and achievements through questionnaires distributed to employers, graduates and academic faculty:

Instrumental competences:

- Capacity for analysis and synthesis;
- Capacity for organisation and planning;
- Basic general knowledge;
- Grounding in basic knowledge of the profession;
- Oral and written communication in your native language;
- Knowledge of a second language;
- Elementary computing skills;
- Information management skills (ability to retrieve and analyze information from different sources);
- Problem solving;
- Decision-making.

Interpersonal competences:

- Critical and self-critical abilities;
- Teamwork;
- Interpersonal skills;
- Ability to work in an interdisciplinary team;

- Ability to communicate with experts in other fields;
- Appreciation of diversity and multiculturality;
- Ability to work in an international context;
- Ethical commitment.

Systemic competences:

- Capacity for applying knowledge in practice;
- Research skills;
- Capacity to learn;
- Capacity to adapt to new situations;
- Capacity for generating new ideas (creativity);
- Leadership;
- Understanding of cultures and customs of other countries;
- Ability to work autonomously;
- Project design and management;
- Initiative and entrepreneurial spirit;
- Concern for quality;
- Will to succeed.

The distinction of generic and subject specific competences adopted for analytical and also practical reasons, allowing cross disciplinary investigations and comparisons, are in some way misleading. In practice, and in cases were an academic subject or discipline and a profession are closely linked – like in engineering – many of the generic competences are essentially subject related and have to be seen as dimensions of complex engineering capabilities. For curriculum development as a synthesizing activity the specification of competences or intended learning outcomes should not lead to the assumption that these isolated competences have to be addressed by separate learning arrangements. Integrative approaches are necessary in the attempt to link so called generic competences or transferable skills with subject or profession related skills.

The subject benchmarking activities of the Quality Assurance Agency UK tried to do so, even more the UK Engineering Professors Council (EPC) Output-Standards. Attempting to identify standards of necessary learning outcomes for engineering besides mentioning at first the "ability to exercise key skills in the completion of engineering-related tasks" the EPC started from engineering design as the integrating and central engineering activity and derived from there 6 basic abilities encompassing altogether 26 different attributes:

(1) **Ability to exercise Key Skills** in the completion of engineering-related tasks at a level implied by the benchmarks associated with the following statements. Key Skills for engineering are Communication, IT, Application of Number, Working with Others, Problem Solving, Improving Own Learning and Performance.

(2) **Ability to transform existing systems into conceptual models**

This means the ability to:

a) Elicit and clarify client's true needs
b) Identify, classify and describe engineering systems
c) Define real target systems in terms of objective functions, performance specifications and other constraints (e.g., define the problem)
d) Take account of risk assessment, and social and environmental impacts, in the setting of constraints (including legal, and health and safety issues)
e) Select, review and experiment with existing engineering systems in order to obtain a database of knowledge and understanding that will contribute to the creation of specific real target systems
f) Resolve difficulties created by imperfect and incomplete information
g) Derive conceptual models of real target systems, identifying the key parameters

(3) **Ability to transform conceptual models into determinable models**

This means the ability to:

a) Construct determinable models over a range of complexity to suit a range of conceptual models
b) Use mathematics and computing skills to create determinable models by deriving appropriate constitutive equations and specifying appropriate boundary conditions
c) Use industry standard software tools and platforms to set up determinable models
d) Recognise the value of Determinable Models of different complexity and the limitations of their application

(4**) Ability to use determinable models to obtain system specifications in terms of parametric values**

This means the ability to:

a) Use mathematics and computing skills to manipulate and solve determinable models and use data sheets in an appropriate way to supplement solutions
b) Use industry standard software platforms and tools to solve determinable models
c) Carry out a parametric sensitivity analysis
d) Critically assess results and, if inadequate or invalid, improve knowledge database by further reference to existing systems, and / or improve performance of determinable models

(5) **Ability to select optimum specifications and create physical models**

This means the ability to:

a) Use objective functions and constraints to identify optimum specifications
b) Plan physical modelling studies, based on determinable modelling, in order to produce critical information
c) Test and collate results, feeding these back into determinable models

(6) **Ability to apply the results from physical models to create real target systems**
This means the ability to:
a) Write sufficiently detailed specifications of real target systems, including risk assessments and impact statements
b) Select production methods and write method statements
c) Implement production and deliver products fit for purpose, in a timely and efficient manner
d) Operate within relevant legislative frameworks

(7) **Ability to critically review real target systems and personal performance**
This means the ability to:
a) Test and evaluate real systems in service against specification and client needs
b) Recognise and make critical judgements about related environmental, social, ethical and professional issues
c) Identify professional, technical and personal development needs and undertake appropriate training and independent research

The quoted examples demonstrate that the terminology to identify or to describe necessary qualification attributes and derive learning objectives or outcomes for curriculum development is not harmonized and allow different preferences to be followed. All mentioned approaches are not prescriptive like to some extent accreditation standards are.

To present examples where outcomes oriented approaches have been agreed on and became requirements for curriculum development, one must indeed refer to accreditation standards more than to governmental regulations and frames. The most prominent example are the 11 outcomes required for the accreditation of engineering programmes leading to a bachelor degree by the ABET Criteria 2000 for USA (see http://www.abet.org):

- an ability to apply knowledge of mathematics to engineering problems;
- an ability to design and conduct experiments, as well as to analyse and interpret data;
- an ability to identify, formulate and solve engineering problems;
- an ability to design a system, component or process to meet desired or customers needs;
- an ability to use the techniques, skills and modern engineering tools necessary for practice;
- an understanding of ethical and professional responsibility;
- an ability to communicate effectively;
- an ability to cooperate in multidisciplinary and international teams;
- a recognition of the need for and the ability to engage in life long learning;
- a broad education necessary to understand the impact of engineering solutions in a societal, economical and global context;
- a knowledge of contemporary issues.

Programmes provided and curricula developed by USA Higher Education Institutions and applying for accreditation have to make evident that these outcomes are achieved. Europe is only at the beginning of a move from in-put standards (in terms of subjects, content lists and contact hours) towards outcomes based curricula and continuous outcomes assessment. However, some Accreditation Agencies, and also Universities and Colleges, already apply these approaches in order to improve the processes of curriculum development or revision and to raise quality. The Engineering Council (EC) and respectively the Engineering Institutions in charge of accreditation are going to amend their accreditation criteria according to the mentioned debate on outcomes orientation in the UK and in due course try to find a common terminology together with QAA and EPC. In Germany the Agency for Accreditation of Programmes in Engineering, Informatics and Natural Sciences (ASIIN) started from in-put oriented standards but, in addition, stresses the need to include (besides technical knowledge, understanding and skills) also interdisciplinary aspects and to educate a range of personal and social competences.

For the sake of an improved cooperation and comparability in Europe E4 A1 strongly recommends that the attempts to reach common approaches in terminology and standards for curriculum development and accreditation in EE throughout Europe should be intensified. The various Socrates Engineering Thematic Networks and University Networks, also National bodies, should contribute as well as FEANI and ESOEPE, the European Network of the National Accreditation Agencies dealing with engineering programmes. In addition, a clearly focused investigation and research project is urgently needed and should be funded by European or national sources. For the time being A1 instead of relying on competence lists has adopted the “ability to ..” statements for learning outcomes specifications, in order to facilitate curriculum development and learning outcomes assessment (see chapter 7).

5.5 Structures and Delivery

Whereas in-put or outcome standards are normally issues of external determinations or recommendations manifested in accreditation criteria (or in prescribed catalogues of subjects and sometimes even contents), the shaping of the curricula itself, in particular the decision on appropriate teaching/learning arrangements and assessment procedures, is primarily in the hands of the Higher Education Institutions and not regulated by standards. Nevertheless, EE throughout Europe is characterized by a great extent of communality, without necessarily arriving at the same profiles or quality of outcomes.

In order to improve comparability and convergence, activities have been strengthened to also influence the structuring of curricula and the modes of delivery and assessment by external regulations or recommendations. In this context only one approach shall be discussed in some detail: the introduction of the European Credit Transfer System (ECTS) and, subsequently, the modularisation of programmes.

ECTS was introduced through an EU financed pilot experiment in the 90s to facilitate mobility of students. To ease the recognition of studies and grades achieved by exchange students at a foreign Higher Education Institution (HEI), a common scheme of 60 credits per year of full-time study should be used in connection with learning contracts and a comparable grading scheme. Every participating HEI or department had to provide a course catalogue with the appropriate ECTS credits attached to each course. As meanwhile well known the amount of credits required in the participating programmes had to be limited to 60 per year. Countries or Universities with different credit systems already in place developed special factors to arrive at ECTS credits. Meanwhile, the introduction of ECTS throughout Europe as a Transfer, as well as Accumulation System, has become a central issue in the Bologna Process. The already mentioned Tuning Project was and still is in its continuation (2003 to 2004) to a great deal focused on the question how ECTS can be improved to really make the respective credits a kind of common European “currency” in higher education. Measures have been taken to introduce the system also in continuing and vocational education.

What are the advantages and challenges of ECTS and how do they affect curriculum development?

Differently from the USA credit system, which is normally based on contact hours, and therefore primarily on teaching activities, ECTS is explicitely based on student workload and therefore on learning activities. One credit should be equivalent to about 25 to 30 hours of learning encompassing all respective activities and amounting to 1500 respectively 1800 hours per year. This concept realises the shift from teaching to learning and corresponds to the introduction of outcomes orientation in curriculum design. Whereas outcomes orientation stresses the qualitative dimension, ECTS add the quantitative dimension. Curriculum developers are forced to think in categories of student learning and calculate which amount of student workload, on average, may be induced by certain intended learning outcomes or teaching/learning arrangements. Usual courses with 3 or 4 contact hours per week can arrive at quite different amount of student workload, and therefore credits, caused by different requirements on students self-study activities including preparations of exams.

As credits can only be earned by successful completion of a course unit or module, and not just by attending a course, the implementation of a credit system like ECTS also affects the examination and assessment patterns. Whereas still many programmes in Europe are based on intermediate and final exams the Credit system, in its accumulation function, strengthens a formative assessment approach with continuous feedback on learning achievements. Final exams – maybe except the defense of a final project or thesis – become obsolete and are replaced by the accumulation of the required number (and quality) of credits. Curriculum designers will have to decide in which relations student workload should be devoted to different subjects and learning activities and quality levels. They also need to develop appropriate assessment concepts and must try to avoid that by continuous assessment the student learning becomes entirely examination driven. This can be the case if students are exposed to a great number of different courses per term or semester. One solution is to integrate existing courses to greater modules or develop new modules.

During the pilot phase of ECTS, with the focus on credit transfer, the participating HEI and departments usually did not change their curricula but – based on negotiations and agreements between the partners – they just assigned appropriate numbers of credits to existing courses. With the extension of ECTS to an accumulation system, affecting not only students studying for some time abroad but the entire student population, the mentioned problems became more evident.
In Germany it was therefore decided that ECTS should be implemented but, in due course, linked to a modularisation of the programmes. For the new bachelor/master programmes this is a compulsory requirement, for the existing traditional programmes it is recommended only. Thus, modularisation in some way became an additional driving force for curriculum development, besides the implementation of bachelor/master programmes, supporting also a shift towards competence and outcomes orientation. As modules are understood as comprehensive teaching/learning units encompassing different courses and learning activities explicit descriptions of the respective learning objectives, the contents and the intended learning outcomes are required. Similar approaches, like the German ones, started much earlier in the UK. One crucial question usually relates to the size of modules in terms of credits, especially when they should add up to 30 credits per semester as required by ECTS. The biggest impact on curriculum and course development stems from approaches which rely on modules all of the same size, like implemented e.g. at many Universities of Applied Sciences in Germany, but also at various Universities in the UK and at the Danish University of Technology Lyngby. Mainly, semester modules of either 5 or 6 credits, are recommended, and could sometimes take the form of double modules of 10 or 12 credits (e.g. if projects have to be covered by a certain module size). As a result, students would have to enrol for 6 or 5 or even less modules per semester. With a prescribed module size constituting the structure of a curriculum course, providers are forced to fit there contents and learning requirements into a certain frame, determined by credits, and consequently by student learning time available (Ahrens 2001).

The full potentials of modularised curricula can be exploited if students get a variety of options to select modules and design their own individualized curricula. This approach is quite in contrast to the existing curricula in EE which tend to be very closed and compulsory, at least in the first and second year. However, a growing number of innovative programmes require only a certain amount of compulsory core modules and for completion provide a range of optional modules where students can choose from. Sometimes these kind of electives are even provided within certain modules if they are big ones encompassing a number of courses.

Modularisation of curricula also corresponds favourably to Open and Distant Learning and to the provisions of Virtual Universities as e.g. the experiences of the UK Open University proves. The innovativeness of these approaches for curriculum development is grounded in its flexibility but, increasingly, also in the way how the modules developed use the possibilities of multi-media and of the new ICT technologies in general. In combination with a harmonised and qualified credit system, which facilitates the recognition of modules and credits gained by ODL, also the flexibility of traditional programmes could be enriched. A future prospect is that nationally developed but internationally recognized modules or modules, developed by networks of Higher Education Institutions (e.g. as part of joint programmes), will contribute favourably to harmonisation, student mobility and the internationalisation of programmes.

A crucial problem, which remains to be solved, is the question how the quantitative aspects of student workload, expressed by credits, and the qualitative aspects of learning outcomes of certain modules, as well as the assessment and grading systems, can be linked and harmonised so that recognition can become more automatic and formal instead of requiring tailor-made solutions for every student. The approach favoured by A1 is to relate credits in terms of workloads to outcome levels or to competences or capabilities achieved.

6. Curriculum Development and Components of Innovative Curricula

6.1 Innovative Methods of Curriculum and Course Design

Curriculum development or revision in practice seems to be much more a bargaining process in a certain prescribed frame, or on the basis of existing experiences and facilities, than a scientifically based systematic approach to achieve a certain goal or product. The balance of interests or the degree of satisfaction of the involved faculty achieved through such a bargaining process should not be underestimated in its effects. However, the attempt to employ a systematic problem solving process should always be made.

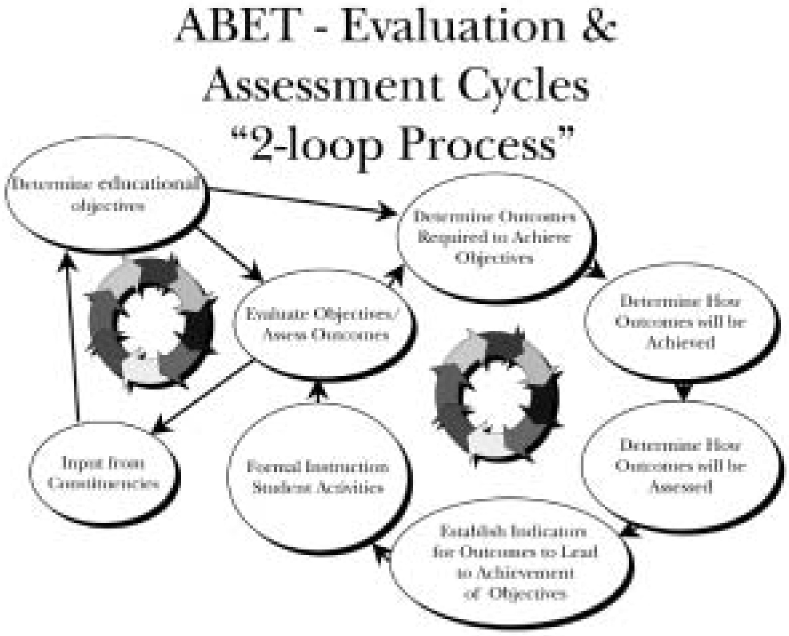
In practice curriculum development from scratch is the exemption, associated with the creation of completely new programmes. Predominant are two other situations:

- continuously and iteratively redesigning existing programmes;
- restructuring programmes on the background of new frame conditions and demands.

The implementation of two tier programmes implementing the Bologna recommendations is mostly not perceived as curriculum development from scratch but primarily as a restructuring exercise. The E4 A1 state-of-the-art investigations indicate that the majority of programme providers try to handle the challenges by regrouping existing course offers instead of grasping the chance of innovative changes. The latter approach would require the adoption of a more systematic approach and not just the development of some new elements. It would also encompass a strategy how changes can be comprehensively and effectively managed to achieve the envisaged targets and how sustainability can be gained, e.g. through continuous quality assessment and, if proved to be necessary, programme revision.

Less the requirement for new curricula in the Bologna Process context but the paradigm shift to outcomes orientation and student learning have recently fostered the use of systematic and comprehensive approaches. Pressures on programme providers and faculty have been caused by respective accreditation or external quality evaluation demands. A good example is the two-loop-feedback-model, used and recommended by ABET for the ABET 2000 accreditation procedures.

It does not only illustrate the link between the "outside world" and the internal programme development and quality assurance process, but determines clearly the subsequent steps to be taken when designing or evaluating a certain programme:



Source: http://www.abet.org

Corresponding to the already mentioned UK QAA activities concerning subject benchmarking and the requirement for programme specifications a vivid debate on comprehensive approaches of curriculum and module design has been promoted by the recently established "Learning and Teaching Support Network" (LTSN), in particular by the LTSN Generic Centre. Based on proposals of John Biggs from 1996 the concept of "constructive alignment" was elaborated and discussed in a Conference in 2002. Even more than in the "two-loop-model" the design of curricula and modules in this concept starts from student learning. Biggs explained the concept in the following way:

"The 'constructive' aspect refers to what the learner does, which is to construct meaning through relevant learning activities. The 'alignment' aspect refers to what the teacher does, which is to set up a learning environment that support the learning activities appropriate to achieving the desired learning outcomes. The key is that the components in the teaching system, especially the teaching methods used and the assessment tasks, are aligned to the learning activities assumed in the intended outcomes" (Biggs 1996).

In practice the alignment process can encompass more dimensions than learning outcomes, teaching activities and assessment, as for instance the alignment to a certain learning culture, the alignment to students interests and abilities, the alignment to facilities, the alignment of teachers and student perceptions, the alignment of approaches taken by different faculty members.

Particularly, the last issue was felt an important point in a good practice example of developing a project centred curriculum in EE at the University Catholique of Louvain (UC) in Belgium. The group in charge stated:
"Adopting a theory of learning is necessary to provide a common reference to discuss issues and make motivated choices. Without an agreed upon theory, everything goes or, putting it differently, intuition rules without bounds. The theory which turned out to be most appealing to the group in charge of the design of the new curriculum is called socio-constructivism (Jonnaert, Vander Borght, 1999), which we combined with the notion of situated learning" (Milgrom 2002, see also on the web site of UCL under UCL: new_eng_curriculum.pdf).

This approach points to the fact that the "curriculum as planned" is not yet the "curriculum as implemented" and will for sure differ later on from the "curriculum as experienced by students and staff". The successful implementation of a comprehensively and systematically planned new or revised curriculum requires to a certain extent an organizational development and a change of action and behaviour of the persons involved. This can be favourably supported by trying to agree in advance on a common approach and basic "philosophy" guiding the changes.

The integrative and rational approach to curriculum design, strongly recommended and supported by E4 Activity 1, also applies in principle to the design of courses or modules or even course units where, usually, an individual faculty member is responsible and has his/her degree of freedom. Limitations may be caused by the fact that courses or modules are mostly not entirely free in their objectives and contents but have to contribute to the goals or specifications of a certain programme.

In practice the 'alignment' approach with regard to modules is implicitly pushed and reflected in the requirements of the German Conference of Ministers of Cultural Affairs (KMK) for the description of modules. These descriptions should not just mentione the courses involved but encompass learning objectives and contents, teaching/learning arrangements, assessment procedures and requirements for achieving credits, number of credits and grading patterns, distribution of the expected workload with regard to different learning activities, the match to certain programmes (KMK 2000).

In the following paragraphs we shall not expose and recommend complete curricula, e.g. as reference points for a harmonisation in Europe, but describe components of "innovative curricula" illustrated by good practice which E4 A1 got to know and found worthwhile to quote. The paragraphs reflect the main aspects which have to be aligned: learning objectives and outcomes, appropriate teaching/learning arrangements and student learning assessment.

6.2 Specification of Learning Objectives and Intended Learning Outcomes

Programme specification and innovative curriculum design start from decisions on overall goals, learning objectives and intended learning outcomes. The previously quoted, and partly described, lists of competences and abilities, knowledge and skills or subject benchmarking considerations are reference points. This applies even to situations where prescribed threshold standards have to be realized by the curricula to be developed. Programme providers have to determine their particular qualification profile and set of qualification attributes. They will normally go beyond the required minimum and focus on special aspects.

As pointed out, no common language or international standards exist. It turned out that just referring or mentioning a range of competences which have to be achieved accompanied by lists of subjects and contents is not enough. Intended learning outcomes have to be specified much more operational in terms of knowledge and understanding, know how, abilities, skills and attitudes, which can be demonstrated by the student or performed in appropriate situations and finally assessed in order to evaluate or measure the degree of achievement.

A good example for a specially profiled curriculum development project, starting from requirements to learning objectives and learning outcomes, is represented by the so called CDIO concept. The abbreviation stands for Conceive, Design, Implement and Operate. It is derived from the overall goal that graduating engineers should be able to conceive, design, implement and operate complex value-added engineering systems in a modern, team-based environment.

Since October 2000, Chalmers University of Technology (Chalmers), the Royal Institute ofTechnology (KTH), Linköping University (LiU), all in Sweden, and Massachusetts Institute of Technology (MIT), MA, USA and recently in addition the Danish Technical University at Lyngby are running a joint four-year programme aimed at developing a new model for EE, focusing on CDIO skills. The concept is characterized by a curriculum organised around the various disciplines while emphasizing that engineering is about projects, a pedagogic model that supports active, experiential group learning, a varied learning environment with classrooms, workshops and the outside world as well as a continuous improvement process.

As the concept should be applicable to different engineering branches it does not go into detail regarding the subject specific engineering knowledge and skills but concentrate on personal, interpersonal and CDIO skills. This is shown in the following table.

The CDIO Syllabus (condensed)

1 TECHNICAL KNOWLEDGE AND REASONING
- 1.1. *Knowledge of Underlying Sciences*
- 1.2. *Core Engineering Fundamental Knowledge*
- 1.3. *Advanced Engineering Fundamental Knowledge*

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
- 2.1. *Engineering Peasoning and Problem Solving*
  - 2.1.1. Problem Identification and Formulation
  - 2.1.2. Modeling
  - 2.1.3. Estimation and Qualitative Analysis
  - 2.1.4. Analysis With Uncertainty
  - 2.1.5. Solution and Recommendation
- 2.2. *Experimentation and Knowledge Discovery*
  - 2.2.1. Hypothesis Formulation
  - 2.2.2. Survey of Print and Electronic Literature
  - 2.2.3. Experimental Inquiry
  - 2.2.4. Hypothesis Test, and Defense
- 2.3. *System Thinking*
  - 2.3.1. Thinking Holistically
  - 2.3.2. Emergence and Interactions in Systems
  - 2.3.3. Prioritization and Focus
  - 2.3.4. Tradeoffs, Judgment and Balance in Resolution
- 2.4. *Personal Skills and Attitudes*
  - 2.4.1. Initiative and Willingness to Take Risks
  - 2.4.2. Perseverance and Flexibility
  - 2.4.3. Creative Thinking
  - 2.4.4. Critical Thinking
  - 2.4.5. Awareness of One's Personal Knowledge, Skills and Attitudes
  - 2.4.6. Curiosity and Lifelong Learning
  - 2.4.7. Time and Resource Management
- 2.5. *Professional Skills and Attitudes*
  - 2.5.1. Professional Ethics, Integrity, Responsibility and Accountability
  - 2.5.2. Professional Behavior
  - 2.5.3. Proactively Planning for One's Career
  - 2.5.4. Staying Current on World of Engineer

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
- 3.1. *Teamwork*
  - 3.1.1. Forming Effective Teams
  - 3.1.2. Team Operation
  - 3.1.3. Team Growth and Evolution
  - 3.1.4. Leadership
  - 3.1.5. Technical Teaming
- 3.2. *Communication*
  - 3.2.1. Communication Strategy
  - 3.2.2. Communication Structure
  - 3.2.3. Written Communication
  - 3.2.4. Electronic/Multimedia Communication
  - 3.2.5. Graphical Communication
  - 3.2.6. Oral Presentation and Interpersonal Communication

4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT
- 4.1. *External and Societal Context*
  - 4.1.1. Roles and Responsibility of Engineers
  - 4.1.2. The Impact of Engineering on Society
  - 4.1.3. Society's Regulation of Engineering
  - 4.1.4. The Historical and Cultural Context
  - 4.1.5. Contemporary Issues and Values
  - 4.1.6. Developing a Global Perspective
- 4.2. *Enterprise and Business Context*
  - 4.2.1. Appreciating Different Enterprise Cultures
  - 4.2.2. Enterprise Strategy, Goals and Planning
  - 4.2.3. Technical Entrepreneurship
  - 4.2.4. Working Successfully in Organizations
- 4.3. *Conceiving and Engineering Systems*
  - 4.3.1. Setting System Goals and Requirements
  - 4.3.2. Defining Function, Concept and Architecture
  - 4.3.3. Modeling of System and Ensuring Goals Can Be Met
  - 4.3.4. Development Project Management
- 4.4. *Designing*
  - 4.4.1. The Design Process
  - 4.4.2. The Design Process Phasing and Approaches
  - 4.4.3. Utilization of Knowledge in Design
  - 4.4.4. Disciplinary Design
  - 4.4.5. Multidisciplinary Design
  - 4.4.6. Multi-objective Design
- 4.5. *Implementing*
  - 4.5.1. Designing the Implementation Process
  - 4.5.2. Hardware Manufacturing Process
  - 4.5.3. Software Implementing Process
  - 4.5.4. Hardware Software Integration
  - 4.5.5. Test, Verification, Validation and Certification
  - 4.5.6. Implementation Management
- 4.6. *Operating*
  - 4.6.1. Designing and Optimizing Operations
  - 4.6.2. Training and Operations
  - 4.6.3. Supporting the System Lifecycle
  - 4.6.4. System Improvement and Evolution
  - 4.6.5. Disposal and Life-End Issues
  - 4.6.6. Operations Management

The condensed version of the CDIO addresses only qualification attributes, on three levels of detail. The complete version contains 5 levels with the fourth level representing learning objectives and the fifth intended learning outcomes. To arrive at learning objectives and outcomes the partner universities tried to find out by a survey among different groups of stakeholders what kind of proficiency level for each topic on the level 2 attributes should be achieved by using a five point proficiency-scale:

- to have experienced or been exposed to,
- to be able to participate in and contribute to,
- to be able to understand and explain,
- to be skilled in the practice or implementation of,
- to be lead or innovate in.

Meanwhile the CDIO syllabus is used by the 5 universities and departments involved for redesigning curricula and shaping appropriate modules or courses. As it is assumed that the CDIO concept can in general contribute to the enhancement of EE and as it is still perceived as a draft, the EE community is invited to make use of it and comment on it (see http://www.cdio.org).

6.3 Promoting Active and Experiental Learning: Project Centred Curricula and Problem-based Learning

The majority of the increasingly demanded key and transferable skills and competences, as well as complex engineering capabilities, can only be acquired if appropriate teaching/learning arrangements are provided to exercise and achieve them. As a possible solution in higher education since the late 60s and the already quoted call for a “paradigm shift from teaching to learning” the proposal was made to move from discipline and subject dominated curricula to problem and project centred curricula and learning provisions. Aalborg and Roskilde in Denmark, the that time new University of Bremen in Germany and the Worcester Polytechnic in USA can be mentioned as examples where this concept has been consequently applied in different disciplines including engineering and to all programmes offered. A guiding principle was that students starting from the beginning of their studies should learn and work in teams and on projects, trying to solve more or less complex, open-ended, often interdisciplinary real-life or research problems. The project work covers most of the learning activities of the students and is supported by project related courses or courses-on-demand and only a few project independent courses of the traditional type. At Aalborg University, where since the beginning in 1974 all programmes have been “project-organised”, the overall share of project work is about 50%, plus 30% for project related and 20% for project independent courses, with relations changing to some extent throughout the years of study (Kjerstam 2002). SEFI, the European Society of Engineering Education, already in one of their first Annual Conferences at Manchester in 1974 addressed the theme: Projects in Engineering Education and the

Curriculum Development Working Group (CDWG) since 1993 in various seminars promoted the concept of project-organized curricula (SEFI 1993).

Starting from restructuring programmes of study in medicine in Canada and, somehow independent and in parallel to the implementation of project-orientation of curricula, the concept of problem-based-learning (PBL) was developed. In Europe it achieved first popularity in the Netherlands, at the beginning in medicine (Maastricht), later on also in EE (Delft University of Technology). Despite some overlap compared to project orientation the PBL-concept was of limited scope. It can be also applied without basically changing the curricular structures just within a course in a certain subject area. Learning is organised through a chain of small problems. Like in more complex projects students work in teams and learn to solve problems, primarily teacher defined, searching themselves for knowledge and methods needed, supported on demand by the teacher in his role as tutor and expert adviser.

Engineering educators occasionally have argued that there is nothing new in project- and problem-based learning as always practical assignments and design projects formed a significant part of engineering curricula. The fundamental difference is that these activities use to be based on the concept of applying previously gained knowledge and understanding. Curricula are respectively organised with an emphasis, in particular in the early years of study, on the teaching of the fundamentals in mathematics, natural sciences and basic engineering subjects. The disadvantages of this curricular structure became more and more evident, not only with regard to the mentioned demand on generic transferable skills and synthesizing engineering capabilities but also because of a lack of attraction for students to start engineering studies or continue to stay.

Obviously for these reasons problem-based learning and project orientation of curricula – based on the experiences already gained by the pioneer universities and colleges – started to spread out in Europe since the 90ties with many innovative applications arriving in recent years and quite some potentials still not used. Let's mention some of the developments based on good practice of Aalborg University and the Engineering Colleges Copenhagen and Odense in Denmark, the Universities of Technology Twente, Eindhoven and Delft in the Netherlands and some of the Hogescholen, the National Technical University of Norway at Trondheim, the UCL Louvain in Belgium, the Technical Universities Berlin and Darmstadt in Germany, the University of Bath in UK:

- project work more often starts in the first semester and is present throughout the whole curriculum but the projects are less complex. They are more planned in the aspects they focus on and the learning outcomes they should achieve in a certain semester or term of the programme (Ponsen 2002);
- real-life problems constitute projects organised in cooperation with industry or structure internship activities as part of the curriculum;
- projects often do not only integrate different subject areas or disciplines but em-

brace virtual cooperation, even on international scale, and international team work;

- problem-based learning or working on "mini- projects" within a certain subject and more time consuming work on complex, sometimes interdisciplinary projects are combined in the structuring of curricula and the provision of active learning arrangements (Gibson 2003);
- project work is more and more supported by ICT facilities;
- independent student projects or undergraduate research projects are encouraged and often credited;
- providing appropriate learning environments and preparing staff for their changing role in project- and problem-based learning is increasingly perceived as a problem and dealt with through various means;
- assessment problems in project and teamwork, often preventing its implementation, are better and better solved by the development of a variety of assessment methods.

Recently, project orientation and problem-based learning have experienced a strong push forward by the role which engineering design and new product and systems development have gained as a structuring feature of educating engineers. It is expected that a comprehensive education in engineering design and project management will enhance the employability of young graduates. It also contributes favourably to entrepreneurship education, a very actual focus of innovative curriculum development which is coupled with the expectation that engineering graduates can and should more actively support economic growth and competitiveness. Engineering design and product development have always been a genuine linking point to problem-based learning and project work, encouraging individual teachers in their courses to start respective activities, the "solo-run" actions as it was phrased by Gibson from the University of Technology in Galway, Ireland (Gibson 2003). Not surprisingly also, project orientation from the very beginning of its raise in the 70s and with the claim for interdisciplinary approaches was promoted by programmes in architecture and construction engineering as well as in regional and town planning.

Interesting recent changes stem from initiatives where engineering design and/or product development became the central and guiding philosophy to completely restructure the curricula, involve the whole faculty providing a programme and even arrive at new and comprehensive learning environments in terms of physical and virtual space. This is basically the expectation connected with the quoted EPC concept of Out-put standards. It applies, in practice, to many recent curriculum changes in Europe mentioned above. In USA the undergraduate design and undergraduate research movement, initiated and promoted to a great deal by the NSF (National Science Foundation), funded so called Coalitions like in particular Gateway, Succeed and Excel as well as the Worcester Polytechnic approach and the E4 project of Drexel University have caused remarkable revisions of curricula in the freshmen and sophomore years of study.

The quoted CDIO syllabus may have similar far reaching results including even the reengineering of the learning environment as reported by the MIT (Crawley 2002, see also http://www.cdio.org). It is based on the CDIO philosophy and an approach to structure the curricula and the students learning process in a way that all available types of (primarily active) learning are provided or facilitated by respective learning environments. In a systems approach to curriculum development and the construction of appropriate educational environments more than 20 different "learning modes" have been identified. A majority of them will find a respective curricular frame and support by physical or virtual facilities.

Finally, project orientation and problem-based learning seems to be the most promising strategy to achieve a proper EE and satisfactory employability by the new three years programmes to a bachelors degree, envisaged by the first cycle of European Higher Education, as recommended by the Bologna Declaration. This will in particular be the case if internship requirements and international project work will be included like practiced by many of the application oriented Higher Education Institutions in Europe. At Universities with 5 years integrated programmes to a master level degree it proved to be quite easy to arrive at a three years bachelor degree with good employability perspectives when the curricula, already from the first year of study, have been project centred or project oriented (Ponsen 2003). A new bachelor/master programme in mechanical engineering, offered by the TU Darmstadt, Germany, adopted this kind of project orientation and received recently a good practice award for innovative curriculum development (see http://www.tu-darmstadt.de).

6.4 Innovative Curricula for "Global" Engineering Education

Internationalisation, besides of other demands, has become a main challenge and driving force not only for restructuring the Higher Education System and competing on a global educational market but also for revising curricula and providing teaching/learning facilities which promote an EE with an explicit international profile. The traditional approaches to internationally oriented education are student exchange and study abroad phases obtained through the decision of individual students to take part. As stressed and reported by Activity 4 of E4 (see Volume E) the focus is primarily on foreign language training and gaining intercultural experiences. Funded European Union exchange programmes like Erasmus have in addition strongly insisted that study abroad activities should be fully recognized with regard to the subject specific learning outcomes and grades achieved and therefore have launched the ECTS.

In this context more recent approaches are of interest where by respective curricular structures, or by provisions of appropriate learning environments, more or less all students of a certain programme are forced to acquire a kind of "global" education. The reasons to do so are quite obvious. Besides of the general values of promoting intercultural understanding and collaboration it is the increasing need to prepare graduates for the global labour market. In engineering, in particular, it is the additional requirement to educate and train students for globally distributed work environments. Graduates who may never leave their home country will be increasingly forced to collaborate in internationally oriented virtual environments or to act on global product markets or serve clients of foreign countries.

Different approaches on the curriculum level are available and have been experienced to deal with these demands e.g.:

- by integrating transnational and intercultural issues in the programme and course offers;
- by providing project work in internationally mixed teams of students;
- by inserting study abroad or internship phases or thesis abroad opportunities into the curriculum;
- by collaborating on a bi- or multilateral basis with Higher Education Institutions in foreign countries on joint programmes.

6.4.1 Internationally Oriented Programme and Course Offers

In EE, since recently programmes have been developed with international orientation as a generic feature like Global Production and Manufacturing Engineering or Export Engineering. Without necessarily sending students abroad – even if favourable and recommended – these programmes consist of a significant share of courses addressing intercultural and global issues or requiring foreign language training as compulsory part of the curriculum and providing course offers in engineering in a foreign language. Apart from these kind of specially focused programmes, also the course offers for the traditional programmes can embrace optional or compulsory modules to let students acquire intercultural competences. It can be limited to narrow technical and professional topics like international law issues, standards and norms, technical foreign language training. It may also take the form of comprehensive modules dealing in depth with intercultural dimensions in the development of technology, work environments, economics and society.

6.4.2 Working on Projects by International Student Teams

Besides gaining experiences, joining international student teams on an optional and often not credited basis during vacation periods, like e.g. the so called JEEP (Joint European Engineering Project Teams) reported in Volume E of the E4 final publication – increasing efforts can be observed to provide international project work for all students of a certain programme. Collaboration with foreign Higher Education Institutions is essential but has been facilitated dramatically by the provision of more and more improved ICT tools and at partly also decreasing costs. The project work is often focused on small research or design assignments and can be executed in entirely virtual environments or in an entirely face-to- face mode. The predominant approach is a mix of meetings, distant courses and collaboration on the web. Recent examples of good practice have been reported by a project on global production development in

Mechanical Engineering at TU Berlin with a three month collaboration on product design of students from Seoul, Michigan Ann Arbor and Berlin, mainly via Internet but also one week of face-to-face meeting at the beginning and at the end.

6.4.3 Study Abroad or Internships in a Foreign Country

An increasing number of programmes demand a semester or even a year of study abroad or internship abroad phases. If not required it can be at least done on an optional basis. To be fully recognised, cooperation with foreign higher education institutions or companies in a foreign country is normally needed but must not arrive at common curricula or modules. These kind of bi- or multilateral agreements must not necessarily result in an exchange programme for students but often do. The advantage of this approach is that international experiences are firmly anchored in the curricula of a certain programme provider.

6.4.4 Joint Degree Programmes

A much more demanding approach from the curriculum development point of view are joint degree programmes, strongly advocated within the Bologna process and recently confirmed at the Bologna-Berlin Conference as a step towards Internationalisation. The European Commission recently started the new Programme of Erasmus Mundi by which European Joint Master programmes, offered by two or more European Universities, shall be developed and offered on a global market.
Even if many Universities still hesitate to get involved and take the necessary activities, quite a range of double degree programmes are already in existence, also in EE. In a survey of the European University Association it is stated that an agreed definition of joint degrees in Europe is still lacking. Sometimes it is just used for programmes where two different subject areas or disciplines have to be studied. Rauhvargers as the author of the survey has however tried to list some main characteristics:
“Joint degrees are normally awarded after study programmes that correspond to all or at least some of the following characteristics:

- the programmes are developed and / or approved jointly by several institutions;
- students of each participating institution study part of the programme at other institutions;
- the students stays at the participating institutions are of comparable length;
- periods of study and exams passed at the partner institution(s) are recognised fully and automatically;
- professors of each participating institution also teach at the other institutions, work out the curriculum jointly and form joint commissions for admission and examinations;
- after completion of the full programme, the student either obtains the national degrees of each participating institution or a degree (in fact usually an unofficial “certificate” or “diploma”) awarded jointly by them” (Tauch C., Rauhvargers A. 2002, page 29).

6.5 Outcomes Based Curricula and Outcomes Assessment

As repeatedly stressed a comprehensive innovative curriculum based on specified learning objectives and intended learning outcomes has to be aligned to an appropriate concept of programme respectively learning outcomes assessment. It has to serve student examination and grading functions but even more feedback functions in general in order to prove that and to what extent intended outcomes of programmes or courses / modules have been achieved. In the USA elaborated plans and a variety of methods of outcomes assessment form a significant part of accreditation procedures.

The shift from teaching to learning and from in-put to out-put oriented curricula will facilitate the assessment of student learning outcomes. In order to achieve this target it is essential that programme as well as course / module objectives are clearly determined, preferably in terms of measurable outcomes. As illustrated, different approaches have been developed and applied recently to specify programme and respectively course or module objectives in a way that the outcomes can be more easily observed or measured and assessed. Students must be challenged and put into the situation to prove or demonstrate that they have achieved the envisaged competences or abilities.

With regard to individual courses or modules the predominating oral and written exams focussing on knowledge and understanding do not allow a satisfactory assessment of an enhanced range of learning objectives specified in terms of competences or skills and abilities. In particular for the so called “soft-skills” like e.g. teamwork abilities more formative assessment approaches to outcomes assessment should be applied. Even student self-assessment based on reports, questionnaires, diaries or portfolios can contribute to it. Usually a variety of assessment procedures should be used but without increasing the tendency to mainly exam and assessment driven curricula and patterns of learning.
With regard to programmes at the whole it is recommended to develop and implement a comprehensive plan (e.g. in a matrix format) by which all provided courses / modules or teaching / learning arrangements are reflected against the list of intended outcomes of the programme, with the envisaged outcomes indicators and assessment procedures connotated to it. (see e.g. Felder R., Brent R. 2003).

Outcomes assessment has to perceived as an integral part of curriculum development. It should not be left entirely to the individual course or module provider. Therefore it is recommended to involve the whole faculty and draft a strategy of implementing comprehensive concepts of outcomes assessment (McGourty J. 1999).

(Activity 1 of E4 together with the Curriculum Developed Working Group of the European Association of Engineering Education – SEFI – has organised a seminar on assessment issues in 2003. The publication of the proceedings is not integrated into this report but will be provided separately as a SEFI Document by November 2003 (see http: / /www.sefi.be). Also available there the SEFI Document No. 23 of a previous seminar on assessment topics. Finally, a special volume of the European Journal of Engineering Education edited by the A1 group member Otto Rompelman is in preparation and will be published in 2004).

7. Guidelines for Core Profiles of Two Tier Curricula

7.1 Introduction

These guidelines or reference points for core profiles of EE in Europe are referring to two already elaborated main factors of influence:

- the implication of the Bologna Declaration with an expressed policy of shaping the education systems in a such a way that increased student migration, cooperation and interchanges will become a natural aspect of European integration;
- the increasing complexity of the engineering world with rapid technical development, new emerging branches and internationalisation of research, development, business and production.

These factors have already had some influence on the education systems. University planners may benefit from analysing current processes and estimate which changes or improvements that will or should take place over the coming years. With such an approach in mind, this proposals are trying to display some common factors and criteria that should be considered when shaping European engineers of the future – typically year 2010. Some considerations and assumptions have to be taken into account:

European integration (Bologna Declaration)
The 3 + 2 tier system appears to be generally recognised, even though there are differences and exceptions. It is reasonable to assume that the 3 + 2 system will be the dominant engineering course structure, and that student migration should be adapted to such a system. For the purpose of this paper a 3 + 2 tier system will be assumed for the Bachelor and Master level courses. The Ph.D. level as such is not included in the discussions. One agreed aim is to facilitate student movement. In recognition of practical obstacles to such movement some basic requirements must be met:

- the academic levels of courses must correspond to each other,
- the knowledge base must cover identical or corresponding areas,
- students must be able to communicate in their environment,
- institutions must remove formal obstacles to student migration,
- degrees awarded must be recognised in all European countries,

Internet education
The Internet will increase in importance and will form the base for new and enhanced teaching methods as well as new types of courses and new ways of obtaining degrees. This proposals do not analyse these trends in depth, but recognise the importance of considering the possibilities and effects that

Internet will have in the future. Students and institutions will be required to master the challenges of the Internet.

Language communication

Language discussions are sometimes difficult, and have a tendency to trigger national feelings, historical attitudes, and policies. Internationally there is, however, a very clear trend of accepting English as the universal language of education. Developments in the computer world, the world of publications, international conferences, international industry and business also show a factor common to all of them: English is accepted as the only common world language. Recognising this as a fact, educators should evaluate which consequence this will have for EE. One obvious conclusion is that all engineers must be able to use English as a working language. Another question is whether all engineering courses should be conducted using English as a common language.

New areas of education

Industry and companies require an increasing degree of specialisation. The traditional engineering fields have given birth to a multitude of new areas such as: environmental engineering, micro system engineering, bioengineering, product development engineering, marine engineering, nuclear engineering, etc. Another trend is to combine and/or supplement EE with other fields of study like business, product development, export engineering, human resource development, and international relations. These trends will most likely continue, and will represent new challenges and possibilities for the educational systems.

7.2 Purpose of the Core Profile Guidelines

In order to form a common basis for European engineering this proposal presents "*guidelines for engineering core profiles*". The profiles describe the qualities that we expect a European engineer of 2010 to represent, and the requirements that his or her educators should use as a base for the formation. The profile does NOT give a detailed list of subjects, hours, etcetera in the traditional way of describing a curriculum, but try to follow an learning outcomes approach by stating which qualities and academic abilities the student should possess at the end of certain courses respectively the degree programme. The student is at the centre of the discussions. How courses are organised and conducted is left to each institution, as long as the student fulfils the requirements at the end. The core profile forms a basis for improved awareness and a reference, but it is also a recommendation. The following factors are considered:

University planning

The core profile is a reference for university planners. The acceptance of the core profile will contribute to shape the curricula in accordance with the intentions of the Bologna Declaration. There will, however, still be ample room for different approaches and national differences, which are still desired. The aim is to create a path for student migration with as few obstacles as possible.

Life-long learning
Engineers of tomorrow will face an increasing demand on their ability to adjust to new technology, new environments, and new types of jobs. This could be described as an ability and an acceptance that life long learning is a natural course of events. Hence the core profile must prepare the student for this aspect of his future career.

Accreditation of the curricula
Accreditation will be carried out by different bodies, and in different ways. The core profile is intended to form a common reference for accreditation bodies. Even though it does not cover any full course program, it should be used as a basic reference that must be met by all courses. Accreditation should be carried out by the national education and engineering authorities, but international agreement should be reached as a basis to the recognition of university degrees in all countries.

Core profile definition
In the context of this paper the core profile is the complexity of courses and knowledge that forms the professional profile of the student. The core courses and requirements must show the difference between engineering and non-engineering studies in the first place, and between various engineering specialisations in the second place. Hence the core should consist of some general requirements needed to define EE and some detailed requirements enough to distinguish between particular specialities. The core courses should be provided by each University as parts of its curricula.

7.3 Engineering Profiles

Tradionally different types of engineers have received their education in institutions giving them different **profiles.** One such clear distinction can be drawn between the “Fachhochschule” and Universities in Germany, and between previous “Polytechnics” and Universities in the UK. Other countries have similar arrangements.

This proposal does not address the differences inherent in such profiles. A true core must be common for all profiles, but must leave space for the diversity that will be and should be part of the institutional characteristics. The core is a reference for a threshold or minimum level which should be fulfilled by all profiles of EE.

Some institutions incorporate periods of practical training as part of the university courses. One may question for example if a 4 year course is really a full 4 years, if several months or even one year are allocated to practical training or internship. However, it may contribute in a significant way to the outcomes and the profile of a degree. This document does not define the workload, duration or contents of a university year of study. With reference to the 3 + 2 years used in the text, these are years of study defined as such by any university in accordance with the Bologna declaration. According to the proposals specified in the Bologna process this would encompass a minimum of 180 ECTS credits for the first cycle degree and additional 120 ECTS credits for the achievement of a second cycle degree.

7.4 Core Requirements

As promoted and agreed on in the E4 A1 group specifications in this document are **outcomes oriented,** and focus on the skills, abilities, potentials and personality of the graduate. Teaching / Learning arrangements and methods provided to generate these kind of outcomes are the responsibility of the university institution and can be based on an increasing range of innovative approaches as already described in previous parts of this volume.
The proposed core does therefore **not** contain:

- a detailed list of subjects and topics which must be taught,
- a specification of how many hours must be devoted to different subjects,
- a specification of how the university should arrange its inputs to the students.

7.4.1 Core Requirement for all Engineering Areas

All Engineers should have a minimum of engineering-related skills, knowledge, and abilities in order to function in an engineering environment. The indicated requirements are hence common for all fields of engineering, but are split into two sections in order to differentiate between the first cycle degree (Bachelor) after 3 years, and the second cycle degree (Master) after additional two years.

The core requirements are divided into two sections: **Personal** and **Academic.** The basis for this division is the increased claim for transferable skills and qualities of the engineers personality in addition to engineering related factual knowledge and understanding and the ability to demonstrate academic performance. The personal dimension aggregates most of the individual and social competences and attributes described in some detail in previous chapters.

The Bachelor level requirements are given in some degree of detail, while the Master level requirements are of a more general nature. This different approach is due to the increased specialisation and diversity on the Master level, and it would be counterproductive to limit the dynamics of the system by narrowing and limiting the possibilities of separate solutions. The basis for student migration is for most practical purposes coupled to the Bachelor level education.

7.4.2 Institutional Requirements

Criteria for accreditation will be part of national and international arrangements, and are not addressed in detail.

In general institutions providing EE of the future must develop beyond some of the traditions of the last century. Some requirements are[8]:

- Students must learn and be able to develop and apply practical skills through project oriented teaching and learning arrangements.
- Institutions must have a satisfactory amount of laboratories and technical facilities relevant to the engineering fields offered.
- Academic staff must focus on student involvement, activities and learning methods.
- Learning methods must stimulate student activity and leave room for student participation in course planning and quality work.
- Courses must be framed under a pattern of the ECTS standard.

[8] The "*Center for Engineering Educational Development*", *at the Technical University of Denmark, DTU, is expressing a general requirement as:*
The engineer shall be capable of interpreting complex problem situations and of translating them into technical or non-technical solvable problems. The engineer shall be able to draw up criteria for the selection of solutions, taking into consideration technical as well as non-technical facts and conditions.

7.4.3 Personal Requirements for all Programmes at:

Bachelor level (3 years):

The graduate should be able to:
communicate information, ideas, problems, and solutions to both specialist and non-specialist audiences
adapt himself to a changing technology and new techniques as part of a life long learning process
function efficiently in project groups and teamwork
understand the interaction process between people working in teams, and be able to adapt himself to the requirements of his working environment
display an understanding of the influence of engineering activity on all life and the environment, and demonstrate a high moral and ethical approach to engineering tasks
apply his learning ability to undertake appropriate further training of a professional or academic nature
critically evaluate arguments, assumptions, abstract concepts and data, in order to make judgements and to contribute to the solution of complex issues in a creative process
show an appreciation of the uncertainty, ambiguity and limitations of knowledge

7.4.4 Additional Personal Requirements for all Programmes at:

Master level (+ 2 years)

The graduate should be able to:
assume an analytical approach to work based on broad and in-depth scientific knowledge
function in leading roles, including management roles, in companies and research organisations, and to contribute to innovation
plan, supervise and carry out research and development projects
explain his ideas and projects to the team of co-workers
find a solution of particular technical and human problems arising in the working environment
apply skills and qualities necessary for employment requiring personal responsibility and decision-making
work in an international environment with appropriate consideration for differences in culture, language, and social and economic factors
communicate information, ideas, problems and solutions to both specialists and non specialists
accept accountability for related decision-making including use of supervision
show awareness and relate to connections with other disciplines and engage in interdisciplinary work

7.4.5 Academic Requirements for all Programmes at:

Bachelor level (3 years)

General. The graduate should be able to:
apply knowledge of mathematics, science and engineering appropriate to his discipline
design and conduct experiments, analyse and interpret data
identify, formulate and solve engineering problems
recognise the interaction between engineering activities and design, fabrication, marketing, user requirements, and product destruction
Computer Science / Informatics. The graduate should be able to:
use common computer tools to produce documents, make presentations, carry out calculations and simulations
design and maintain an Internet presentation of his work
carry out computer based tasks using object oriented programming and expert systems
use professional computer codes to prepare data, and obtain reasonable results from calculations
Mathematics. The graduate should be able to:
construct a mathematical model of a given problem using differential calculus
apply the technique used for setting up definite integrals
classify, set up for solution and solve a selection of ordinary differential equations
use mathematical tools to report the results of his work
use intelligent software tools applied to the solution of mathematical problems
understand and use the concept of sets and classes and be familiar with Boolean algebra
manipulate complex numbers in Cartesian and polar form
use Matrix algebra and its application in solving systems of linear equations
understand the concepts of vectors representing lines and planes in 3-D space
explain topics like Fourier series and Laplace-transforms and their applications in problem solving.
apply linear transformations
understand and interpret information in statistical information
use statistical methods for planning, control, interpretation and decisions
Physics. The graduate should be able to:
use the relevant laws of kinematics and dynamics to solve problems of rotational and lateral movement
explain harmonic oscillations, damped oscillations and forced oscillations and treat such oscillations mathematically
describe waves mathematically and explain the concept of wave lore
explain the first and second law of thermodynamics and solve problems applying these laws

explain the principles of electric and magnetic fields and apply the basic laws of electric circuits
explain the basic priciples of quantum theory
Chemistry. The graduate should be able to:
display basic knowledge of general chemistry, organic and inorganic chemistry
assess the environmental influence and use this knowledge in solving technical problems
Environment. The graduate should be able to:
understand the influence of technical activities or processes on the environment, and outline possible ways of reducing such influence.
display a clear understanding of the interaction between environmental issues and technological issues and on the basis of this knowledge be able to make independent recommendations on topics of work environment.

7.4.6 Additional Academic Requirements for all Programmes at:

Master level (+ 2 years)

The graduate should be able to:
demonstrate an in-depth understanding of his subject area as part of a general engineering technology
demonstrate in-depth knowledge and understanding of a specialised area related to his field of study
plan, supervise and carry out research in his specialised field
Mathematics: The graduate should be able to: formulate mathematically and to solve practical problems related to designing and exploitation of a real technical systems
Computer Science / Informatics. The graduate should be able to: understand the algorithms of professional codes, their limitations and requirements, to prepare the data for the code in the proper way and to analyse obtained results of calculations

7.5 Specific Core Requirements for Particular Subject Areas

In addition to the general core requirements the student must fulfil requirements that are related to his particular field of study. The following sections describe these requirements for main and some selected engineering areas. A large proportion of the several hundred different engineering courses in Europe will have a related or similar academic structure, and should be able to benefit from this core reference.

7.5.1. Chemical Engineering

Bachelor level (3 years)

The graduate should be able to:
understand the processes in organic and inorganic chemistry
analyse the chemical composition of industrial raw materials and products
make the energy and mass balance for chemical installation
assess the quality of the product of chemical installation
understand and apply the basic technological processes in industrial practice
understand the safety problems and the risk of environment pollution by chemical processes
understand the basics of biotechnology

Chemical Engineering

Master level (+2 years)

The graduate should be able to:
apply differential equations for calculation of processes in chemical reactors
design chemical reactors of various types and sizes
assess the influence of chemical installation on the environment
analyse the system of waste management in chemical industry

7.5.2. Civil Engineering

Bachelor level (3 years)

The graduate should be able to:
design buildings and constructions on a basic level
carry out independent project management and supervision of small civil engineering projects
apply static calculations to dimension structures of metals, concrete and wood.
take part in planning work related to water supply, drainage and sewer, communications, and mapping
Assume the role of responsible engineer in sub-projects as part of large construction works, in fields like roads, bridges, tunnels, harbours, buildings and landscaping

Civil Engineering

Master level (+2 years)

The graduate should be able to:
show in-depth understanding of general phenomena and problems relating to civil engineering
learn how to increase insight into civil engineering problems and how to find acceptable solutions, in connection with other sciences, taking into account given or anticipated preconditions
apply skills for designing, realizing and maintaining civil engineering constructions and systems from the point of view of strength, stability, safety, environment and costs
explain the social aspects of civil engineering and the social context in which civil engineering projects are realised
use his general knowledge, acquired scientific attitude and designing skills regarding the above objectives
show insight into and proficiency in the area of one of the major fields. After a training period, the recently graduated civil engineer has to be capable of bearing responsibility for the tasks which he/she performs at an academic level in the area in which he/she majored
use the skills required for recognizing, formulating, applying and analysing problems in the area of civil engineering in order to find one or more acceptable solutions. To this end the Civil Engineering student has to be enabled to obtain knowledge of and insight into the developments and methods of scientific and applied scientific research, particularly in the area in which the student majored

7.5.3. Computer Engineering

Bachelor level (3 years)

The graduate should be able to:
install, use, and maintain common operating systems, programs and hardware
carry out object oriented programming
apply 2-dimensional and 3-dimensional computer graphics and modelling
develop graphical and dialogue based user interface
configure and apply standard properties and functions in data base systems
program microcontrollers in assembly and high level languages like C
create and maintain Internet web presentations using standard editing tools and web functions
implement i/o-programming with standard protocols and bus systems applied to control systems
install and maintain operating systems
design basic digital circuits and systems using off-the-shelf components
take part in the development of large computer programs
explain the principles of digital signal processing
explain processes and mechanisms in computer networking and assume the role of network supervisor

Computer Engineering

Master level (+2 years)

The graduate should be able to:
assume the role of engineering supervisor of large computer networks
design and establish computer based communication systems
develop advance intelligent computer applications
plan and implement computer based solutions in engineering projects and technical applications
estimate social, economic, and environmental impacts of computer applications

7.5.4. Electrical Engineering

Bachelor level (3 years)

The graduate should be able to:
apply the basic laws of electrical theory to RCL networks
calculate dimensions of electrical distribution systems
explain principles and systems for power generation and distribution
display knowledge of rules and regulations relating to distribution of electrical power and installation of power systems
take part in planning and implementation of private and professional electricity systems
work with basic analogue and digital components as part of larger systems
plan, install and maintain basic control systems

Electrical Engineering
Master level (+2 years)

The graduate should be able to:
take part in the design of large electrical installations
assume a responsible role in supervision of large electrical systems
explain economical, social and environmental aspects of power generation and distribution
explain safety criteria in electrical systems

7.5.5. Electronic Engineering

Bachelor level (3 years)

The graduate should be able to:
carry out electric network analysis and calculations
explain the theory of electric and magnetic fields, and carry out simple calculations
carry out calculations on RCL circuits using differential equations
carry out calculations on AC circuits using vector analysis and complex algebra
explain the operation of circuits based on digital semiconductors
explain the principles of operation of common analogue semiconductors and other parts
use Boolean algebra in the analysis and design of circuits
use computer simulation tools in designing electronic circuits
explain the principles of operation of microprocessors and carry out simple microprocessor programming
use common laboratory equipment for test, design and development purposes
explain the principles of electromagnetic transmissions

Electronic Engineering

Master level (+2 years)

The graduate should be able to:
use advanced mathematical methods in research and design
carry out independent research and development project in a specialised field
display in-depth knowledge of state-of-the-art electronic technology
plan and supervise quality assurance for electronic systems
explain the impact on environment from electronic engineering

7.5.6. Energy Engineering

Bachelor level (3 years)

The graduate should be able to:
explain the basis of flow and mass transfer processes
explain processes and systems for energy transformation
explain the principles of electricity generating plants and electric systems and common appliances
carry out simple design and calculation of main elements of energy plants and systems
use measuring equipment to control parameters of energy systems
carry out simple design and calculation of main elements of energy plants and systems
characterise the factors governing sustainability in energy systems
evaluate direct energy costs of technical processes, services and everyday life activities
perform simple calculations of total costs of energy

Energy Engineering

Master level (+2 years)

The graduate should be able to:
formulate equations involved in complex energy systems
design energy plants and systems
carry out detailed measurements and experiments on energy systems
perform environmental impact assessments of energy plants
design multivariable optimisation analysis of energy systems
explain and evaluate integrated energy planning

7.5.7. Environmental Engineering

Bachelor level (3 years)

The graduate should be able to:
display knowledge the environmental law and regulations in his country and in EU
explain chemical interactions between elements of environment: atmosphere, soil and water
analyse the data regarding the pollution of all elements of the environment
explain the way pollution is transported in the atmosphere, in water and in the soil
assess the cost of environment pollution and calculate relevant fees
explain the influence of industry on all elements of the environment
explain the technologies of removal of harmful substances from gas, water and soil in industrial systems
apply the basics of environmental management in a work situation
supervise the system of waste management in the industrial enterprise and in inhabited area

Environmental Engineering

Master level (+2 years)

The graduate should be able to:
perform measurements of environment pollution using typical methods
calculate the pollution concentration in the atmosphere as a result of particular emission
make the energy balance and mass balance for industrial installation
design the gas cleaning system and water cleaning system
create the system of waste management in the industry and in inhabited area
determine costs of pollution of the environment and suggest way of its minimisation

7.5.8. Mechanical Engineering

Bachelor level (3 years)

The graduate should be able to:
explain the basics of mechanics and fluid mechanics
explain the basics of material science and stress of materials
explain the basics of thermal science: thermodynamics and heat transfer
carry out designing of elements of machines and mechanical systems using computer aided design codes
explain the principles of operation of common machines: pumps, ventilators, turbines, engines
perform calculations of parameters of hydraulic and gaseous systems, and to choose characteristics of commercially produced machines
calculate the mass balance, energy balance and efficiency of power systems
use common measuring equipment to control the existing power and mechanical system
explain the impact of materials use and machine engineering on the environment

Mechanical Engineering

Master level (+2 years)

The graduate should be able to:
apply the differential equation and formula of fluid mechanics and thermal processes and their solutions
carry out evaluation of advanced stresses phenomena
design mechanical and power machines and systems
carry out detailed measurement of parameters of mechanical and thermal systems
assess the impact of machines and systems on the environment
explain economics relations in designing and exploitation of machines and systems,
explain the basics of operation and maintenance of mechanical systems

7.5.9. Mining and Geological Engineering

Bachelor level (3 years)

The student should be able to:
explain the geological processes of formation of the rock structure
analyse the chemical and morphological composition of rocks
explain the basics of mining geology and geochemistry
supervise the methods of rock exploitation
apply the safety procedures in mining industry
supervise the ventilation system in the mine
understand the impact of mining process on the environment
understand the technology of enrichment of excavated material and its preparation for industrial use
supervise the waste material utilisation

Mining and Geological Engineering

Master level (+2 years)

The student should be able to:
design the elements of mining technology and systems: pits, excavations and other
apply the proper materials for mining technology and construction
assess the thread of possible dangerous incidents in the mining technology
assess the impact of the mining process on underground water, earth surface and atmosphere
apply the technology of underground water quality control and pumping system
explain the procedures of ventilation and air quality control
apply the technology of waste material management and earth surface conservation

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The references to be found on the following web page and also included in the reference list of this volume complement the core curriculum, and can be used to cast light on areas not covered in detail, or to compare with other ways of specifying educational systems, processes or requirements.

REFERENCES / LINKS from web page http://ri.hive.no/arne/E4A1Core/

8. Conclusions

The work of Activity 1 of E4 on curriculum development issues has been guided by the intention to contribute to the establishment of a European Higher Education Area by addressing crucial aspects of harmonisation, compatibility and comparability. In due course the activities aspired to contribute to the enhancement of EE by encouraging diversity and innovative solutions to deal with a range of changing demands. Creative competitiveness and the strive for specific profiles of engineering qualifications on a high level of quality must be accompanied by the attempt to make diversity and quality transparent based on common terms. Thematic Networks can contribute to these challenges but from time frame, participation and money provided they are not prepared to implement practical changes and collect the respective experiences with pilot projects. However, they can develop or promote innovative approaches and prove by collecting of and referring to good practice how implementation works and experiences are. This was the approach which A1 has taken and would advocate to strengthen in the future, maybe with a focus on special aspects of curriculum development, provision of innovative teaching/learning arrangements and recognition of qualifications handled by smaller special interest groups.

From the experiences gained it would be also very helpful if this kind of focused and coordinated activities could – at least with regard to some issues – be supported and extended through respective research projects executed by full time staff and funded by either European or diverse national sources. A Network and working group infrastructure which provides the staff and facilities to apply for it seems necessary. Increased cooperation of the engineering related networks in the future may ensure that more generic and general aspects of curriculum development are applied in the context of certain branches of engineering, that the wheel has not always be reinvented again and synergy effects are obtained and that a comprehensive structure for dissemination and reflection is provided.

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Annex 1

Communication of CESAER and SEFI on the Bologna Declaration

Based on the joint seminar organized at
Helsinki University of Technology
February 2003

Taking into account the viewpoints of industry, national and EU administrations, as well as those of engineering associations/networks such as BEST, CLAIU, FEANI, CLUSTER, IAESTE, TN SOCRATES - “E4”, TIME and the EUA

The Role of CESAER and SEFI

CESAER – The Conference of European Schools for Advanced Engineering Education and Research – is a multinational association of some 50 leading European universities and schools specialised in engineering education and research. These institutions exert a powerful influence on technological growth and workforce development, and ultimately on the viability of the European economy.

SEFI – The European Society for Engineering Education – founded in 1973, is an international non-profit organization linking together 480 members amongst which ones 250 European universities and institutions of higher engineering education (38 countries). Through its network and its numerous activities and services offered to its members, SEFI has a serious expertise relating to the situation of higher engineering education in Europe. SEFI contributes to the development and improvement of HEE, to the improvement of exchanges between teachers, researchers and students, and of industry with the academics.

CESAER and SEFI both have wide representational roles in the field of European Engineering Education. They have been engaged in and have supported the Bologna Process since its inception. In addition, they have been very active in organising debate and investigations into the future of European engineering education. They remain committed to playing a constructive role in the creation of the European Higher Education Area. They have produced this communication in order to present to the wider Higher Education community and to political decision-makers their views on particular issues in the debate on the Bologna Process.

CESAER and SEFI strongly support the idea of the creation of a European Higher Education Area.

In particular,

- CESAER and SEFI share the opinion of the Ministers concerning the need for a system of easily readable and comparable degrees, through a Diploma Supplement or otherwise,
- CESAER and SEFI support a wider use of the ECTS system as a proper means to promote student mobility,
- CESAER and SEFI are convinced of the importance of increased mobility for students, teachers, researchers and administrative staff and it does in many ways promote such mobility,
- CESAER and SEFI are already, by statutes, committed to the idea of developing the European dimension in Education,
- CESAER and SEFI share the opinion of the European Ministers concerning the importance of European cooperation in quality assurance and accreditation. In certain countries in Europe, Engineering Education programmes are already accredited by competent bodies. We welcome any initiative leading to a common reflection, aiming at a deeper understanding and cooperation between these agencies. CESAER and SEFI are fully prepared to pursue actions in this area, in cooperation with these accreditation agencies and other organizations.

Recommendations of CESAER and SEFI

Recognition of Special Factors that Affect Engineering

The supply of highly qualified engineers is of vital importance to the future economic and societal development of Europe, particularly to the aim of making Europe the most competitive and dynamic knowledge-based economy in the world. Thus, the Higher Engineering Institutions producing such engineering graduates form a crucial sector in European Higher Education which should be specifically represented in the discussions and strategies that constitute the Bologna Process. They should be given a voice in the debate.
The implementation of the Bologna objectives must make clear provision for the special factors that apply to advanced engineering education. There is need to ensure that the competences required for engineering graduates are recognized and are not compromised by developments directed to the whole of Higher Education.

Recommendation 1
The special role and features of engineering must be taken into account in the Bologna Process.

Second degree as goal for scientifically oriented programmes

In the Bologna Declaration the Ministers commit themselves to the adoption of a higher education system based on two main cycles, undergraduate and graduate, where the first cycle shall in itself be relevant to the labour market and where the second should lead to a Master's degree. Basically CESAER and SEFI support this approach provided that the specific needs of engineering education are properly taken into account. More precisely, today, in Europe two distinct types of engineering curricula are offered, one longer, more scientifically oriented and the other shorter, more application or vocationally oriented. Both have been developed to respond to particular needs and are well accepted by the job market.

In the context of the new structure of first and second cycle degrees, the engineering community in Europe agrees that in order to attain high level scientifically oriented competences, engineering graduates need to be educated to a level corresponding to second cycle Masters level degrees. It is thus important that any new procedures and regulations do not compromise the number and quality of such graduates. In particular, there must continue to be provision for an integrated route through to Masters level as this preserves the coherence and efficiency of the formation. This implies that where structures include the award of a first cycle (Bachelors) degree, that stage should be regarded mainly as a pivot-point rather than a normal finishing point. The pivot-point allows choice of specialization and also of mobility between first and second cycles but it is important that financial and regulatory barriers do not impede the continuation to the second cycle stage.

The introduction of a larger number of second cycle (Master's) degree programmes, building on first cycle (Bachelor's) degrees, will no doubt make European Engineering Education more attractive for non-European students, especially if the programmes are run entirely or partly in English. It will also facilitate student mobility within Europe. CESAER and SEFI therefore welcome a large-scale introduction of separate 1-2 year Master's Programmes in Engineering.

Most European countries also have various forms of shorter Engineering Education. The length and character of these curricula may vary slightly from country to country but they have normally two factors in common; they are more vocationally oriented, or application-oriented, than the longer programmes and they will typically lead to a first cycle degree. Even if they are not primarily designed as a first part of a two-tier system, bridges to second cycle degree programs should be provided. Graduates of these programs play an important role, particularly in small and medium-sized enterprises.

CESAER and SEFI are convinced that this existing European system for Engineering Education has much merit, that the system is quite compatible with the vision of a European Higher Education Area and that it should not be sacrificed. The cultural diversity of Europe is also a source of richness and changes in the architecture of Engineering Education must not be allowed to destroy this richness.

Also, it should be stressed that engineers have a continuing need for up-dating courses and professional development and to participate in lifelong learning. CESAER and SEFI reaffirm, that lifelong learning could become one of the most important features of the European Higher Education Area.

Recommendation 2
In the scientifically oriented programmes the students should normally be educated to the level of the second degree. There must continue to be provision for an integrated route through to second cycle Masters level.

Recommendation 3
The specific qualities of the presently existing, application oriented first cycle degrees must be recognized and safe-guarded with bridges to second cycle programmes being provided

Research and the doctorate

University education has to be strongly based on original and relevant research. The confluence of the European Higher Education Area and the European Research Area is vital not only for a high quality of both sides but also for the achievement of a globally competitive economy. Universities and other higher engineering institutions are the major contributors in Europe to research both by carrying out the bulk of fundamental and strategic research and also through the training of professional researchers on doctoral programmes. This is particularly true in engineering.

It is therefore necessary to create stronger links between the European Higher Education Area and the European Research Area. More specifically it will be necessary to strengthen the latter, e.g. by creating a European Research Council, with the primary goals to strengthen research quality in Europe, to develop capacity across the continent and to promote the best research through competition at European level. This competition has to be based on merits and on quality and the independence of the funding agencies (at national and at European level) must be safeguarded.

Research has to be carried out primarily at Institutions of higher learning thus automatically leading to the desired effect of strengthening the interaction between research and teaching. Doctoral students play a crucial role in research and they play a particular role in inter-linking teaching and research. Hence strengthening research and its ties to teaching will also mean creating additional doctoral position in the framework of networks of highly qualified research groups and even more importantly promoting joint programmes for doctoral studies. However, doctoral programmes are intimately related to universities' research organization and activities. Excessive interference in this would harm the output as research is by its nature a highly creative process in which the freedom to develop new ideas and approaches is at a premium. Thus, doctoral studies should not be brought into the ambit of the Bologna Process. There is already wide agreement across Europe on the criteria for successful doctoral programmes.

Recommendation 4
The European Research Area and its links to the Higher Education Area have to be strengthened. Competition for support has to be based on merits and on quality. Joint Programmes for doctoral studies should be supported, but the doctoral level as such should not be brought into the Bologna process.

Steering by Output Parameters

Engineers need high level competences in areas such as design, problem-solving and innovation, particularly related to the advancement of technology; there is a strong scientific basis to their work and they have particular responsibilities to society as a whole. Thus, it is natural and important that the primary criteria for determining the level reached by engineering degree programs are expressed in learning outcomes which relate to these competences rather than criteria which are expressed mainly by student work-load. This competence based approach also leads to greater transparency and improved comparability internationally. It enables allowance to be made for differences in national educational traditions in areas such as student selection and teaching methods.

Recommendation 5
Criteria for degrees in engineering should be based on learning outcome and on competence rather than solely on student work-load.

Excellence and distinctive profiles of institutions

It is vital that Higher Engineering Education Institutions are enabled to compete in the global market place for students and staff and for the employment of their graduates. To do this effectively they need to develop their own strengths and particular profiles.

In particular they need to make their own decisions regarding the balance of their activities and how these relate to both global and regional needs. This requires institutional autonomy. Excessive regulation in matters such as admission policy and the balance between different degree cycles would be counterproductive. Any political steering of universities should be based on objectively defined and mutually agreed output parameters. There should be no external interference with operational aspects and no artificially imposed uniformity of mission and structures. For example, separate Masters degrees, intended mainly for international students, may become an important part of the provision of some engineering institutions.

Recommendation 6
Higher education institutions need to strive for quality and for excellence. Their governance structures and decision-making processes must support these goals.

Quality Assurance

The production of world-class engineering graduates depends both on the provision of world-class resources and also on good management. Quality assurance is an important aspect of this. Higher education institutions themselves have the primary responsibility for the quality assurance of their own programmes. External accountability and guidelines for best practice can be provided by national quality assurance agencies. The European dimension of quality assurance is best developed (a) by networks of universities in Europe working together to produce similar procedures and sharing expertise, and (b) through liaison between national quality agencies directed to the adoption of common approaches and standards. Centralized European control of quality assurance is likely to be counter productive and will lead to an excessively bureaucratic approach.

Recommendation 7
Higher education institutions themselves have the primary responsibility for the quality assurance of their own programmes. Networking of Universities and liaison between national quality agencies could create added value, centralized European control has to be avoided.

Accreditation and Professional Recognition

In certain European countries, engineering education programs are already accredited by competent bodies. We welcome any initiatives leading to a common reflection aiming at a deeper understanding and cooperation between these agencies. CESAER and SEFI are fully prepared to pursue constructive actions in this area in cooperation with accreditation agencies.
Comparable degree structures and cooperation between accreditation agencies must pave the way to transnational recognition at professional level.

Recommendation 8
Transnational recognition of Engineering degrees at professional level has to be a primary goal.

Summary of the recommendations of CESAER and SEFI

In view of the European University Aassociation (EUA) Graz Conference, May 2003, and of the European Education Ministers Summit, Berlin, September 2003:

1. The special role and features of engineering must be taken into account in the Bologna Process.

2. In the scientifically oriented programmes the students should normally be educated to the level of the second degree. There must continue to be provision for an integrated route through to second cycle Masters level.

3. The specific qualities of the presently existing, vocationally oriented first cycle degrees must be recognized and safe-guarded with bridges to second cycle programmes being provided.

4. The European Research Area and its links to the Higher Education Area have to be strengthened. Competition for support has to be based on merits and on quality. Joint Programmes for doctoral studies should be supported, but the doctoral level as such should not be brought into the Bologna process.

5. Criteria for degrees in engineering should be based on learning outcome and on competence rather than solely on student work-load.

6. Higher education institutions need to strive for quality and for excellence. Their governance structures and decision-making processes must support these goals.

7. Higher education institutions themselves have the primary responsibility for the quality assurance of their own programmes. Networking of Universities and liaison between national quality agencies could create added value, centralized European control has to be avoided.

8. Transnational recognition of engineering degrees at professional level has to be a primary goal.

and

CESAER and SEFI believe that any attempt to harmonize the National academic calendars and to promote foreign languages within the higher engineering education curricula, would certainly represent important initiatives to overcome too frequent obstacles to the mobility of students, professors and researchers.

Approved by the members of the CESAER/SEFI Bologna Working Group:

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Annex 2

Thematic Network E4 - Activity 1

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