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Career Space is supported by CEN/ISSS, the European standardisation body for the information society, EUREL, the Convention of National Societies of Electrical Engineers of Europe, *e*-skills NTO, the UK national training organisation for ICT and over twenty universities and technical institutions across Europe.

Project management and co-ordination is provided by ICEL, International Co-operation Europe Ltd.

The Career Space consortium would like to acknowledge the support of the European Commission and CEDEFOP and to thank their colleagues and all others who contributed to this work.

For further information please visit our website at www.career-space.com

Curriculum Development Guidelines

New ICT curricula for the 21st century: designing tomorrow's education

Luxembourg: Office for Official Publications of the European Communities, 2001

A great deal of additional information on the European Union is available on the Internet. It can be accessed through the Europa server (http://europa.eu.int).

Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 2001

ISBN 92-896-0074-8

Printed in Belgium

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Foreword

Viviane Reding
European Commissioner for Education and Culture

Education plays an essential role in the achievement of the ambitious objective the European Union set itself at the Lisbon Summit, March 2000 "*to become the most competitive and dynamic knowledge-based society in the world capable of sustained economic growth with more and better jobs and greater social cohesion*"

European education systems must face the challenge of the knowledge society and equip young people with the skills and competencies required for the new culture and the new economy. Information and Communication Technologies have an important role to play. In the future, a society's economic and social performance will be increasingly determined by the extent to which its citizens, and in particular its young citizens, and its economic and social forces can harness the potential of these new technologies.

The *eLearning initiative*, an educational response to the Lisbon challenge, seeks to mobilise the education and cultural communities, as well as the economic and social players, in Europe, to this end. Open and constructive dialogue and effective co-operation between education stakeholders is the best way to accelerate and facilitate change and adaptation.

Career Space, an eLearning flagship project, is an excellent example of this dialogue and co-operation. Started in 1999 by DG Employment, for a better assessment of the "skills gap", the lack of qualified people for the high number of jobs linked to new technologies, and continued by DG Enterprise, for a better definition of new ICT curricula and job profiles. Now, it is the time for universities themselves to test and develop these inputs, and DG Education and Culture is willing to support their effort.

Top ICT companies have worked together with top European universities in the preparation of these "*Curriculum Development Guidelines, New ICT Curricula for the 21st Century*". The ICT sector is the backbone of the knowledge society, but its development in Europe is facing difficulties due to the lack of enough ICT graduates. An increasing demand from industry coincides with a decreasing number of students choosing scientific and technical careers.

These guidelines are an effort to redress this situation. Based on comparative analysis of existing curricula and practices in E-universities, well-structured recommendations for future development have been developed. Technical requirements as well as social and cultural issues have been considered; hard and soft skills find their right place.

We hope that these Guidelines will be a useful tool for Universities in this moment of change, and that they will contribute to fostering fruitful public-private partnerships in education.

1. Executive summary

Career Space is a consortium of major Information and Communications Technology (ICT) companies – BT, Cisco Systems, IBM Europe, Intel, Microsoft Europe, Nokia, Nortel Networks, Philips Semiconductors, Siemens AG, Telefónica S.A. and Thales – plus EICTA, the European Information, Communications and Consumer Electronics Industry Technology Association. It is working in partnership with the European Commission to encourage and enable more people to join and benefit from a dynamic and exciting e-Europe and to narrow the current skills gap that threatens Europe's prosperity.

A crucial first phase was to describe better the roles essential to achieving e-Europe and the wide range of skills and capabilities these involve. The next phase was to build on this and work with the education sector to devise curricula guidelines that would equip new ICT graduates for life in the information age. This curricula work has been actively supported by CEN/ISSS (the European standardisation body for the information society), Eurel (the convention of national societies of electrical engineers of Europe) and *e*-skills NTO (the UK national training organisation for ICT). Most importantly though, it has benefited from the direct involvement and support of over twenty universities and technical institutions across Europe. The resulting guidelines build on existing good curricula together with information and suggestions from the companies and associations. They provide a basis for universities and technical institutions to review and revise relevant courses.

The Career Space consortium believes that the way in which engineering and computer studies students are educated should change to meet the needs of the ICT industry in the 21st century. It does not presume to tell the University sector how to design curricula but offers information and suggestions about the needs of the ICT sector and the ways in which the skills gap might be narrowed.

ICT graduates need a solid foundation in technical skills from both the engineering and informatics cultures, with a particular emphasis on a broad systems perspective. They need training in team working, with real experience of team projects where several activities are undertaken in parallel. They also need a basic understanding of economics, market and business issues.

In addition, ICT graduates need to have good personal skills such as problem-solving abilities, awareness of the need for lifelong learning, readiness to understand fully the needs of the customer and their project colleagues, and awareness of cultural differences when acting in a global environment.

The same skill sets are as relevant to ICT professionals working in SMEs (small and medium sized enterprises) or in ICT dedicated roles within 'user' companies, as to those working in major ICT companies.

This objective can be achieved by various means and by different curriculum designs. However, the Career Space consortium recommends that ICT curricula should consist of the following core elements:

(a) a scientific base of ~30%;
(b) a technology base of ~30%;
(c) an application base and systems thinking of ~25%;
(d) a personal and business skills element of up to ~15%.

The Career Space core generic skills profiles are offered as a reference point for universities. The Career Space core profiles represent the most important areas where skills shortages are currently experienced and anticipated in the future. The profiles can be clustered into three or four curricula as appropriate to the institution concerned. Furthermore, the use of a series of core modules, followed by sets of area-specific modules and accompanied by a set of elective modules, is suggested as a flexible way to approach the design of new curricula.

The Career Space consortium recommends that practical experience of working in the ICT industry, of at least three months but ideally longer, should be an integral part of ICT curricula. An additional three months minimum should be spent on project work applying what has been learnt from lectures, etc..

Mobility of staff between academia and the ICT Industry should be facilitated.

For its part, the ICT industry undertakes to support such schemes by facilitating and releasing its personnel from other duties to perform guest lecturing and other teaching at universities as appropriate. The ICT Industry will also seek to involve locally based university staff in its research projects to further facilitate this mobility and exchange of knowledge where possible.

The boards of universities providing ICT courses should include a representative of an ICT Company.

The Career Space consortium suggests that university ICT professors organise ongoing communications between the stakeholders, with a particular focus on schools, to increase the ability of first year degree students to respond successfully to the university curriculum objectives.

In developing ICT curricula universities should first define the profile or group of profiles for which it wants to qualify the students. This should be agreed in close discussion with ICT employers and other stakeholders in an anticipated outcomes feedback loop.

The Career Space consortium further considers that stakeholders, in the form of local employers, representatives of the profession accreditation bodies, government, the students themselves, and the universities, should ideally be involved in the feedback loop with regard to the type of courses needed at universities.

Universities should set up a quality control process with documented results, and the information gleaned should be applied to the further improvement of the programme.

The consortium also urges that competence in continuous learning be developed in students during their ICT courses.

The Career Space consortium urges European universities to implement both the new ICT curricula and the Bologna agreement to help solve Europe's ICT skills gap. In this context, the Bologna style of two cycle degrees is recommended, i.e. a first cycle degree (FCD) following three or four years of study at Bachelor degree level and a second cycle degree (SCD) following a further two year study at Master level. A period of work experience is to be recommended between the first and second cycle degrees.

The Career Space consortium suggests that any ICT curriculum should consist of hierarchically organised modules:

(a) sets of core modules;
(b) sets of area-specific core modules;
(c) sets of optional (elective) modules;

It is hoped that the successful implementation of these guidelines will be of mutual benefit to industry, students and academia, enhancing and strengthening all of them and encouraging more young people to pursue the many satisfying educational and career opportunities in this exciting field.

2. Introduction

The Information and Communications Technology (ICT) industry in Europe is experiencing a severe shortage of skilled personnel that is threatening to slow progress towards *e*Europe. With the support of the European Commission, a consortium of eleven major ICT companies, (BT, Cisco Systems, IBM Europe, Intel, Microsoft Europe, Nokia, Nortel Networks, Philips Semiconductors, Siemens AG, Telefónica S.A., Thales), and EICTA, the European Information, Communications and Consumer Electronics Industry Technology Association, have been exploring new ways of addressing this skills shortage. A project was set up, co-ordinated by International Co-operation Europe Ltd., to put in place a clear framework for students, education institutions and governments that describes the skills and competencies required by the ICT industry in Europe.

The first step was to develop core generic skills profiles relevant to jobs in the consortium companies' main activity areas, and to create a dedicated website to make this information widely available (www.career-space.com). The core generic skills profiles cover the main job areas for which the ICT industry is experiencing skills shortages. These core profiles describe the jobs, setting out the vision, role and lifestyle associated with them. The specific technology areas and tasks associated with each job are also outlined, as well as the level of behavioural and technical skills required to carry out the profiled jobs.

The second step was to invite a number of universities across Europe to join the ICT companies in a working group aimed at drafting curriculum development guidelines. These guidelines are intended to assist universities in designing courses to match the skills profiles and needs of the ICT industry.

This document sets out the guidelines developed by the working group and endorsed by the ICT companies involved in the project. It outlines the development of the ICT industry, and the history of ICT curricula in universities. The need for significant change is described, given the rapid development of technology in this fast-moving area and the changing nature of jobs in the industry. Recommendations are given for the content areas of new ICT curricula covering the variety of skills required.

It is not the intention of the Career Space consortium to be rigid in these guidelines: there is a considerable spectrum of job opportunities and skill requirements, and universities may wish to specialise in particular areas. However substantial changes to curricula are considered necessary if new graduates are to be well prepared for the challenges they will encounter working in ICT.

The purpose of the curriculum development guidelines is to assist the development of courses, which will cover the whole range of needs in particular fields. The guidelines describe industry's ideal model for ICT curriculum content, give general guidelines for curriculum development and specific suggestions for new ICT curricula. They emphasise the importance of balanced curriculum content containing technical knowledge and skills, behavioural skills, industrial placements and project work. The focus is on first and second cycle degrees at Bachelor and Master level. Doctorates are not covered due to their more specialist and research-oriented nature.

2.1. Development of the ICT Industry

Throughout history, mankind has dreamt of finding ways of communicating at a distance, and ways of enhancing his natural skills in maintaining and processing information. It took a long time to develop suitable basic technologies.

Although some concepts of how to transmit messages and calculate data were developed in antiquity, real progress began with mechanical solutions for railway signalling systems and for the first calculators. Ultimately the potential for purely mechanical technologies for use in more complex ICT applications turned out to be rather limited.

The next major step forward in these technologies came with the use of electricity. Electro-mechanics, discrete electronics and finally microelectronics allowed the creation of far more complex and sophisticated systems for generating, transmitting, storing and processing information.

Given this history it is not surprising that much of today's ICT industry has its origins in companies from the electrical sector. Initially they were mainly hardware oriented and had a rich experience in realising quite complex system functions using hardware structures.

However, the growing complexity of systems, and the need for greater flexibility, required a more general system solution. The vision was to implement system functions in a more flexible way by programming universal hardware structures.

Thus computer architecture was born and a new science – computer science, informatics – started to approach the problem in a different (rather abstract) way, developing methods for software construction and information management using universal computer hardware as a processing platform.

Modern ICT solutions are combinations of both hardware and software, focussed on meeting users' requirements. Consequently, ICT is a combination of many disciplines: basic technologies and science (microelectronics, materials); structural science (computer science, informatics); and the creation and implementation of specific solutions to meet customers' needs and realise business opportunities.

Nowadays, ICT companies not only produce, install and maintain ICT equipment and systems, they also act as innovators and consultants as well as being the solution and service provider for the customer. They no longer belong only to either the production or service sectors of the economy, but increasingly participate in both: a new ICT industry sector.

This development of the ICT industry is not just an evolution of past practices, with new activities being absorbed into existing structures and ways of working. A subtle and fundamental change is under way: a revolution towards the information and communication society which will be as significant as the industrial revolution was one and a half centuries ago.

As the computer has become a more central part of modern products, both in the form of servers and workstations and as embedded systems, it has become possible to create ubiquitous, interactive, intelligent information and communication systems. These are no longer single function products, to be used for specific tasks in isolation. Instead, they have become integral to the fabric of society, communicating with other devices and people and capable of performing information processing and other tasks far beyond the capabilities of an isolated individual.

Thus, as the industrial revolution freed society from constraints of mechanical power, the information and communication revolution will free society from the constraints of information organising and processing power. The effects on future society are not yet fully apparent: but it is certain that they will be profound.

2.2. History of ICT curricula at universities

The teaching of ICT curricula in universities evolved from the development of natural and structural sciences. One main route is from electrical engineering deriving from physics, while the other route is from informatics/computer science and derives from mathematics. Historically these two routes evolved in different university departments/faculties and they developed different approaches, methodologies and cultures, even when tackling similar problems. It is not surprising that the aims and contents of ICT related curricula coming from such different origins are also different.

From the beginning the faculties of electrical engineering focused on the use of electrical technologies in two main application areas: power and information. Since they understood that the science and technology of electricity and electromagnetism is the foundation of their R&D and education activities, they have always striven to keep these fundamentals as the core of the curricula they offer to students. So ICT-related curricula within electrical engineering courses have always been science and technology biased. Another important aspect has been the teaching of engineering methodology, which has proved to be very successful in enabling practitioners to adopt new technologies. The ICT Industry is now encouraging the adoption of similar methodologies outside the hardware area.

This philosophy led to a common core curriculum in the first part of the study programme for electrical engineering. The split into different application-oriented areas (such as power, information, etc.) took place in the second part of the course. Such curricula ‘produced’ rather traditional, hardware-oriented ICT engineers. The recognition of software as an important teaching area was generally not accepted for a long time, and even today the content of informatics subjects tends to be under-represented in the curricula for electrical engineering.

In contrast, the faculties of informatics focused on software-related structures and methods. Considering mathematics and algorithms to be the foundation of their R&D and teaching activities, these fundamentals are still kept as the core of the curricula offered to students by these departments. Traditional informatics and computer science curricula are, therefore, often abstract and mathematics biased, with a rather weak relation to engineering and hardware technology as well as to application related software areas. In some European countries a degree in informatics is not considered to be an engineering degree, which illustrates the cultural difference between engineering and informatics.

Although many efforts have been made to encourage cross-disciplinary teaching in recent years, there remains an impression that much university course work retains its foundations in the two differing traditions, with different methods, different terminology and a different focus. Department and policy-making structures in some universities may tend to perpetuate an artificial divide between these two aspects of ICT skills.

It should not be forgotten that other disciplines are relevant to ICT curricula, as well as technical ones. Economics, business studies, creative design, social sciences and psychology all have important and increasing parts to play in ICT training. Indeed, for some ICT careers these aspects have greater importance than the technical skills (see core generic skills profiles at www.career-space.com for details). Again, university structures may sometimes inhibit the adoption of innovative cross-disciplinary ICT curricula incorporating those elements.

3. The ICT industry’s needs

The Career-Space consortium recognises the importance of the diversity of skills, which have arisen from the traditional electrical engineering and informatics course backgrounds. This is especially true for R&D activities in the universities. The ICT industry still needs graduates with these two diverse profiles, especially at Master level, for its own R&D activities in different ICT fields. However, the quantitative need for graduates qualified in such a way is limited to less than one third of total university graduate staff in industry.

3.1. New ICT programmes are required

The vast majority of employees in the ICT industry need a different focus to suit their main activities: the development of application-oriented solutions; implementation, management and support of ICT systems; and ICT selling and consultancy. The majority of graduates increasingly need a combined qualification from both the engineering and informatics cultures as well as from other related disciplines such as business and behavioural skills.

3.2. Combine elements of electrical engineering and informatics

This different focus of the ICT industry’s needs in terms of technical skills is summarised in Figure1. The core generic skills profiles (see www.career-space.com) are placed along the technical skills axis between engineering and informatics just to indicate the wide range of skills profiles in the ICT industry. Traditional engineering programmes are still needed, as are the traditional informatics programmes, but they do not adequately cover the whole range or the middle ground. This is why new ICT curricula are needed.

Therefore, the Career-Space consortium would urge universities who see themselves as endeavouring to meet the needs of the ICT industry to create and develop new curricula which contain elements from electrical engineering, elements from informatics, and a significant focus on the teaching, training and practice of behavioural and business skills.

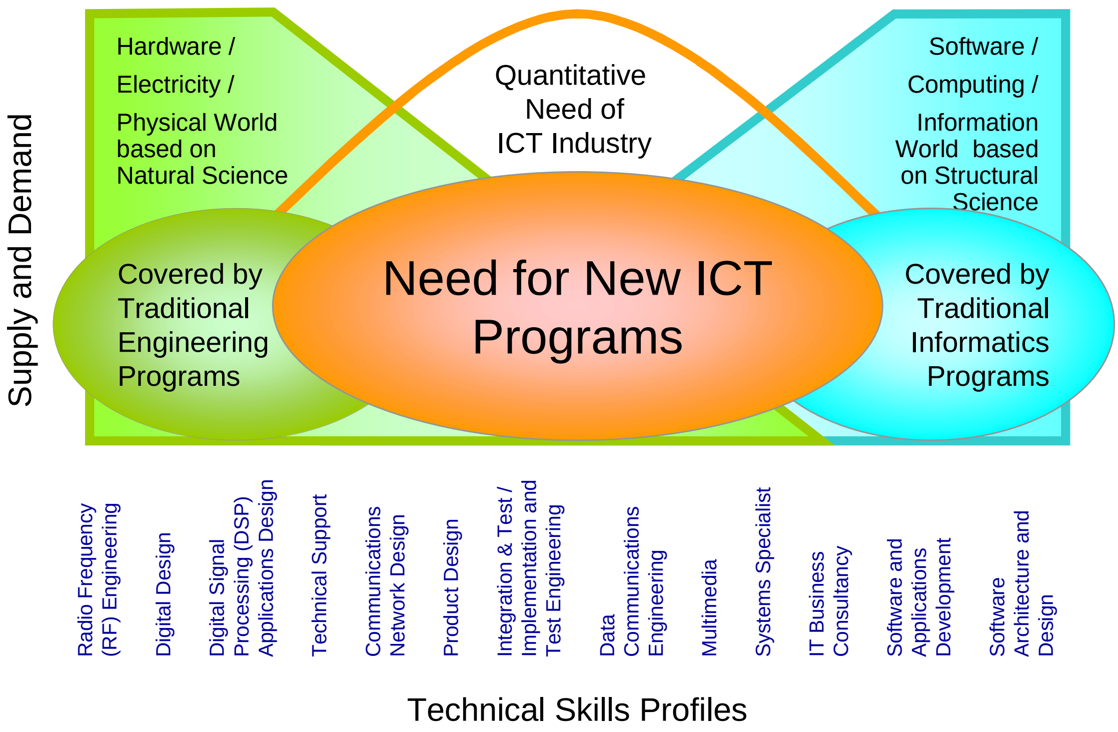

Figure 1 **The profile of ICT industry's needs for degree qualifications depicting new curricula which combine elements of traditional engineering and informatics programmes**

3.3. A broad systems view is necessary

The training needed for ICT graduates is not just a combination of the elements mentioned above. The need for a broad systems viewpoint is essential, with the ability to understand the possibilities and constraints of the various technologies and to talk in a common language with the diversity of people involved. At present, this systems viewpoint and the corresponding ability to create complete system solutions seems to be seriously lacking in many new graduates in the ICT industry.

3.4. Business knowledge is required

At outlined above, ICT system solutions are increasingly at the heart of the way companies do business. Indeed, they are often inseparable from business processes, and the functions they perform may be the core of how a company manages to do business at all. A clear understanding of the fundamentals of business is, therefore, a necessary element of a wellrounded ICT graduate's training. This aspect seems to receive little or no attention within existing ICT curricula.

3.5. New behavioural skills are required

As well as working on different things, people in the ICT industry now work in different ways. The complexity of systems continues to multiply, and the introduction rate or time to market of new products continues to get faster and shorter. Also, many different technologies may be combined to produce an overall system solution.

This means that many people must work together on the same project, not in sequence but at the same time and in parallel. So this approach is different from a traditional model, where it was important for an engineer or computer scientist to work alone on a project of lesser complexity and produce a solution over a longer time frame.

Specialists now work as part of multi-disciplinary development teams, which are often international and located on different sites. There is an increasing trend for products to be designed for a global market, with national boundaries becoming less relevant. Marketing staff and customers tend to be involved in the development of a product right from the start.

An ICT graduate needs to be able to work with others from different cultures and backgrounds and arrive at a mutual understanding, in order to meet deadlines while working in this parallel way. Consequently, these behavioural aspects need to be taught in university curricula. What is needed is situational and contextual learning, both embedded in technical and scientific courses and more explicitly taught. Students should be made aware of the value and importance of this type of learning to the ICT industry.

Since technologies improve and change rapidly, some things which have been learnt may become less relevant over time, and other new aspects need to be studied further for a fuller understanding.

It is, therefore, necessary for the teaching environment to encourage and develop competence in continuous learning as a natural process of the student's own development, which certainly should not stop after leaving university.

3.6. Increased mobility between academia and industry

It is also suggested that, as well as student mobility being facilitated and encouraged, the mobility of university lecturers and professors between academia and the ICT industry should be developed. The ICT industry proposes to support the changes, which it is asking universities to make by providing guest lecturers and professors from among its staff members.

Long and shorter periods of teaching activity by ICT industry personnel could be envisaged to meet the needs of academia. Government and accreditation body rules and regulations, which inhibit or prevent such university-industry personnel exchanges, should be reviewed and altered as required.

The ICT industry accepts the challenge made to it by universities asking it to involve university staff based locally in its research projects so that the academics in question can work in the industry for long and short periods, perhaps during sabbaticals and other mutually convenient periods, and thus experience directly for themselves the changing needs of the ICT industry and feed these back into curriculum design.

Vision of University-ICT Industry Relationship

by Lionel Brunie, National Institute of Applied Science, Lyon, France,
Member of the Career Space Curriculum Development Guidelines working group

The relationship between Universities and companies is a key issue for the development of academic programmes. The Career Space project is a clear illustration of this fact. However, one must admit that this relationship has long been a relationship of mutual suspicion: most companies considered that Universities did not prepare students for their actual needs i.e., for an immediately effective and profitable integration within development teams, because programmes focused too much on concepts and theory and not enough on know how. In turn, Universities criticised companies for minimising education on citizenship and personal development which they, Universities, considered as the core of their mission.

Fortunately, over the last 10 years, things have evolved positively. All Universities now place student employability at the heart of their programmes while companies, seeing the need to cope with a rapidly changing world, agree that a strong methodological and scientific background is a *sine qua non* to prepare employees for technological change.

As a consequence, universities and companies need to co-operate to design and tailor academic programmes. In this framework, several recommendations can be made. First of all (this is now commonly implemented), all ICT curricula should include work periods in companies in order to allow students to discover 'real life' in a company, to integrate the project dimension of their future work and to apply the know-how they learn at the university.

Career Space also recommends that the board of an ICT university involve representatives of companies (or at least that the board regularly invite participation from such representatives) in order to discuss together the curriculum components and their appropriateness to industry needs. Indeed, curriculum evolution and adaptation is a key issue in a rapidly changing technological sector like telecommunications or informatics. This adaptation should be carried out in close collaboration with industry (which knows its own needs) and between researchers and teachers who work on the development of future technologies. Curriculum evolution should reflect deep, structural technological changes and not short-term 'technical fads or fashions'.

Furthermore, as is common practice in many management schools, ICT departments should benefit from industry partners giving lectures on their courses (e.g. for approximately 20% of the teaching time), especially in domains like ICT project management or software quality, for which practical experience of large multinational multi-sited projects is clearly desirable.

Thus, when national regulations allow, associate professors with a mixed status (university-company) can play a very positive role in a teaching team. National regulations which, inhibit or prevent this type of cross-fertilisation should be reviewed with a view to being relaxed or changed.

Finally, it is suggested that agreements or conventions be signed between university departments and companies to allow teachers to integrate into industrial project teams as observers (e.g. half a day per week) so that, on the one hand, teachers are aware of the actual concerns of companies and improve their knowledge and hands-on experience of industrial project management, software specifications, quality insurance, etc. and, on the other hand, companies are made aware of the latest research innovations.

3.7. Summarising industry's needs

To summarise, ICT graduates need a solid foundation in technical skills from both the engineering and informatics cultures, with a particular emphasis on a broad systems perspective. They need training in team working, with real experience of team projects where several activities are undertaken in parallel. They need a basic understanding of economics, market and business issues too.

In addition, ICT graduates need to have good personal skills such as problem-solving abilities, communication and persuasion skills, awareness of the need for lifelong learning, readiness to understand fully the needs of the customer and their project colleagues, and awareness of cultural differences when acting in a global environment.

In other words, they need qualifications, which enable them to work in the activity areas described in the ICT consortium's Career Space core generic skills profiles for the ICT industry in Europe (www.career-space.com).

At the start of the 21st century the need for such graduates in the ICT industry is rapidly increasing and a number of question should be asked:.

(a) are European universities and other institutions ready to respond to this need?

(b) are their ICT curricula designed for the needs of the 21st century?

(c) will they give solid foundations for graduates to become effective leaders and innovators in the ICT industry?

These are the key challenges the Career Space ICT consortium puts to European universities.

4. New ICT curriculum development guidelines

In order to find answers to the above challenges, the Career Space consortium established a working group on ICT curricula development. Representatives from over 20 universities and from the Career Space consortium companies participated. They examined existing ICT curricula and produced the new ICT curricula development guidelines, which are set out below. The working group evaluated the core generic skills competence profiles in relation to the curricula content in about 100 ICT study programmes at thirteen universities in nine European countries.

4.1. State of the art of current ICT curricula

In the first step, the participating universities were asked to indicate all ICT study programmes in these institutions offered by any department or faculty. The question was then posed as to how these programmes relate to the core generic skills profiles defined by the consortium. In this exercise, universities identified the extent to which the outcome of the programmes meets the skills requirements of each core generic skills profile (fully, partly or not at all).

The result shows that many of these European ICT curricula cover all the core skills profiles to a certain degree, although the extent of coverage varies widely.

	Skills Profile	F (%)	P (%)	N (%)
1	SW & Application Development	54	31	15
2	Systems Specialist	48	37	15
3	SW Architecture & Design	45	42	13
4	Data Communications Engineering	35	40	25
5	IT Business Consultancy	32	23	45
6	Digital Design	31	33	36
7	Communications Network Design	29	45	26
8	Product Design	26	48	26
9	Technical Support	23	42	35
10	Integr./Implement./Test Engineering	20	60	20
11	DSP Application Design	17	42	41
12	Multimedia Design	15	54	31
13	RF Engineering	11	25	64

F = requirements fully met; P = partly met; N = not met

Figure 2 Extent to which current curricula match skills requirements of Career Space core generic skills profiles shown in order of highest match

Another conclusion was that most study programmes focus on the skills profiles ‘software and application development’, ‘system specialist’ and ‘software architecture and design’. About 50 % of all programmes cover these skills profiles fully.

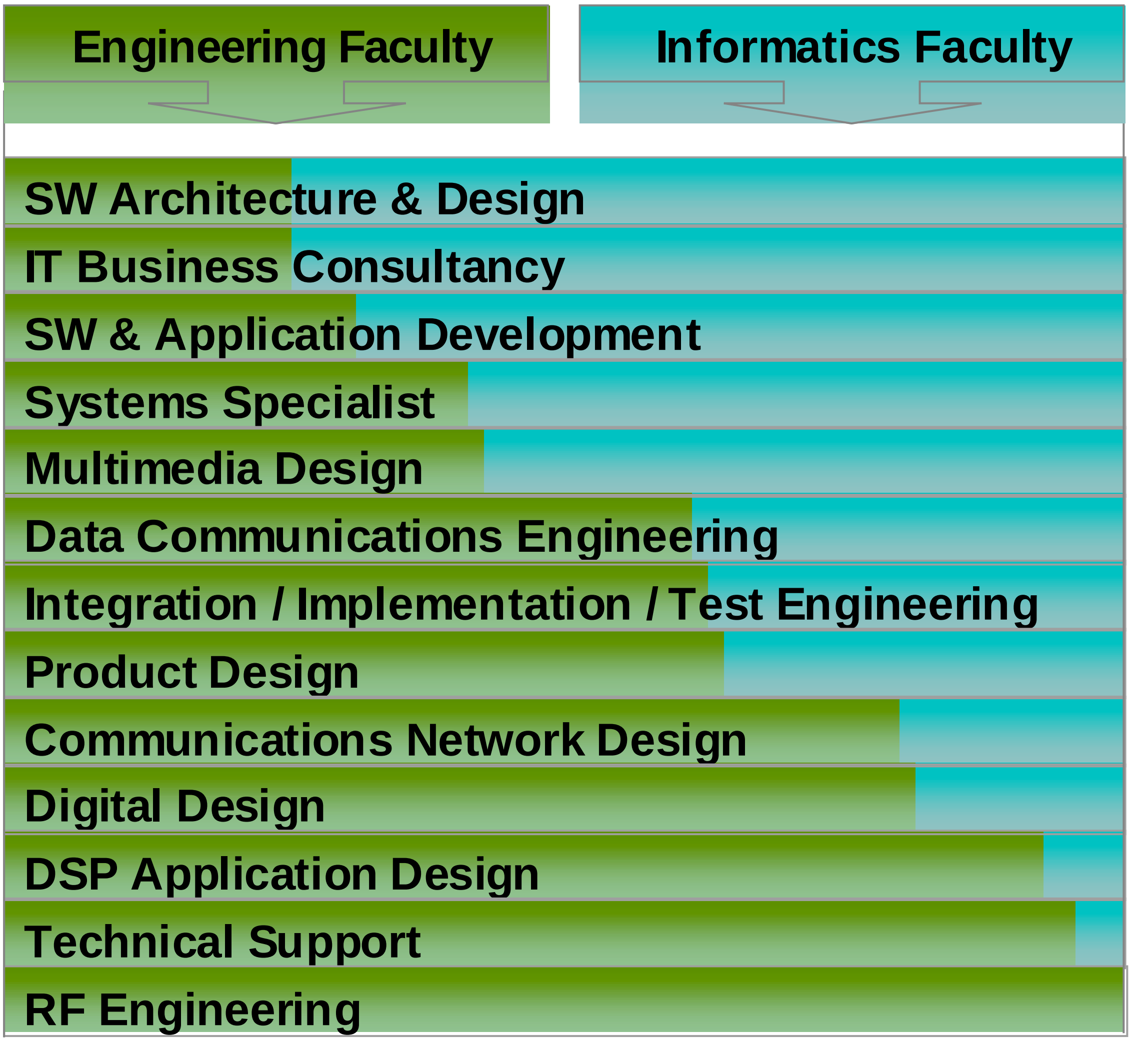

Figure 3 Current faculty origin of programme coverage for Career Space generic skills profiles

Our study also showed that there is a different focus between engineering and informatics faculties (Figure 3).

Informatics faculties design their study programmes around software oriented issues. Their graduates seem to be well-prepared for activities in areas such as ‘software architecture and design’, ‘IT business consultancy’, and ‘software and applications development’ (www.career-space.com). Engineering departments, and here particularly the electrical and electronics departments, prepare students for activities in telecommunications and hardware design. This approach covers core skills profiles such as ‘communications network design’, ‘digital design’, and ‘digital signal processing applications (DSP) design’, as well as ‘technical support’ and ‘radio frequency (RF) engineering’.

As one would expect, the results reflect the traditional emphasis and differences between ICT curricula and the subjects studied in engineering and informatics faculties, depending on the department responsible for delivering the ICT course.

4.2. What content is needed?

The second part of the working group’s investigation related to the curricula content. The purpose was to evaluate the content of each study programme in relation to the ICT industry's requirements for graduates' qualifications. But just what are the industry's requirements for a university study programme? This question was answered first.

The content of curricula is always a key issue for discussions inside faculties, as well as for dialogue between industry and universities. University professors ask industry these key questions:

(a) what competencies do graduates need in industry?

(b) what knowledge should be taught?

The question about the competencies required can be answered easily by industrialists. Since they have to deal with opportunities and problems in their day–to-day activities, they are very clear about what technical, professional and personal competencies are needed in order to be successful in business.

A wide range of technical skills is needed by all employees, while singular in-depth skills are needed for people working in particular specialised areas. The ability to take a systems perspective is required. Communicating effectively with others in different fields is a necessary attribute. Working in multi-disciplinary multi-cultural project teams is a way of life. The ability to take initiatives and create system solutions or solve problems is fundamental.

However it is not so easy to identify what knowledge is required to achieve the desired competencies. Experienced people know what specialised knowledge is needed for their particular activities, because this is vital for success in their daily work. However, specialised knowledge can only be deployed if it is built on the foundation of a solid, broad general understanding. This fact is often neglected. Identifying this foundation is much more difficult.

So what is the ideal content distribution of an ICT curriculum? Is there only one optimum solution, or are there many possible ways to achieve excellent results? The working group considered these issues, and came to the following recommendations.

4.3. ICT industry's model for ICT curriculum content

The Career Space ICT consortium believes that there is no one single way to design the best ICT curriculum. On the contrary, if the cultural diversity in Europe is to be used to give competitive advantage to this region, each university must find its own best solution. Nevertheless, a framework based on experience and best practice can lead to a set of useful guidelines. Following these guidelines will help universities find their own way to success.

The Career Space consortium believes that the same skill sets are needed by SME's (small and medium sized enterprises) as by the larger companies involved in this project.

Analysis of an ICT graduate's work in industry shows that it consists of various tasks characteristic of a particular job. The activities depend on various factors such as specialist area, functional area, company size, etc., each placing specific demands on the staff member's knowledge and ability. Although these demands may vary for different tasks, the basic structure of the knowledge required is the same.

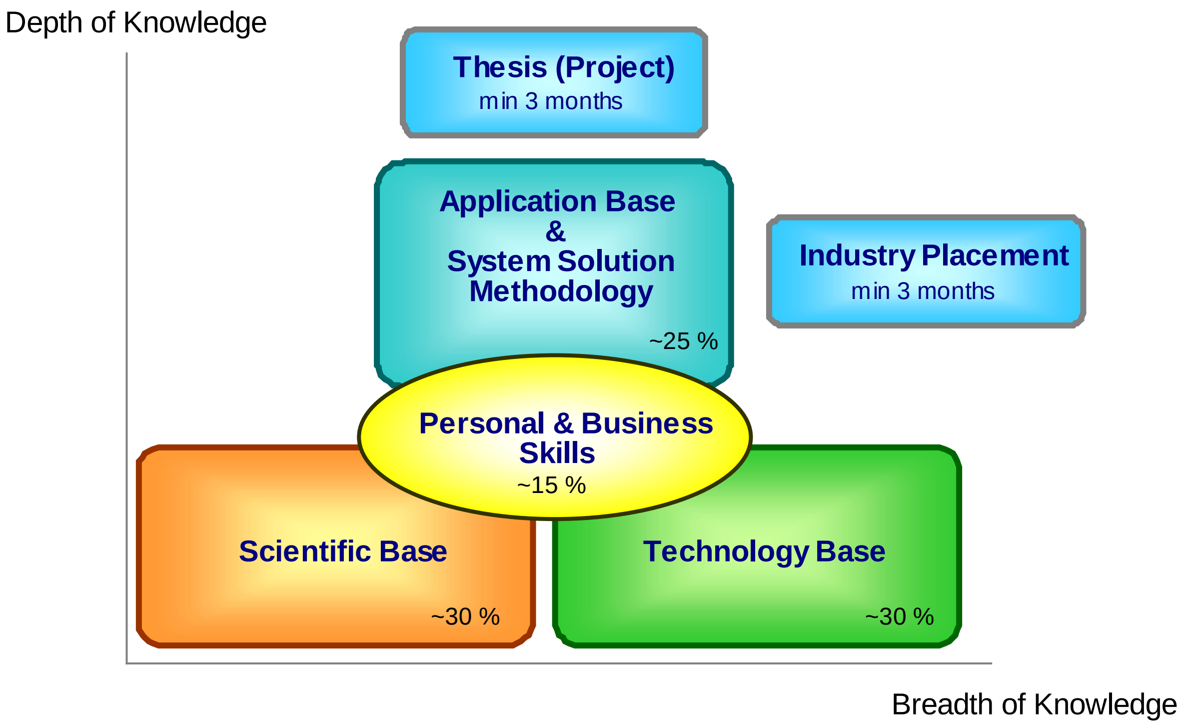

Figure 4 Scope of competence, showing model ICT curriculum content

The scope of graduates' professional competence can be illustrated in a diagram using two co-ordinate axes ‘Depth of knowledge’ and ‘Breadth of knowledge’. The specialised areas are located along the ‘Breadth of knowledge’ axis. ‘Depth of knowledge’ indicates the level of knowledge in these areas, up to a standard of full professional expertise. This principle is used in the diagram, Figure 4. This diagram also points towards methods of organising courses and the means of delivery of courses to gain the competencies in question by mentioning the industrial placement, as well as project and thesis work.

Clearly it is not possible for everyone to become an expert in all areas. Broad knowledge is, in general, only feasible at the foundation level. Specialisation to the leading edge of knowledge and deep understanding is normally only possible in one specific area.

4.3.1. Broad basics are necessary

The basis of the necessary technical qualifications is a broad spectrum of knowledge in mathematics, science and technology. This basic knowledge is essential for a broad understanding of natural processes and their utilisation in technical applications; however, it also serves as a foundation for attaining a breadth and depth of knowledge in a specialist field of application.

A broad foundation is also an important prerequisite to enable graduates to communicate effectively with colleagues from other areas using a common ‘technical language’.

So the core of qualifications to be attained during an ICT education should comprise a scientific base and a technology base, i.e. a broad spectrum of mathematical, scientific and technical knowledge. This core should extend to all subjects under consideration, thus laying the foundation for subsequent professional mobility. The teaching of this core should not go to too great a depth, but should give students a balanced overview: it should also teach them how they can independently acquire the additional knowledge they need, both during their studies and in later professional life.

4.3.2. Scientific base ~30% is recommended

The scientific base covers the fundamental principles relevant to the concepts used in the ICT industry. In addition to a foundation in science and mathematics, the scientific base should foster an understanding of scientific methods for analysis and design.

4.3.3. Technology base ~30% is recommended

The technology base is more concerned with giving a broad overview of the various technologies available, the functions they can perform and their advantages and constraints. In addition to studying the current capability of a technology, students should be given some insight into how that technology might develop in the future.

The sound teaching of a broad foundation during ICT studies is very important, because experience shows that gaps in knowledge are difficult to bridge once a professional career has begun.

In considering what proportion of the curriculum should be devoted to these core subjects, assessment indicates that an optimal compromise in ICT education can be attained with about 30% of the course devoted to each of these foundation subjects: the scientific base, and the technology base. These elements are shown in Figure 4.

4.3.4. Strong linkage between science and technology bases

Of course these topics should not be taught in isolation: it is important to highlight the links between the science and technology base. This is necessary to avoid perceptions in the minds of the students of theories with no practical use, technologies with no analytical basis, or technologies with no connection to other technologies. It is considered that this solid, broad foundation of basic science and technology is necessary for all ICT graduates.

4.3.5. Application base and systems thinking ~ 25% is recommended

However, a command of the basics is not in itself sufficient for assuring professional competence in industry. In order to meet the demands of the job, ICT graduates also need an in-depth fundamental knowledge of their specialised fields, general knowledge of problem solving methods, and, finally, particular application knowledge in accordance with workplace demands for the particular job profile.

In-depth general knowledge of an application area gives the graduate an overview of the entire scope of the task, the ability to see how his/her particular solution fits into the overall system solution, and the competence to master interface problems.

The key requirements here are knowledge of system functions in the field in question, and understanding of the technological possibilities (hardware and software) for realising or implementing those functions with the help of procedural methods.

Given the growing complexity of modern devices, equipment and systems, the ability to see things as a whole, to think in terms of systems and to communicate at a systems level with all those working on the project and with the customers is increasingly important. We recommend about 25% of the curriculum should be devoted to this area, marked as application base and system solution methodology in Figure 4.

Systems Thinking & Learning

by Andreas Kaiser, ISEN, Lille, France,
Member of the Career Space Curriculum Development Guidelines working group.

Today, young graduate recruits have to integrate into teams working on very complex systems with close interaction and interdependence of various system components and aspects. This makes it ever more necessary to develop 'systems skills' as part of the curriculum, as these skills are essential to professional success.

Traditionally, educational focus was on the development of the capacity of abstraction by teaching mathematics. This approach has two limitations: on the one hand, the overall aim of increasing the numbers of graduates in the ICT field is incompatible with a 'selection process' based on mathematics, which is increasingly being rejected as a discipline by the younger generation. On the other hand, capacity of abstraction (ability to do abstract thinking) alone is not sufficient.

'System skills' include the ability to analyse, represent, partition systems, to isolate problems as well as problem solving. This is 'systems thinking'. These systems skills are closely linked to 'behavioural skills' such as teamwork, personal communication, problem formulation, information retrieval, etc., as no single person can master all aspects of very the complex systems common in the ICT industry today.

Today these 'system skills' do not appear explicitly on university curricula. They are mostly hidden or imbedded in activities such as projects and are not necessarily explicitly evaluated or examined. Furthermore, there is a lack of teaching tools to help students to acquire these skills. Consequently 'system skills' are a challenge to universities as they need to develop new teaching and evaluation methods, and introduce such teaching in years 1 and 2 of higher education ICT courses.

4.3.6. Personal and business skills – a key element should make-up circa 15% of an ICT Curriculum

Industry is seriously concerned that universities do not give enough attention to personal and business skills in their current ICT curricula. We recommend therefore that ICT curriculum delivery should be designed so as to provide on-going use and development of personal and business skills through team projects, commercial simulations, negotiation, presentations, etc., throughout the course. Coupling this implicit learning with feedback and coaching from lecturers not only on the academic aspects, but on how well these skills are acquired and deployed should provide the on-going learning stimulus needed to develop these skills which are vital for a career in ICT. Particular attention should also be paid to embedding the teaching of these essential personal and business skills, into the more technical subjects areas. We recommend that at least 15% of the curriculum should be devoted to personal and business skills.

NOTE ON SITUATIONAL LEARNING
THE EXPLICIT ACQUISITION OF BEHAVIOURAL SKILLS

by Peter Revill, e Skills, NTO UK,
Member of the Career Space Curriculum Development Guidelines working group.

One of the most fundamental concepts in learning is transfer, i.e., the ability to apply something learned in one situation to another setting. Transfer of learning can be defined operationally as improved performance on one task as a result of knowledge acquired on a previous task. This could apply to any type of skill (e.g., analytical, communication, problem solving, leadership, etc.).

Historically, methods of didactic education, often an integral part of higher education delivery, assume a separation between knowing and doing, treating knowledge as something integral and self-sufficient, theoretically independent of the situations in which it is learned and used. However, more experiential teaching methods use direct debriefing opportunities designed to help the student ‘situationalise’ and recognise, the many aspects of learning taking place. These methods are particularly useful with regard to the softer or behavioural skills.

To reinforce the idea that behavioural concepts are both situated and progressively developed through activity, the idea that they are abstract, implicit and self-contained should be abandoned. Instead, it may be more useful to consider behavioural skills as being a set of tools. Such tools in this context can only be fully understood through use, and using them entails changing the user's view of the world. If behavioural skills are thought of in this way they can be used to distinguish between the ‘mere acquisition of inert concepts and the development of useful, robust knowledge’ (Whitehead 1929).

It is possible to acquire a tool but be unable to use it because either its acquisition has not been recognised by the learner or she/he is unable to transfer the learning from one situation to another. Students who are given the opportunity to use behavioural skills in a context-oriented environment, where opportunities exist for the emerging learning to be made explicit and recognised by the learner, build a richer understanding of themselves and their abilities and increase their own self confidence to perform the myriad tasks expected of them by potential employers. Lifelong learning is a process of working in ‘situations’. Guided reflection assisted by the teacher, but undertaken by the learner about the activities integral to that ‘situation’ will help recognition of the learning-taking place.

4.3.7. Practical work experience – minimum 3 months, preferably longer

Two other key elements of a well-structured ICT curriculum need to be mentioned. It is not sufficient just to learn about technical and other issues and pass exams; the techniques need to be used in real situations. This is particularly important to emphasise the connections between different aspects, to encourage a broad systems view and to illustrate the practical, technological and human constraints of solving real-world problems.

In addition, concerns about intellectual property rights and commercial confidentiality should be resolved by industry so that they do not impede opportunities for students to work in industry.

In order to develop a better understanding of how industry operates, the consortium recommends an industry placement for the student of at least 3 months duration**.** Not only does this give practical experience of real problem-solving, it should also help the student more clearly to identify the kind of work she/he would enjoy after graduation. It may also lead to mutually beneficial contacts and networking opportunities.

4.3.8. Project work – minimum 3 months

Project work at university is vital in developing these skills, and we recommend that at least 3 months be allocated for the project and the related thesis. It is recognised that there are difficulties in assessing the performance of individual students when team projects are being undertaken. Nevertheless, the Career Space consortium believes some experience of team working on a significant real project is an essential element of a good ICT education. The challenge of assessing and crediting team-work by students needs to be addressed by academia. As these skills are deemed essential core skills in the ICT industry, it has developed means of assessing and improving them in its workforce. Academia might benefit from this industry experience of assessment of these skills.

All these elements are included in Figure 4, which can be considered the general structure of a 'model ICT curriculum' as recommended by the Career Space consortium.

5. General guidelines for curriculum development

University education is a complex process. The quality of the outcome is measured using graduates' success in their professions. That depends on different stakeholders inside and outside the university, and they should all be involved in the design, control and operation of this process (Figure 5).

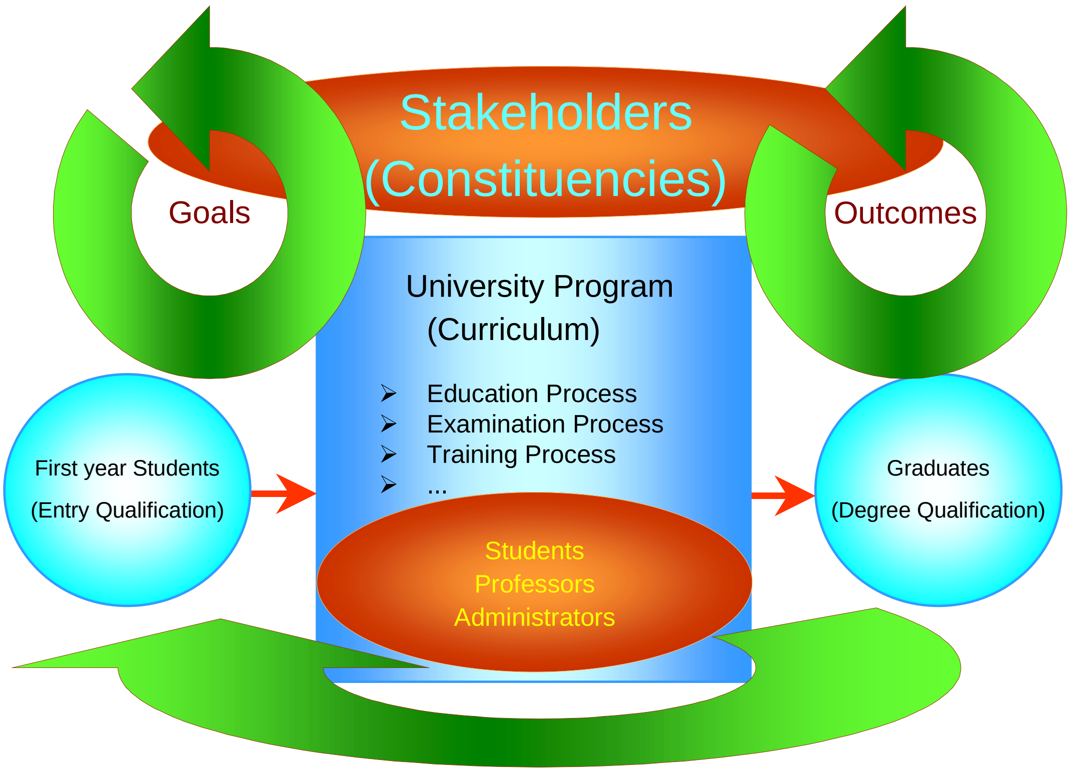

Figure 5 The University Education Process

5.1. Set-up entry requirements

At the start of the process of higher education, there is a student with a certain entry qualification profile and level. In first cycle courses the student's level and qualifications have been acquired through general secondary education up to the age of 18 years. Second cycle courses will normally build on a first cycle degree. The university must clearly define the required entry qualification for each programme they offer, specifying the knowledge, skills and abilities the students are expected to have.

Entry requirements or expectations, where they exist, should reflect the university policy and the goals of the programme, but they should also take into account the real performance of the secondary education process, which precedes the university education process. The main stakeholders here are university professors, primary and secondary school teachers, and ministries for education, pupils and their parents.

The Career Space consortium suggests that university professors organise a permanent communication between the stakeholders, especially with primary and secondary schools, to increase the ability of first year students to respond well to university curriculum objectives.

5.2. Define outcomes

The output of the university education process is a graduate with a degree qualification and certain abilities, which should qualify him or her for activities in the ICT sector. The level and skills profile should be relevant to labour market requirements. Therefore, the graduate qualification should be described as a set of abilities required to exercise the profession, rather than just listing the knowledge acquired in the education process. The main stakeholders here are university professors, representatives from the profession (e.g. industry), industrial and professional associations, accreditation bodies, government, and, not least, the students themselves.

The ICT Consortium recommends that university professors organise a second loop of permanent communication between the stakeholders, especially local employers though they may in fact be global operators, in order to adjust the outcomes to the needs of the profession continuously, to keep the outcomes up-to-date, and to increase the employability of their graduates on an on-going basis. A valuable input for defining the outcomes of ICT curricula are the core generic skills profiles established by the Career Space ICT consortium.

5.3. Define the qualification process

The core of the qualification process is the university programme (curriculum) the aim of which is to bridge the gap between input and output requirements. An ideal curriculum is strictly focussed on outcomes, lifting the students' qualification from entry to a clearly defined graduate level.

The curriculum defines the education process (the sequence of adjusted lectures and exercises which deliver knowledge), the examination process (which evaluates the students' achievements), and the training process (which helps practise these skills and develop abilities).

The internal protagonists in all these processes are students, professors and other academic and administrative staff. Externally, industry representatives are involved whenever students spend the placement period, work on theses or work in industry during holiday periods. The quality of this process depends hugely on coordination between the sub-processes as well as between the protagonists involved and the feedback loops put in place at all levels.

5.4. Implement curriculum quality control

Universities should set up a quality control process with documented results, and the information gleaned should be applied to the further improvement of the programme. Such a process should take feedback from the student in terms of how well the course matched outcome objectives and whether the student felt he or she acquired the right knowledge and skills for the job from the course. The quality control process should also get feedback from industry in assessing the former students competencies in both technical and behavioural areas following recruitment. It is suggested, for example, that a feedback request could be sent to all students after they graduate and to their employer some time between one and three years later.

6. The European higher education system for the 21st century

6.1. European state of the art: diversity of national systems

In Europe, the national educational systems are, in a special way, the expression of the cultural identity of each individual country. Despite many common roots, this has lead to pronounced structural differences.

Reflecting national needs and attitudes, the first major difference can be seen at secondary school level. From country to country there are different types of schools, with a different emphasis on content, different pedagogical approaches embodying different standards, cultural norms and duration of education. Similar differences can be found in university education at tertiary level: different types of universities with their own educational profiles, different levels of theory and practice in education, different academic values for their degrees, different titles and again different lengths of study. Two main education systems have evolved in Europe:

(a) The ‘continental system’ based on two types of university programme:
- the ‘long education programme’ (normally 5 years, more theoretically oriented);
- the ‘short education programme’ (normally 3-4 years, more application oriented).

(b) The ‘Anglo-American system’ based on two consecutive cycles of university programmes:
- the ‘undergraduate programme" (normally 3-4 years with Bachelor degrees)
- the ‘graduate programme’ (normally 1-2 years with Master degrees).

For a long time the systems had a low degree of compatibility. The result was a rather restricted mobility of students and graduates between the two systems.

In this age of globalisation, international university education is needed. An open, global society needs an open and flowing exchange between regions, and industry increasingly needs employees with an international orientation, foreign language skills and ties to diverse cultures. To meet these demands, students should have more opportunities to complete a phase of their studies abroad in order to gain experience of other cultures. Typically, knowledge of other cultures and peoples is acquired when learning foreign languages. Globally, the ICT industry works in English.

6.2. A common European approach: the Bologna Declaration

The Anglo-American consecutive system has established a *de-facto* world-wide standard with its consecutive Bachelor, Master, and PhD degrees. These degrees serve as widely recognised mobility-enabling labels in the global educational system. They are especially suitable for promoting the international mobility of students and graduates. The European Union Ministers of Education and Science agreed in June 1999 to create a 'European area of higher education' and establish a 'European system of higher education' (ESHE) by 2010. This agreement is called the ***Bologna Declaration***.

The ESHE is based essentially on two main cycles, undergraduate and graduate. Access to the second cycle requires successful completion of the first cycle studies, lasting a minimum of three years.

The degree awarded after the first cycle is relevant to the European labour market as an appropriate level of qualification. The second cycle leads to the Master and/or doctorate degree, as in many European countries at present.

Some European countries have reacted very quickly to the Bologna Declaration and have already changed their educational legislation (e.g. Germany, Italy) to implement it. In the transition period, university programmes in Europe will be a combination of the old and new systems, i.e. we will see the coexistence of traditional 'long' and 'short' courses and consecutive first and second cycle courses. The formal compatibility of degree levels in traditional and new programmes is shown in Figure 6.

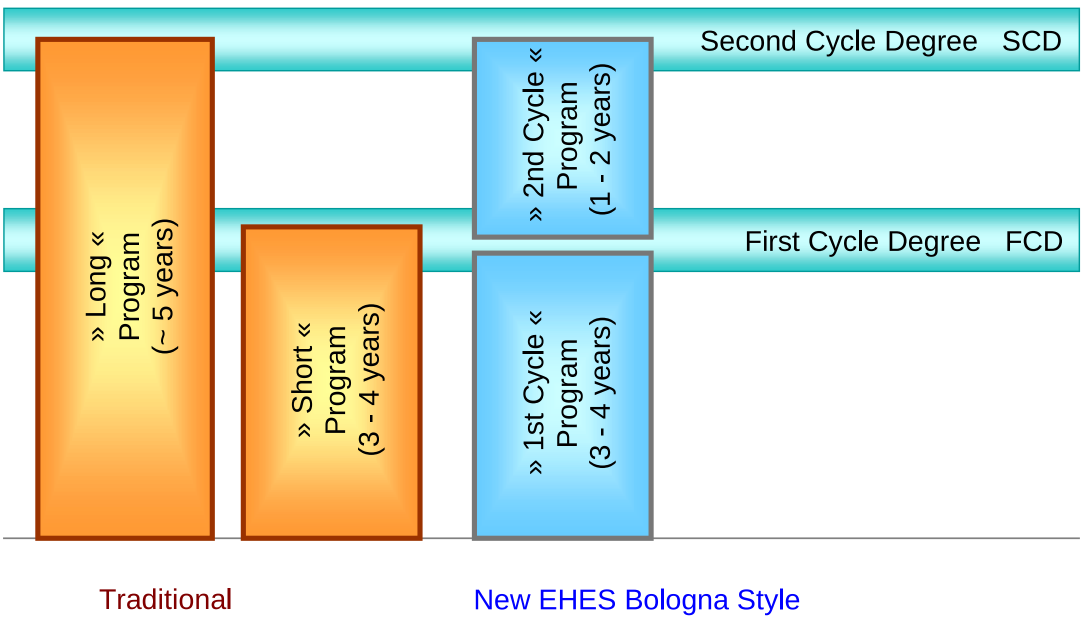

Figure 6 The formal compatibility of degree levels in traditional and new European higher education system programmes

The ICT Industry in Europe welcomes the Bologna declaration and recommends that governments and universities implement the new European higher education system urgently. Students can take the two cycles in different countries and gain international experience in different cultures during their studies. In planning their lifelong education they can also distribute the learning phases over a longer time, e.g. working and gaining professional experience in the period between the two cycles and returning to part-time or full time study to upgrade and get up-to-date education as whenever its appropriate. This is a particular advantage for subject areas with a rapid pace of change, such as ICT.

Universities will be expected to increasingly offer a new variety of ICT first cycle degree (FCD) courses and different types of second cycle degree (SCD) programmes (consecutive and conversion) in ICT and ICT-related sectors:

(a) first cycle degree (FCD) ICT programmes (3-4 years) focussing on education of ICT specialists for different ICT generic skills profiles groups (new courses at basic level ICT education);

(b) consecutive second cycle degree ICT programmes (1-2 years) for graduates with FCD in ICT leading to a higher level of specialisation primarily for R&D activities in specialised ICT sectors;

(c) conversion second cycle degree (SCD) programmes for graduates with FCD in ICT, such as MBAs, qualifying them for a wide range of tasks in industry where both solid ICT and business skills are required.

(d) Conversion SCD ICT Programmes for graduates with FCD in non ICT disciplines so that they can become effective innovators in many application areas in the ICT industry.

The Career Space consortium expects that conversion courses will also be offered in part time and/or distance learning continuing education in order to respond more effectively to the needs of those who are in the labour market. When appropriate, universities should not insist on a first cycle degree but should rather consider applicants on merit including work experience for entry to second cycle degree courses.

The introduction of new ICT and ICT-related consecutive and conversion courses will help universities to attract more students and industry and society to substantially reduce the ICT skills shortage in Europe.

7. Recommendations for designing new ICT curricula

The cycle of knowledge creation, distribution, learning and utilisation is becoming shorter. This, in turn, leads to a need for continuous qualification of the workforce and an update of the learning content.

As a result, new curricula reflecting novel content, learning objectives, teaching methodology, certification and relevant learning process need to be designed. These curricula should meet the needs of traditional full-time learners as well as non-traditional learners such as part-timers and mature students.

In order to meet all these requirements the ICT curricula need a flexible structure on a modular basis so that they can be easily adapted to different target groups, different skills profile needs and the rapid pace of change.

7.1. Curriculum Structure

In general, no curriculum can prepare students for activities at expert level in all skill profiles. However, every ICT curriculum should provide a common ICT platform at basic level, enabling the graduates to work in teams on common projects and to communicate in common ICT language even if they have specialised in different ICT sectors. A deeper qualification should be provided for a group of skills profiles which are rather similar and have a common set of knowledge and skills requirements. The in-depth qualification should normally meet the requirements of one selected generic skills profile and contain the knowledge and skills related to that profile.

Consequently the Career Space consortium suggests that any ICT curriculum should consist of hierarchically organised modules:

(a) sets of core modules;
(b) sets of area-specific core modules;
(c) sets of optional (elective) modules.

In the area of technical knowledge:

(a) the core modules represent the scientific and technology base giving the fundamentals and basis for all ICT skills profiles. They also represent slow-changing knowledge. A selection from these modules is recommended to be scheduled during the first year of study;

(b) the area-specific core modules represent the technological and engineering base which are specific for the technological area of the group of core skill profiles targeted; they also represent faster-changing knowledge. It is suggested that they be scheduled in the second or later years of study;

(c) the elective modules reflect fastest-changing knowledge with a period of ageing of this knowledge of 3-5 years. They reflect novel technological and engineering knowledge. These modules are used to provide a specialised and in-depth approach and to equalise the differences, thus giving flexibility and the potential to specialise in certain areas;

(d) the personal and business skills shall be developed during the entire study, starting in the first semester. Primarily they should be integrated into the teaching of technical subjects. Where additional modules are necessary, they should follow the same structure as the technical knowledge area.

This structure can be applied to curricula leading to both first and second cycle degrees taking into account that all the modules in a second cycle degree programme should be designed at an advanced level. A generic structure of a model curriculum is presented in Figure 7.

------------------------**SECOND CYCLE DEGREE (SCD)** ------------------------

Year 1 &/or 2 of SCD	**Advanced Broad & Conversion** Content: Advanced Topics of ● Scientific Base ● Technology Base ● Applications Base & System Solution methodology ● Personal & Business Skills ● Project in industry and/or academia (3-6 months) ● SCD (Master) Thesis

------------------------**FIRST CYCLE DEGREE (FCD)** ------------------------

Year 3 and/or 4	**SPECIALISATION & ADVANCED TOPICS** Content: ● Technology Base ● Applications Base & System Solution methodology ● Personal & Business Skills ● Project in industry and/or academia (3-6 months) ● FCD (Bachelor) Thesis
Year 2	**AREA-SPECIFIC CORE & ELECTIVE MODULES** Content: ● Scientific Base ● Technology Base ● Applications Base & System Solution methodology ● Personal & Business Skills
Year 1	**CORE MODULES** Content: ● Scientific Base ● Technology Base ● Personal & Business Skills

Figure 7 Generic structure of ICT curricula

7.2. Clustering of ICT generic skills profiles

7.2.1. First Step: Definition of generic skills profiles to be covered

In developing ICT curricula a university should first define the profile or group of profiles for which it wants to qualify the students. This should be agreed in close discussion with ICT employers and other stakeholders in an outcomes feedback loop.

Universities are also invited to use the ICT core generic skills profiles published by the Career Space consortium as a reference point. These are:

(a) software architecture and design;
(b) software and applications development;
(c) IT business consultancy;
(d) systems specialist;
(e) multimedia;
(f) data communications engineering;
(g) integration and test/implementation and test engineering;
(h) product design;
(i) communications network design;
(j) technical support;
(k) digital design;
(l) digital signal processing (DSP) applications design;
(m) radio frequency (RF) engineering.

7.2.2. Second Step: Clustering in groups to be covered by one curriculum

There are different ways of grouping skills profiles, according to teaching and R&D competencies and the mission and goals of universities. Starting with the core generic skills profiles defined by the Career Space consortium, assuming that all of them should be covered and that two traditional ICT curricula exist - one related to electrical engineering (EE) and the other to computer science (CS) - a simple solution could be clustering into three groups. Working from those with the most computer science content to those with more electronic engineering content, the cluster of profiles in the middle, i.e. the integrated curriculum, would build the group of skills requiring knowledge from both CS and EE as well as business skills. A possible picture would be:

(1) Computer Science	(2) Integrated Curriculum	(3) Information Technology
• Software Architecture and Design • Software and Applications Development • IT Business Consultancy	• Systems Specialist • Multimedia • Data Communications Engineering • Integration & Test / Implementation and Test Engineering • Product Design • Communications Network Design	• Radio Frequency (RF) Engineering • Digital Signal Processing (DSP) Applications Design • Digital Design • Technical Support

The design of the curriculum is a matter for each institution. It can be in-depth, focusing on one or two of the core job profiles clustered together, or broader, focusing on a wider multidisciplinary area. The content or subject matter for the above groups would be:

(a) predominantly topics in multidisciplinary curricula integrating business and transferable skills;

(b) predominantly integrated multidisciplinary curricula having significant components from computer science, electronic engineering and telecommunications with strong business and behavioural skills components;

(c) predominantly electrical engineering topics in multidisciplinary curricula integrating business and behavioural skills.

Clustering in this way, group 1 and group 3 represent the wide area of existing ICT curricula whereas group 2 would include the innovative area of new ICT curricula which tend not to exist at present, but which are urgently needed to meet a high demand from industry for graduates with particular specialised qualifications.

However, there are other solutions possible, e.g. clustering the thirteen core generic skills profiles into four groups assigned to areas such as computer science (software), IT systems, IT networks and electrical engineering (information technology):

(A) Computer Science (Software)	(B) IT Systems	(C) IT Networks	(D) Electrical Engineering (Information Technology)
• Software Architecture and Design • Software and Applications Development • Multimedia Design	• Systems Specialist • IT Business Consultancy • Integration & Test / Implementation and Test Engineering	• Communications Network Design • Data Communications Engineering • Technical Support	• Radio Frequency (RF) Engineering • Digital Signal Processing (DSP) Applications • Digital Design • Product Design

Such a grouping might make it easier, for example, to find common subjects in area-specific core modules.

8. Conclusion

It is hoped that the successful implementation of these guidelines will be of mutual benefit to industry, students and academia, enhancing and strengthening all of them and encouraging more young people to pursue the many satisfying education and career opportunities in this exciting field.

The Career Space consortium wishes to thank CEN/ISSS (the European standardisation body for the information society) for facilitating the curriculum development guidelines working group meetings and the European Commission for its continued support.

The Career Space consortium also wishes to thank the members of the curriculum guidelines working group, especially the universities, for their valuable contribution to these guidelines.

9. Annex I: Career Space check list to universities

9.1. Purpose of the check list

Industry recognises that different cultures and countries have different curriculum development processes and standards and, at the present time, it may not be possible for every country/institution to meet all the requirements listed below. However, the checklist below acts as a useful summary of the parameters against which industry would assess a university curriculum for best practice in line with the Career Space curriculum development guidelines set out in this document.

9.2. The check list

(a) Curriculum content:

- the curriculum has been developed in line with national guidelines for ICT course content;

- the curriculum is reviewed and revised at least every 3 years;

- the curriculum incorporates teaching on how to take a systems view of technology by considering the relationship of the specific topics being taught to the systems in which they are found (and the impact the design decisions made relating to the topic being taught have on the system). Relationships need to be considered in a broad context such as performance, usability, maintainability, availability, security and risk.

(b) Industry relations

- university staff actively involved in the design and delivery of the ICT curriculum have a network of industry partners used in helping to keep abreast of changes in requirements and technologies;

- industry partners support the delivery of the curriculum by delivering at least one lecture/session per course year;

- all students have the opportunity to gain work experience and are actively encouraged to do so.

(c) Industry partners

- the university has identified industrial partners requiring the skills taught in its ICT courses, and meets with them regularly (at least once every three years) to review with them the appropriateness of the course content;

- an ICT company participates on the university or faculty board.

(d) Behavioural-related/soft skills

- mechanisms exist and are used to assess students' analytical, communication, teamwork, flexibility and self-learning, and creative skills. Students are encouraged to develop these skills and are given practical guidance in doing so;

- via tutorials or other mechanisms, students are facilitated in learning about learning through reflecting on course assignments and activities;

- mechanisms exist and are used to ensure students are encouraged to develop responsibilities and leadership skills inside and outside of their academic studies;

- credits are awarded for the acquisition of behavioural skills.

(e) Relations with schools

- university staff actively involved in the design and delivery of the ICT curriculum have a network of secondary school partners that is used to encourage and inform potential ICT students;

- secondary schools are encouraged to develop competence in mathematics in their students so that they can fully enjoy the benefits of working in the ICT age.

(f) ICT industry core generic skills profiles

- the university has identified which skills profiles/job types, e.g. with reference to the Career Space generic skills profiles or other references in the ICT industry, it wishes to target and for which its courses aim to provide appropriate optimum qualifications.

(g) Integrated courses

- the university has ICT courses with elements from informatics, computer science, and electrical engineering which include both embedded and explicit behavioural skills training in their course content.

(h) Curriculum quality control and feedback

- the university checks/consults with employers, which recruit a significant number of its graduates, as well as with graduates themselves after between one to three years following graduation, on the suitability and adequacy of education and training of the academic course for the job they are doing and uses this feedback to improve its courses.

10. Annex II: Members of the Curriculum Development Guidelines working group

Name of Representative	Company/University
Dr. Kruno Hernaut	Siemens AG, Chairman of the Working Group
Ms. Marian Conneely	ICEL, Project Management and Co-ordination
Mr. David Freestone	BT
Mr. Michael Furminger	Cisco Systems
Mr. Manfred Reinhardt	IBM Europe
Mr. Alan Freeland	IBM Europe
Mr. Dieter Gollmann	Microsoft Europe
Mr. Karsten Vandrup	Nokia
Mr. John Kinghorn	Philips Semiconductors
Mr. Roberto Prada	Telefónica S.A.
Mr. Pascal Foix	Thales
Mr. Luc Van den Berghe	CEN/ISSS
Prof. Joerg Muhlbacher	Johannes Kepler Universität Linz, Austria
Prof. Dr. Richard Eier	Technische Universität Wien, Austria
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Ms. Maryse Béguin	ENSIMAG, Grenoble, France
Mr. J. M. Dolmazon	ENSIMAG, Grenoble, France
Mr. Andreas Kaiser	EIMN – ISEN, Lille, France
Mr. Lionel Brunie	INSA Lyon, France
Mr. Maurice Pinkus	UIMM-FIEEC, Paris, France
Prof. Dr. Armin Bolz	Universität Karlsruhe, Germany
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Prof. Reinhard Keil-Slawik	Universität-GH Paderborn, Germany
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Luxembourg: Office for Official Publications of the European Communities

2001 – VI, 49 pp. – 21.0 x 29.7 cm

ISBN 92-896-0074-8

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