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Development of a Shared Curriculum for Studies in Computer Science and Information Systems

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DEVELOPMENT OF A SHARED CURRICULUM FOR STUDIES IN COMPUTER SCIENCE AND INFORMATION SYSTEMS

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ABSTRACT

The basic principles of the development of modern curriculum in computer science and information systems in Latvia as well as lessons learnt are discussed. The curriculum is based on two widely used documents "Computing Curricula 1991" and "IS'97". At the same time the curriculum is strongly influenced by the local conditions of Latvian higher education system and requirements of the labour market. Some international experience in a model curriculum development has been acquired, too. New trends have emerged and new requirements have been fixed. Now, after ten years of experience there is a strong necessity to weight the pros and cons and to start revising of the curriculum.

INTRODUCTION

In the early 1990s when Latvia regained independence, sweeping changes started to affect the all education system including the higher school education. Many institutions of higher education have been renamed, for instance, Riga Politechnical Institute was renamed the Riga Technical University, Riga Medical Institute was renamed the Riga Medical Academy, Latvian Academy of Agriculture, in its turn, was renamed the Latvian University of Agriculture. Changes of names were not an end unto themselves. More important is the fact that the restructuring of the whole education process followed the change of names. Strictly predetermined curricula, which include only mandatory courses, were replaces step by step by more flexible ones containing compulsory courses, restricted electives and free electives. Students get much more possibilities to choose courses of their own interests.

The serious reconstruction of engineering studies was carried out at the Faculty of Computer Science and Information Technology of Riga Technical University (RTU). This reconstruction was based on a survey of a great number of curricula implemented in universities all over the world, in particular, in USA, Great Britain, Canada, Sweden, Finland and several other European countries. The main lesson that resulted from this work is that although the experience of foreign universities can be used for definition of core requirements the development of curricula that satisfy local need must be based on flexible approach offered on the model curriculum paradigm. The "Computing Curriculum 1991" (Tucker, et. al, 1991) and "Model Curriculum and Guidelines for Undergraduate Degree Programs in Information Systems" (Davis, et. al., 1997) are two relevant documents which are used to develop and to improve a curriculum which shared basics in computer science and information systems. In this shared curriculum the balance between the traditions of most East Europe universities to give students a strong background of knowledge in mathematics and physics and the modern trends to accent management and economic topics has been found (at least it is an attempt to find).

The paper is organized as follows. The next section presents the common and different points of studies in computer science and information systems in Latvia and in RTU, in particular. The local flavour of academic and professional studies in computer science and information systems is given in the second section. The third section introduces the basic principles for the development of a model curriculum suitable for technical universities of Latvia. The first experience from participation in the international project "Modern Curriculum in Information Systems" (MOCURIS) at master level is described in the fourth section. The fifth section is devoted to the observed imperfections of the existed curriculum and the outline of future developments. We conclude with considerations about future trends in higher education field in Latvia and their impact to study programs in Latvia.

1. STUDY FIELDS OF COMPUTER SCIENCE AND INFORMATION SYSTEMS

Computer-based systems have become an important part of products, services, planning and management of organizations. Organizations being under permanent industrial pressure are now using more and more advanced information technology to seek ways how to stay highly innovative in their products and services. The effective and efficient use of advanced information technology to support decision making, planning, knowledge management, etc. is an important element of modern organizations allowing them to preserve, maintain, re-use and reproduce their competence. Rapidly growing demands for well-educated professionals in the field place heavy demands on corresponding faculties to develop and implement up-to-date curricula. Analysing various curricula in computer science and related areas, one can notice that information systems as a field of professional and academic studies exist under a variety of names – informatics, management information systems, information technology systems and information science are only few examples (Davis, et. al., 1997). Frequently there is a close relationship between computer science and information systems and students from both fields may take the same courses. This may cause misunderstanding and confusion for students who are considering their focus of interest.

In fact, information systems and computer science are distinct areas of studies but both share a common subset of core knowledge. In the "IS'97" (Davis, et. al., 1997) differences are outlined in the context of the work to be performed, the types of problems to be solved, the types of systems to be analysed, designed and managed, and the way the information technology is employed. Information systems focus on organizational objectives and applications of information technology to further these goals. There are two areas of information systems as a study field: 1) development, implementation and management of information technology, i.e., computers, computer networks and communications; 2) development of systems for organizations, i.e., methods, techniques, tools, and methodologies for data, information and knowledge acquisition, as well as analysis, design and implementation of computer-based systems. Many universities try to support these two areas giving students different background. So, students who are enrolled in programs related to the first area of information systems have their background in electrical engineering while students who are enrolled in programs related to the second area of information systems have their background in computer science. At RTU we have this division for years and only recently taking into account local particularities and objective tendencies that mentioned areas more and more converge we have started to implement several study programs with the same background, namely, computer science. It is worth to stress that local conditions are the main constraints for tailoring the curricula. It will be shown in more details in the next section.

2. EVOLUTION OF EDUCATION IN COMPUTER SCIENCE AND INFORMATION SYSTEMS IN LATVIA

Computer systems as a field of academic and professional studies in Latvia started in the 1960s at two largest institutions of higher education – the University of Latvia (LU) and Riga Politechnical Institute (now RTU), respectively. All curricula have been reconstructed at the beginning of 90-ies. Two directions of computer science started to dominate. The first reposes on the strong mathematical background and has the focus on theoretical foundations of computer science. This direction has been established in the University of Latvia and later has been accepted by several other universities (humanitarian ones). The second direction is based on the engineering subjects and has its focus more on application aspects of computer science. This direction has been set up at the Riga Technical University. Three other universities met this view on education in computer science a little bit later. A lot of work has been done during an attempt to standardize bachelor's study programs in computer science and related areas. The goal of this work was to make transitions between programs more easy for students of different institutions. As the result, two different standards of undergraduate (bachelor) degree programs have been accepted. Contents of study programs reflect a wide spectrum of topics in computer science and related areas including topics in information systems. These contents reflect local situation. Latvia is a small country with relatively small software and information technology companies (the largest Latvian software company has over 500 employees). In these circumstances undergraduate education must be as large-scaled as possible. Specializations are planned only in master's level study programs as well as in professional study programs. Specializations usually keep traditions and reflect qualification and research interests of the academic staff.

During the last decade a new form of professional studies emerges in universities, namely, college education. Under the law of higher education in Latvia college education is classified as the first level professional higher education. In spite of the fact that several college programs already existed in RTU during last five years (programmer, technician of computer networks) development of European dimension first level professional study programs started only last year. Activities were supported and financed by EU Phare program "Professional Education 2000". The "bottom-up" approach was used to develop the curriculum. First, the structure of the information technology branch (see Figure 1) in Latvia has been investigated (Lusis, et. al., 2000). Results helped to choose two specializations for the pilot curriculum of the first level professional higher education, namely, programmer and computer network administrator. Investigation gave a clear evidence that local structure significantly differs from the worldwide structure of the information technology branch where, for instance, the volume of software is only 9% while the volume of telecommunications is 50% (Lusis, et. al., 2000). Second, local experts from industry defined a set of requirements for professionals in programming and computer network administration. Third, requirements were translated into a set of goals that would be achieved in implemented curriculum.

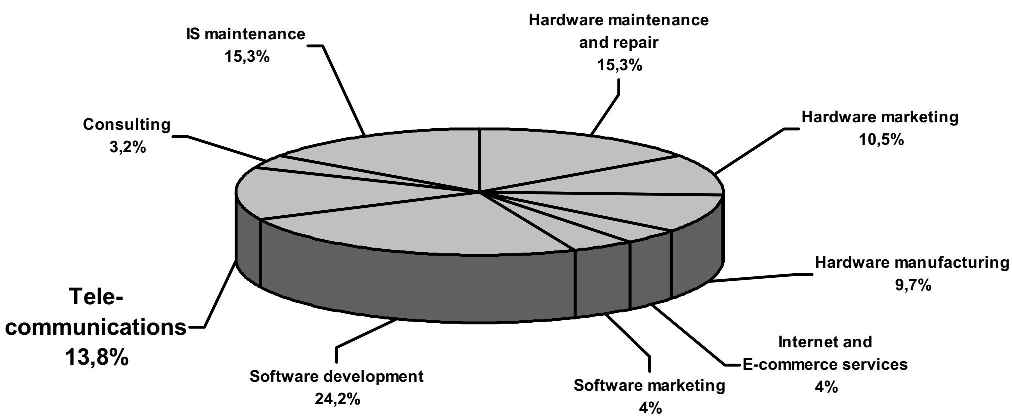

Figure 1. The structure of the information technology branch in Latvia

Several iterations were needed for curriculum development during which a list of courses and their contents have been determined. The final version of the curriculum has three parts:

- general education
- profile subjects
- specialization subjects.

The first two parts are common for both programmers and computer network administrators. Approximately 12% of subjects for programmers are related to data base management and information systems development. The curriculum was discussed, evaluated and approved by the Council of professional educations in information technology, telecommunications and electronics. The acceptance of professional standards for programmers and computer network administrators finished establishment of a framework for professional education in mentioned above areas of computer science. At the present moment five (from 11) first level professional study programs are based on the professional standards and the typical curriculum.

3. A MODEL CURRICULUM SUITABLE FOR TECHNICAL UNIVERSITIES OF LATVIA

As discussed in the previous section two largest institutions of higher education in Latvia, namely, the University of Latvia and Riga Technical University have different profiles and, as a consequence, different approaches to curricula development in computer science and related fields. Institution restrictions, general education structure established by university Senates, and availability of resources such as academic staff, libraries, computing facilities, capacity of laboratories and classrooms, must be added to the list of constraints. It makes impossible utilization of any study program suggested in documents (Tucker, et. al, 1991, Davis, et. al., 1997) or adapted from other universities.

Without loss of generality let have a closer look at the characteristic features of curricula development in Riga Technical University. The established academic education structure is as follows: three years to receive a bachelor's degree, two extra years to receive an engineer's diploma or three extra years to receive a master's degree. The curricula structure is regulated in general, i.e., volumes of fundamental engineering subjects (mathematics, physics, chemistry, electronics, introduction to computers, material science, electronics, mechanics), volumes for subjects in humanities as well as volumes for subjects of specialization fields are strictly defined.

The education structure of the Faculty of Computer Science and Information Technology (CS&IT) corresponds to the general structure of RTU. It is displayed in Figure 2.

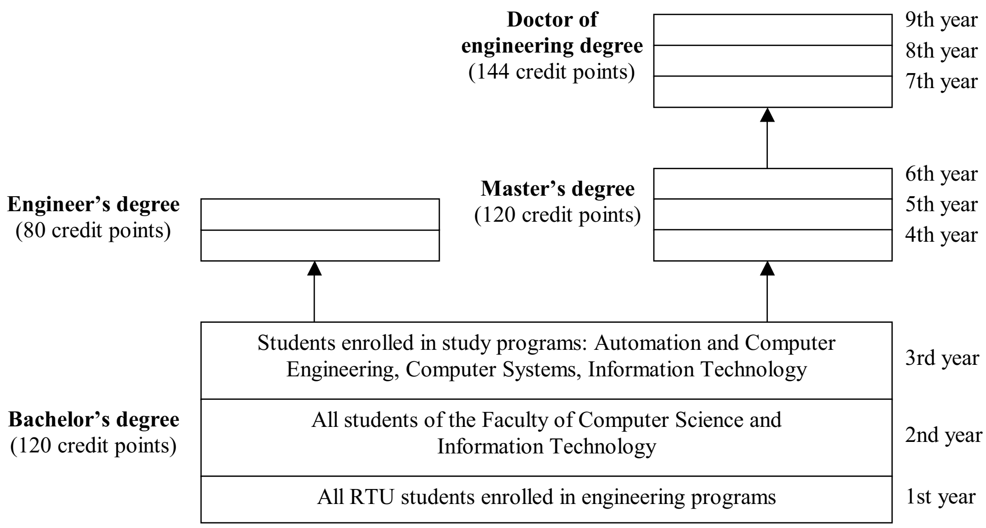

Figure 2. The academic education structure of the faculty of CS&IT (the volume of each study year is equal to 40 credit points)

At the present moment professional education structure is established according to Figure 3. Under the law of higher education in Latvia accepted in 2000 graduates from the universities with professional education diplomas also will have possibility to reach doctor's degree. For this purpose degrees of bachelor of engineering and master of engineering have been introduced. The corresponding curricula are under the development right now.

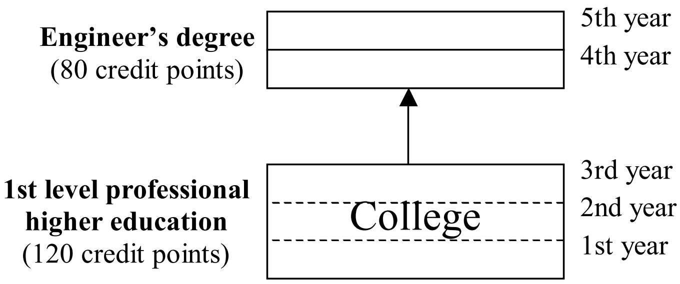

Figure 3. The professional education structure of the faculty of CS&IT

It is quite obvious that the education structure shown in Figures 2 and 3 differ from those established at the greater part of universities of other countries. This fact together with lack of textbooks in the Latvian language, insufficient skills in foreign languages among students and even the faculty staff, lack of financial resources for computing facilities and modern classrooms may be listed as the main reasons why one-to-one mapping of any curriculum is impossible in local situation. Moreover, decisions made by the Ministry of Education and Science to standardize the volume and contents of undergraduate degree programs for all universities in Latvia made the issue of model curriculum development even more essential.

The experience obtained from efforts to standardize a mandatory part of computer science curricula in Latvia allows to draw a conclusion that it is quite easy to reach consensus with respect to course titles. It is much harder to reach consensus with respect to course sequence (syllabus) and contents because institutions have their own opinion, traditions and interpretations. Thus, it is reasonable to develop a model curriculum that would be easily adoptable to local requirements of a specific department. This model curriculum developed for undergraduate and graduate degrees at technical universities is based on the expertise summarized in "Curriculum'91" and "IS'97" (Tucker, et. al, 1991, Davis, et. al., 1997). The usage of small, independent, composable and decomposable units called learning units or knowledge units is the most important principle used in both documents (Tucker, et. al, 1991, Davis, et. al., 1997). This principle has been taken over and applied for the development of a model curriculum (Grundspenkis, 1998).

In (Davis, et. al., 1997) a learning unit is defined as a description of a set of material to be learned by students. Each learning unit has a set of topics that define the coverage of the unit. All topics must be derived from surveys of practitioners and academicians. In case of a shared model curriculum a set of topics have been chosen from lists suggested in both documents "Curriculum'91" and "IS'97", i.e., they have been chosen from areas of computer science and information systems. For each topic a presentation area has been defined. First of all, the education levels needed to form computer science and information systems courses have been defined as follows: prerequisite, learning units of mathematics, fundamental engineering, economics and business knowledge.

The prerequisite level provides personal capability for students to use mathematical methods for modelling and implementation of computer based systems. Topics include linear algebra, calculus, discrete mathematics, probability theory and mathematical statistics, discrete mathematics and numerical methods. Fundamental engineering knowledge gives students the necessary background for deep understanding and use of information technology. Major topics cover physics, electronics, electrical engineering, basics of computer hardware, mechanics and material science. Topics in economics and business include accounting, finance, marketing, entrepreneurship, resource planning and organizational management.

Level 1. This mandatory level provides students with basic knowledge in the field of computer science. Topics cover both hardware and software: computer architecture, data structures, computer networks, operating systems, programming languages, data base management systems, software engineering, systems modelling, operation research and artificial intelligence. Of course, these topics coincide with topics of information systems fundamentals and information technology as they are defined in (Davis, et. al., 1997). The difference is in knowledge competence levels. In the developed model curriculum knowledge competence levels are higher than proposed in (Davis, et. al., 1997) and correspond to those that are suggested in (Tucker, et. al, 1991). It is because philosophy of the shared model curriculum is "to reach considerable knowledge competence level of computer science fundamentals (stretching from literacy till detailed understanding and application) and afterwards also of information system fundamentals".

Level 2. Courses at this level belong to the category of majors. So these courses, as a rule, must be different for each study program. They are planned as introductory courses to the particular concentration area. For instance, such topics as systems theory, systems analysis, information system design, CASE tools, and project management are recommended for those who want to specialize in information system development. These topics to the certain extent cover curriculum areas and courses defined in "IS'97" (Davis, et. al., 1997). At this level the corresponding depth of knowledge for competence levels mainly are concept use or detailed understanding and application.

Level 3. The courses at the level 2 must be considered as prerequisites for courses at the level 3. Students proficient at this level are preparing for their career. For example, if they planned their career in computer based systems development they must reach skilled use of knowledge for systems analysis, synthesis and evaluation. In fact, education structure shown in Figure 2 determines splitting of the level 3. The level 3a has focus on theoretical knowledge (master's degree) while the level 3b has focus on real-life applications (engineer's qualification). In both cases the highest possible knowledge competence level – "skilled use" must be provided. At the same time even if courses are constructed from the same knowledge units, learning objectives and, as a consequence, organization of learning process must be different.

Following the "IS'97" (Davis, et. al., 1997) the shared model curriculum at the third level is organized as a set of curriculum presentation areas. Each area includes several courses. A fragment of presentation areas is given in Figure 4.

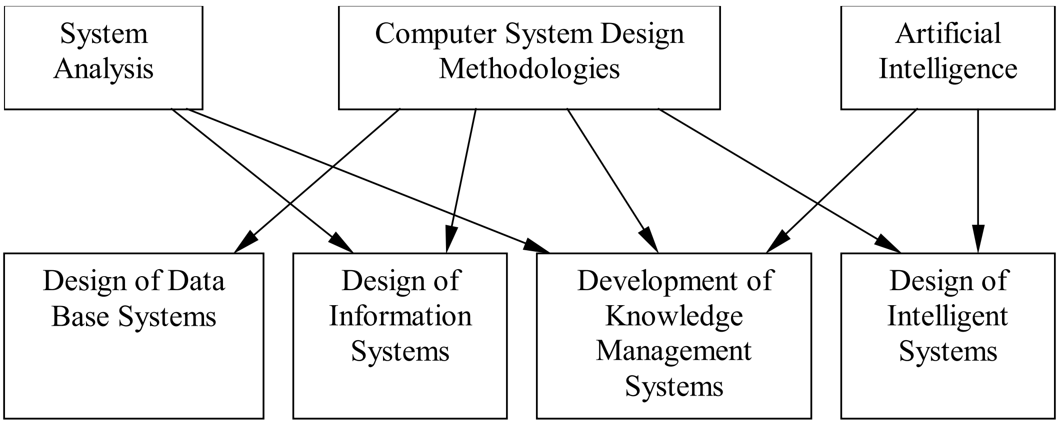

Figure 4. A fragment of curriculum presentation areas

Curriculum presentation areas have descriptions that do to the scope of this paper are omitted. It is worth to point out that Figure 4 displays also a sequence in which learning units included in the corresponding areas are acquired by students, i.e., it determines the core of corresponding syllabus.

In model curriculum the exit characteristics of all areas are defined, too. Exit characteristics are related to objectives of the curriculum in terms of "ability to…" and "using the knowledge of …" (Davis, et.

al., 1997). In Table 1 a fragment of exit characteristics of presentation area "Artificial Intelligence" is presented.

Table 1

A fragment of exit characteristics of AI

Characteristics	With ability to …	Using knowledge of …
Artificial Intelligence	• select problems which can be solved by intelligent systems	• state space
	• choose appropriate tools for intelligent system development	• search algorithms
	• apply knowledge representation schemes	• knowledge representation schemes
	• apply problem solving techniques	• methods of intelligent system design

The same "knowledge unit" principle was used during development of the first level professional (college) study program. The competence levels of mandatory subjects mainly are defined equal to detailed understanding and application or skilled use.

4. EXPERIENCE OBTAINED FROM THE INTERNATIONAL PROJECT "MOCURIS"

Project started in 2000 within the framework of ERASMUS program. The coordinator of the project is Vilnius Gedimino Technical University (Lithuania). Partners are Technical University Braunschweig (Germany), Tallinn Technical University (Estonia), Politechnic University of Catalonia (Spain), Klaipeda University (Lithuania), Vitautas Magnus University (Lithuania), Riga Technical University (Latvia) and Vaxjo University (Sweden).

The objective of the project is the development of a modern master degree program in informatics with emphasis on information systems. This objective will be reached by redesigning and integrating already existent modules and complementing the program with new modules. The new curriculum would meet advanced requirements for information technology specialists and the needs of European labour marker. The curriculum will enable students to specialize in systems design, analysis, implementation or operation by the selection of optional modules. The new curriculum is based on five multimodular courses:

- Theoretical Foundations of Informatics
- Advanced Concepts of Information Systems
- Engineering Fundamentals of Informatics
- Management Issues of Informatics
- Philosophical and Interdisciplinary Issues of Informatics

Five multimodular courses totally contain twenty-one module. Contents of modules reflect the guidelines of the document "MSIS 2000" (Gorgone, et. al., 2000). The "knowledge unit" principle described in the previous section is used to determine topics in each module. Work on the curriculum is organized in five working groups – one group for each multimodular course. Partners have free choice to participate in particular working group activities based on the experience and interests of their home universities. Technology of work on the curriculum is divided into several phases starting with module descriptions, followed by development of teaching materials, tailoring of the curriculum and ending by evaluation of the project and its impacts by the university authorities. Representatives of those partner universities that have the best teaching experience of the corresponding topics are involved in development of each particular module. Feedback from other participants of the working group is asked before the final version of the module description is developed. The same technology is used for development of teaching materials.

One year after the start of the project obtained experience may be summarized as follows:

- Contents of modules are strongly influenced by the different viewpoints of partner organizations. In case of this project contrasts are even deeper because some of the partners have not information system programs for undergraduates.

- Cooperation and feedback during development process of modules are rather weak.

- The "knowledge unit" principle that is already approbated in model curriculum development for technical universities in Latvia seems to be appropriate also for the international project of the model curriculum.

5. DRAWBACKS OF THE EXISTENT CURRICULA AND FUTURE DEVELOPMENTS

Fast growing need for highly educated people in information technology and software has caused serious changes of requirements towards curricula. Investigations are going in several directions. Efforts are known to determine what knowledge is important to software professionals (Lethbridge, 2000). The responsibility of institutions that teach software is discussed in (Meyer, 2001). Common conclusion from mentioned and related investigations is that institutions must have the development plans for advanced curricula and training programs for information technology professionals. Fortunately this is well understood by professional organizations who are trying to define computing curricula for modern age, publish draft documents of computing curricula projects seeking feedback (CC, 2001) and try to predict future needs of labour market (Lusis, et. al., 2000).

Comparison of curricula for academic and professional studies of universities of Sweden, Finland, UK and USA shows that, in spite of their different duration, all curricula are quite similar concerning such areas as mathematics, programming, general engineering, computer science basic and general courses. Analysis of publications and ten years long experience of curricula development and modification reveal that there are common drawbacks for all curricula in computer science. First, investigations show that many important topics (for instance, human-computer interaction, management, real-time system design) are not extensively taught, and, contrary, some unimportant topics (calculus, differential equations, linear algebra, chemistry and physics) are extensively taught (Lethbridge, 2000). This suggests that the education what today's computer professionals receive may not be entirely appropriate. The overtaught topics either should be taught less or teaching mathematics and physics should be in conjunction with hardware examples and programming exercises. Another suggestion is to shift the emphasis in mathematics from continuous towards discrete mathematics (logic, mathematical reasoning, formal semantics) and statistics. Investigations also show that the greatest on-job-learning occurs in the software configuration and management, project management, maintenance and reengineering, testing, verification and quality assurance. The detected drawbacks are indicators for re-examination of curricula and teaching methods. Complementary elements must be added to curricula, too. They include lasting concepts that underline the whole field, practical problem-solving techniques, tools that facilitate the application of principles and practices and teaching by doing (Meyer, 2001). Future trends in evolution of labour market also must be taken into account in curricula development plans. Interesting results were disclosed in polling of Latvian software and information technology companies (Lusis, et. al., 2000). As it could be predicted before polling, all companies give the forecast that the number of their employees will grow in the near future (see Table 2).

Figures given in Table 2 may be considered as additional indicators for re-examination of curricula in Latvian universities. For example, introducing of new separated (not shared) curriculum in information systems seems motiveless because forecast shown relatively slow increase in number of employees in this sector. At the same time sectors, where the greatest density of employees is predicted, and, as a consequence, the on the charts professions will be programmers, project managers, systems analysts and computer network administrators (Lusis, et. al., 2000).

Table 2

Forecast of the number of employees

No	Sectors	Number of employees in 2002 compared with the number in 2000, %	Number of employees in 2005 compared with the number in 2000, %
1.	Internet and E-commerce services	257	363
2.	Software development	161	194
3.	Consulting	151	201
4.	Hardware marketing	141	177
5.	Software marketing	141	173
6.	Information systems maintenance	130	153
7.	Hardware manufacturing	129	172

The forecasted trends in needed qualification levels of information technology professionals may cause a crucial impact on the development and modification of curricula in future. Table 3 shows the density of employees especially those who have the fourth professional qualification level (college education) and the fifth professional qualification level (engineer's qualification and master's degree).

Table 3

Distribution of qualification levels

No	Sector	Density of employees, % (the difference till 100% refers to lower qualification levels)	
		4th qualification level	5th qualification level
1.	Internet and E-commerce services	40	21
2.	Software development	36	28
3.	Consulting	33	32
4.	Hardware marketing	41	25
5.	Software marketing	43	22
6.	Information systems maintenance	38	21
7.	Hardware manufacturing	37	24

Table 3 shows that approximately 60% from all employees in different sectors of information technology must have a higher education. At the same time those who have the college education will be needed 1,5 to 2 times more than those who have the university education. Current analysis of higher education structure in Latvia shows that from all freshmen enrolled in computer science and related area study programs only near 20% are college students. Additional efforts will be needed to develop more attractive study programs and teaching methods as well as to advertise college programs in Latvia.

It seems obvious that all changes in existent curricula may be based on already published documents such as "IS'97" ((Davis, et. al., 1997), "MSIS 2000" (Gorgone, et. al., 2000). In particular, "Computing Curriculum 2001" (CC 2001) where suggestions are given how to amalgamate curricula in computer science, computer engineering, software engineering and information systems obviously will be widely used in future developments.

CONCLUSIONS

Analysis of education structure, local conditions and future trends of labour market in information technology sectors in Latvia shows that the most appropriate approach in higher education is to develop a shared curriculum where majors of computer science and information systems are integrated. It is clear that demand for professional higher education, especially for college education, will grow very rapidly in the nearest future. Institutions of higher education must react immediately to these tendencies. New study programs for college students must be opened which cover all spectrum of information technology sectors. The number of students of academic study programs will grow permanently. This fact causes the need for new teaching methods, namely, learning in groups, introduction of distance learning elements, teaching by doing, as well as new computer based techniques of knowledge assessment for a great number of students simultaneously. Labour market dictates that practical skills and case studies of applications must be stressed even in academic education. All these factors determine the urgent need to re-examine and to modify the curricula in computer science, information systems and related fields. Computer Curricula 2001 provides very good bases for curricula development in future.

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