A Graduate School in Information Technology and Computer Science in Estonia

Feasibility Study

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Final Report

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Participants:

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A. Project Report

1. Introduction

Information technology is going to be one of the highest priorities in the development of Estonia in the next ten years. Expanding labour market in information technology (IT), computer science (CS) and software engineering (SE) requires people with different levels of education and competence in these areas.

Universities responsible for teaching IT and CS on the highest level suffer from the lack of qualified teachers because of the collapse of the internal staff development system. As a consequence, inadequate university level teaching restrains other forms of education and application fields of IT and CS.

The current project has been devoted to the problems of MSc and PhD level education in IT and CS in Estonia. On the one hand, it is hard to find critical mass of teachers for advanced studies to cover all inevitable fields in the framework of one particular university. On the other hand, it is too expensive to run similar MSc and PhD courses at different universities for only a very small number of students.

Previous and continuing co-operation between Estonian universities, research institutes and partners of connected projects (SJEP-06145, SJEP-07256, JEP-06032, CME-02078) has led to the idea of forming a permanent institution for supporting advanced studies and staff training in Estonia - a Graduate School in Information Technology and Computer Science (GS).

Feasibility study has been considered to be the first stage to start such a school or a similar institution as there are many open questions and problems arising.

2. Project objective

The main goal of the project has been to find solutions to the problems of graduate and postgraduate level education in information technology and computer science in Estonia including

- raising quality and international recognition of MSc and PhD-studies in the subject area,
- reducing costs of teaching per student and increasing number of students,
- investigating and meeting current needs of the Estonian society,
- improving the supporting infrastructure and staff training system.

To achieve certain objectivity, the consortium members have performed a feasibility study that concentrates on the following problems:

- form of legal existence and concrete responsibilities of the Graduate School,
- potential students, role of the school in supporting students financially,
- potential teachers: existing staff, people from industry and other institutions, foreign lecturers,
- teaching languages,
- IT and CS labour market in Estonia,
- co-operation of the GS with state institutions and companies,
- international and academic co-operation,
- financial aspects and needs for other resources, staff needs and perspectives, management, supporting infrastructure,
- contents of IT and CS education, links to curricula, introduction of new courses and renewal of existing courses, new forms of teaching,
- publicity - means to attract students and co-operation partners.

3. Planned outcomes

One result of the study is a project outline for the Graduate School in IT and CS in Estonia including:

- overview of an existing postgraduate education system in Estonia and in partner countries,
- general goals and objectives of the GS,
- analysis of the demands of the Estonian society,

- proposals concerning the contents of MSc and PhD studies in IT and CS,
- implementation plan for the Estonian GS considering:
    - responsibilities and the form of the school,
    - student financing model,
    - practical organisation and tasks performed by the GS,
    - curricula requirements and forms of teaching,
    - management and financing of the GS,
    - potential students and student selection procedures,
    - staff and supervision of students,
    - needs for other resources,
    - social impacts and publicity,
    - further and connected activities.

Impacts of the project become apparent on different levels:
- support to faculties responsible for MSc and PhD studies,
- support to co-operation between Estonian universities,
- support to Estonian government strategy on IT,
- new contacts and international co-operation.

4. Activities

The following groups of activities were planned to be carried out:
- seminars connected to the project meetings,
- workshops,
- expert group meetings,
- organising inquiries,
- publication of project materials,
- evaluation of project results,
- experimental courses.

Three seminars took place in Estonia:
- "Graduate Schools - Current State, Experience and problems". Tartu, January, 11 - 12, 1996 (30 participants),
- "Teaching IT and CS - Methodology, Contents and New Trends". Tallinn, May, 03, 1996 (15 participants),
- "Management, Financing and PR". Tartu, June, 06 - 07, 1996 (21 participants).

The following workshops were held to make the know-how of the partner institutions available to for the academic staff from Estonia:
- First meeting of all partners in Pori, Finland, October, 18 - 20, 1995 (15 participants),
- Workshop on practical organisation of graduate schools in Helsinki and Turku, December, 14 - 15, 1995 (10 participants),
- Workshop on research-based postgraduate education and evaluation of results in Stockholm, August, 26 - 27, 1996 (9 participants).

A project meeting on preparing the final report was held in Tallinn, September, 24 - 25, 1996 (5 participants).

Four expert groups were organised to cover different topics of the study:
- Graduate schools in general, chairman J. Pöial, members L. Mõtus, M. Penttonen, J. Kiho
- Management and financing, chairman T. Järvi, members J. Penjam, H. Jaakkola, M. Meriste, J. Vain
- Curricula and contents of studies, chairman R. Kurki-Suonio, members J. Penjam, E. Tõugu, A. Kalja, M. Tombak
- Challenges from Estonian society, chairman J. Vain

CIDEC held on an inquiry for Estonian companies, state institutions, universities, etc. to investigate their needs related to IT and CS education.

All project material is available on the World Wide Web:
`http://www.cs.ut.ee/~jaanus/cme`

Project overview is published in Estonian journal "A&A" (Arvutustehnika ja Andmetöötlus) (ISSN 0234-064x), No 4, 1996, p. 38 - 44: J. Pöial, Problems of Graduate Studies in Computer Science and Information Technology (in Estonian) and in Information Journal of University of Turku (Yliopistotiedot), vol. 35, No 13, p. 11 - 12: T. Järvi, Information Technology Graduate School in Estonia? - Experiences from a Tempus-project (in Finnish).

CIDEC did not introduce experimental MSc (or PhD) courses in the framework of this project (no financing was planned for this activity), but organised summer (winter) schools using the resources of other projects.

Estonian Ministry of Education has been informed about the progress of the project. Representative of the ministry was involved in the project seminar in Tartu. Summaries of conclusions from the project events were sent to the ministry.

This project has induced related activities, targeted to improve the situation in IT and CS education, e.g. ideas about connecting postgraduate studies to the Centre of Intellectual and Technological Competence for Information Society (CITCIS) and a new CME-project for quality assurance system for informatics education.

5. Actual results

5.1. Current state of postgraduate education in IT and CS

The first part of the study concentrates on the existing system and the problems inherited from the past.

The following aspects outline the current situation in teaching IT and CS in TU and TTU:

- The faculties (departments) are responsible for teaching IT and CS on undergraduate level. The instruction is mainly carried out by the faculty staff. Both universities have different problems with the contents of the courses, with the curricula, staff etc. but, in general, teaching on undergraduate level can be improved within the framework of these universities.
- The postgraduate level teaching is not yet well developed, neither formally nor in contents. There are only a few strong and attractive research groups in Estonia to carry out research-based postgraduate education.
- The number of students is too small for the increasing labour market in IT in Estonia. There is nearly no diversity in the current system of higher education.
- The existing staff of the universities is aged and overloaded (the staff age is 45 - 55 years as a rule).
- Motivation for an academic career is low amongst the students and a remarkable brain drain takes place. Salaries in education and science fields are very low in Estonia.
- Estonia has a relatively small population and it is hard to find a critical mass of teachers to cover all urgent fields in the framework of one particular university.
- Possibilities to use visiting lecturers are limited and occasional, there is little motivation for lecturers to stay for a longer period.
- Universities cannot count on lecturers from industry because of the low level of information technology there.

These and other problems were discussed on the seminar "Graduate Schools - Current State, Experience and Problems". In addition, the workshop "Practical Organisation of Graduate Schools" gave an overview on the situation in Finland.

As a result, common understanding was achieved about the objectives of the graduate schools and about the possibilities to solve different problems like

- application procedures,
- selection of students,
- supervision and progress control,
- financing,
- management,
- course scheduling etc.

The present situation varies between the partner countries. In context of this project, it is somewhat better in Finland than in Sweden.

The graduate schools in the partner countries include only PhD studies in their teaching programmes, whereas in Estonia (where the number of PhD students is very small) we also need to take MSc studies into consideration. In this project we refer to BSc and MSc studies as "graduate" and PhD studies as "postgraduate".

5.2. Questioning of Estonian IT companies, state organisations and academic institutions

5.2.1. Background and motivation

The aim of the questioning has been to summarise general attitudes and needs concerning graduate studies in IT, and to spread the idea of a graduate school among different IT oriented organisations in Estonia.

Questions cover 5 types of data: general data about the companies (organisations) and persons questioned, the present state of and needs for the staff, the staff quality insurance policy of employing organisations, evaluation of the higher education in general, and the specific role and expectations to the GS.

5.2.2. Results of the questioning

Wide range of institutions were chosen under observation to obtain an adequate picture about the need for CS and IT related teaching activities. The organisations were divided into three categories according to their institutional status: academic institutions (5), state organisations (4) and businesses (26).

The second group of questions elucidates general needs of institutions for the staff with different qualification. Following table gives percentages of organisations which need staff with specified level of qualification:

Staff needed\Type of organisation	Academic institutions	State organisations	Businesses
Technicians	-	45%	36 %
Bachelors	58%	39%	52 %
Masters/doctors	42%	16%	12 %

Employment of masters and doctors as the main group under observation in this project was studied in more detail. Following table demonstrates how the allocation of masters/doctors differs depending on the type of businesses and organisations where they are employed:

Allocation\Type of organisation	Academic institutions	State organisations	Businesses
R&D	43%	50%	68%
Training	39%	33%	16%
Management	18%	17%	16%

The study of the present training policy of organisations (3rd group of questions) helped to clarify the roles of different training institutions and the niche for the GS. The most preferred (85%) category of employees is the young professionals with specialised training after their academic studies. Of the post academic training, 46% takes place at the employing institutions, and 54% at special training centres. About 50% of organisations use training services abroad. Data above indicate that the main role of the universities and the GS is expected to be a systematic education which will be complemented with training activities at the employing institutions or at training centres.

Next table shows the percentage of institutions pointing necessity to improve present higher education system in following respects:

Improvements required\Type of organisation	Academic institutions	State organisations	Businesses
General knowledge and constructive thinking	100%	100%	73%
Basic theoretical knowledge	100%	100%	31%
Technical training and practical skills	100%	75%	69%
Other	-	-	23%

We can conclude from the data that improvements are needed mainly in constructive thinking and in practical preparations. To implement these, it is necessary to pay more attention to curricula work (composing and relating curricula) as well as to the practical teaching. For acquiring better practical knowledge, the teaching process should be related more to new technological development and it should rely on co-operation with industrial partners.

The role of the Graduate School in improving academic education in IT was seen in the following ways.

Role of GS\ Type of organisation	Academic institutions	State organisations	Businesses
Proper need for GS is missing	-	25%	27%
Supporting activities to graduate studies	50%	-	27%
Planning and providing graduate courses	50%	75%	43%
Directing and implementing IT policy for universities in general	-	75%	23%

Estimates about the acceptable price of teaching a graduate are given in terms of repaying years. During this time, the graduate has to work full time for the employer after the studies to reimburse the employer for the expenses. The duration of this period ranges from 1,5 to 5 years (average 2,93 years). The estimated amount of the state support is expected to cover range from 50 to 100 per cent (average 61,2 per cent) of all costs related to teaching.

Different types of employers are willing to support the GS as follows:

Support to GS\Type of organisation	Academic institutions	State organisations	Businesses
Not willing to support	-	25%	19%
Supporting joint projects and practical placements	100%	75%	69%
Supporting grants	100%	75%	12%

5.2.3. Conclusions from the inquiry

Most Estonian IT companies and organisations are relatively new (1-5 years) and in the present very dynamic market situation their efforts are mainly concentrated on arranging and stabilising business activities and structures. Only the biggest or very narrowly specialised companies have resources for strategic development (with appropriate research). For that reason only 12% of the companies claimed the need for graduated people. Still, in the long run, the need for graduates has a tendency to grow as international experiences show us. Several companies involved or switching into international projects are planning to hire part- or full-time employees with master or doctoral degrees for research consuming projects.

Results of the questionnaire reflect often attitudes of the administrative managers instead of those who are primarily responsible for the development work and staff retraining at the company (if these positions exist in the company).

Individual aspects - the opinion of potential graduate students - are missing in the present questionnaire.

Sometimes the results of the questionnaire seem to depend on the interviewer and his (her) ability to explain the idea of a graduate school. Still, in a sufficiently large set of answers, these deviations can be ignored. Subjectivism of estimates plays a more important role in academic and state organisations where the number of answers is remarkably smaller than that in businesses.

In general, employers perceive the need to improve the level of IT education of their staff. Willingness to co-operate with the GS is sufficient considering present economic and political conditions (more than 70% expressed their readiness to co-operate in some form).

5.3. Implementation of a Graduate School

5.3.1. Goals to achieve

Informatics is one of the strategically important fields the development of which should guarantee both the competitiveness of the Estonian economy and the success of the society on the whole. The state can contribute to the establishment of a modern information society first of all via appropriate education policy and by favouring information-capacious production and global development of infotechnological infrastructure. For this aim, it is important to promote basic research in informatics and guarantee the higher infotechnological education of the personnel.

Proceeding from the analysis of current situation the following more specific goals can be formulated

- rapid improvement of MSc and PhD level education in IT and CS, co-ordinating the graduate studies in content and confirming these with European education standards,
- increasing the number of masters and doctors according to the objective demand from Estonian society, including those with so called professional degrees,
- adding flexibility to the existing degree-education system,
- making graduation process more systematic but also more attractive,
- creating motivation both among students and teachers,
- better responding to changes in society,
- using existing resources more efficiently,
- supporting universities in all aspects of organising MSc and PhD-studies, including curricula development and co-ordination, co-operation between universities and other organizatory tasks.

5.3.2. Organisation of a Graduate School

At present, teaching informatics and basic research in computer science and information technology is split up in Estonian universities and research institutes. That has caused a relatively lower level of these fields during the last years. Often subjects of this field are taught by people without necessary skills and practical experience in information technology. The age of the teaching and research staff at the universities has reached the point where it is not difficult to predict serious staff problems in 5-10 years from now. The cost of the split up teaching is inadmissible compared to its effectiveness. To improve the situation the efforts of different universities and research institutes should be united and co-ordinated especially with the aim to reproduce academic staff.

Considering Estonian resources, especially the small number of PhD students and staff, it is reasonable to establish one graduate school between Estonian universities to educate people with academic and professional degrees both for universities (teachers) and organisations oriented to research and applications in informatics related fields.

In practice such a school could be organised as follows.

Students starting master or doctoral studies at a university (their home university which participates in the GS) automatically enter the GS; the student gives account of his (her) study results to the home university which also issues a certificate of graduation at the end of studies.

The GS uses its funds (appropriated by the state or other organisations) to grant scholarships to students. These scholarships should be sufficient enough to motivate the studies of a successful student and prepare him (her) for a further academic career. The GS should also support the home universities in establishing the necessary infrastructure and working conditions for graduate students

(computerised workplaces, project rooms and student labs, scientific literature of the speciality, distant courses from other universities in the world). Through GS every graduate student should get an opportunity to study at least one semester abroad in some partner university.

The first year master studies of the GS are organised as two three-month semesters of which one will take place in TU and the other in TTU. The aim of this is to pass the best basic study courses of both universities that complement each other, and get acquainted with the conditions, teaching and research staff and their research work (at both universities) necessary for further co-operation.

Starting from the second year the graduate studies will be organised in accordance with modern distant learning: the active studies will take place in the form of courses during two sessions - winter and summer school - where part of teaching will be carried out by invited lecturers from abroad. During these sessions, 2-3 intensive courses discussing the latest results in informatics science will be passed. The winter school could last two and the summer school three weeks. The latter would also contain mutual sessions for the students to defend their papers. Between the sessions, the student will do research work, take reading courses, study the semester abroad, take part in scientific conferences and other academic events.

5.3.3. GS staff and management

The director of the GS can be a teacher/researcher with a scientific degree and should be active in the field of informatics. The director is elected for five years in a public competition, his position should be at the same level with a university professors position. The duty of the director is to carry out the policy elaborated by the board of the school, to co-ordinate and organise the studies. The director reports about his activities to the board of the GS and to the rectors of the associated with GS universities.

Besides the director, no other academic jobs are foreseen in the GS, since the studies (in GS) form part of working obligation for academic staff (ordinary, extraordinary or working by the hour) of the university. To cover the co-ordinating and developing activities, and also to maintain the computing equipment and libraries, a secretary and some technical personnel jobs are foreseen.

The support for preparation of new courses, getting consultants for student projects and curricula development is achieved by hiring people for limited time and/or to perform defined tasks. The foreign lecturers are paid on the same basis.

The highest management authority of the GS is the GS Board, which consists of representatives from departments giving informatics education in the associated universities.

5.3.4. Costs of a Graduate School

The amount of students in a GS is calculated considering the realistic possibilities in Estonia and should be 16 PhD and 30 Master students in the GS as a whole (estimated output is 3 doctors and 12 masters per year). The scholarship paid to the student by the GS (considering the level in neighbour countries) should be for master students at least 2 and for doctoral students at least 4 official minimum salaries. It would be today 1360 and 2720 EEK per month respectively. That will make 1,1 M EEK per year.

In addition, the graduate student can take a study loan. The rules of paying off the loan should support the working of the graduates at positions strategically important to Estonia for at least five years after the graduation.

The amount of financial support necessary for other purposes can be estimated in general on the basis of so far costs of TEMPUS JEP-06145 since the objectives of this project, its activities (organising lectures, seminars and schools, obtaining literature, modern computing equipment and maintenance, mobility of Estonian students and teaching staff to West European universities) and number of participants is comparable to the ones planned in here. It would be in average 180000 ECU ~ 2,7 M EEK per year.

The GS uses the premises and infrastructure of the universities for its activities. Therefore it is necessary to plan finances to cover the overhead costs. Using the formula 20% of the total costs, we can get an estimate for GS budget per year (1,1+2,7)*1,2 =4,56 M EEK.

The activities mentioned above cover only the teaching of special subjects and do not take into account studying languages, social sciences etc. Presumably these subjects are chosen from the

curricula of the home university and the corresponding costs should get covered as well. If we assume that the share (in cost) of these subjects is up to 1/4 of the whole studies, we can estimate the cost of the total informatics graduate studies to be 6,08 M EEK per year. To compare, considering the standards in force, the graduate studies in the same capacity should cost 2,82 M EEK. The amount calculated here is considerably larger than the standards allow but we should also note that:
a) informatics studies are more expensive on the average because of the equipment used;
b) in comparison to traditional studies, the costs above include several additional activities like students foreign semester, regular usage of foreign lecturers, usage of modern computing equipment in studies and research, which all should increase the quality of education obtained.

5.3.5. Legal status of a Graduate School

The GS could at first be a virtual organisation that unites members (universities) associated with it. The GS could also be an economically independent institution under the subordination of one of the universities if a consensus agreement about it can be reached among the departments prevailing in informatics education of the associated universities.

As other alternatives, a graduate studies centre could be established under the subordination of the Estonian Academy of Sciences or, if an information technology centre of excellence should be established in Estonia, the GS could be part of it.

The establishment of GS in Informatics observed here should be considered as a pilot project, during which the advantages and bottlenecks of functioning of an analogue inter-university institution will be made clear. Taking into account the higher education structure formed in Estonia, it is not expected that a lot of such graduate schools should appear in the near future. Informatics is probably one of the few fields where such co-operation can come into question. In other fields, mainly co-operation with schools outside Estonia might be considered.

5.3.6. Contents of graduate studies in CS and IT

Goal: to provide university education at the third level of academic studies with the aim to teach scientific and teaching staff for Estonian universities and research institutions and project leaders for R&D firms. The students of the GS will be striving for scientific or professional degrees.

A graduate course compromises:
- general lecture courses (discrete mathematics, theoretical computer science, general engineering subjects etc.) - will be given in co-operation between TU and TTU during the first study year,
- intensive courses on the latest results in computer science and engineering,
- reading courses on actual topics of R&D research activities on thesis.

The curriculum should cover all subfields of CS & IT and correspond to the generally recognised standards of CS & IT education.

For example, ACM and IEEE recommendations for CS curriculum cover the following topics:
- Algorithms and Data Structures
- Architecture
- Artificial Intelligence and Robotics
- Database and Information Retrieval
- Human-Computer Communication
- Numerical and Symbolic Computation
- Operating Systems
- Programming Languages
- Software Methodology and Engineering

The titles above should be interpreted accordingly to the up-to-date research topics and results.

In general, curricula in information technology has to be designed having in mind its interdisciplinary nature (currently IT curricula is heavily CS-oriented).

The variety of degrees by subject (engineering, applied mathematics, theoretical computer science etc.) or by level (Master, Doctor, scientific or professional degrees) will be obtained by individual study plans of students and proportioning three following aspects of the studies:
- theory (or the underlying mathematical principles that apply computing)
- abstraction (or experimental science applied to development of algorithms and software by forming hypotheses, collecting data, modelling, designing experiments, and analysing the results);
- design (the engineering of computing systems, through requirements and specifications, design and implementation, testing and analysis).

To compare with undergraduate courses, the graduate studies will emphasise more theory. The difference between scientific and professional degrees will be obtained by the proper proportion between theory and design. Professional degrees presume that students participate in computer projects, and that they study and practice in project management and group working.

6. Further steps and related activities

The following activities are planned to continue the reform of IT & CS education in Estonia:
- Dissemination of the study results and continuation of negotiations about the GS between universities, Ministry of Education and other interested parties. This process also includes final evaluation of the GS-project by these institutions.
- Finding resources to implement the GS (new CME-project or/and other grants, state budget, budgets of participating institutes, ...).
- Working on details of implementation of GS, especially concerning the legal status of GS and its activities on student financing.

But then, the GS-project is only a part of the reform and other related activities are going on in parallel:
- CME-02078 “Quality assurance system for informatics education”,
- CITCIS “Centre of Intellectual and Technological Competence for Information Society”,
- Reform of the undergraduate education in Estonian universities (new BSc and diploma programs in IT, new faculties, etc.),
- New projects of CIDEC, including co-operation with Finnish universities, support in fields of applied research, continuos education etc.,
- New projects on IT in teacher education and other school-related events as, for example, the project of computerisation of secondary schools.

In general, during last three years remarkable changes in the field of IT & CS have started.

7. Assessment of project implementation and management

All partners have rated the performance of the project in achieving its outcomes and ended up with average mark 3.75 (in scale of 1-5). The following shortcomings were mentioned:
- Because of a late response from the Tempus office, the actual working period was only 10 months (considering actual utilisation of the grant only 9 months) instead of 12.
- Some events were planned for too short a time (efficiency could be better).
- The fact that contracting and co-ordinating institutions were in different countries sometimes caused difficulties in management and bookkeeping, e.g. using of different currencies, different rules at universities etc.
- People involved were very busy with other duties. EU partners were represented by only a small number of participants. Owing to these (and other) reasons, the estimated amount of mobility was not achieved.
- Information exchange between partners was sometimes slow (e.g. calls for seminars were too late and not always clear enough, updates of WWW-site were not announced).
- Official leaders of faculties and departments were not actively involved.
- Connection to other similar projects could help in running this project more effectively. Maybe it is reasonable to organise regional short courses in management of EU projects for contractors and co-ordinators.

The management of the project has been a useful experience for CIDEC and in general the planned mission was fulfilled. Outcomes are visible and the GS model for Estonia is created.

8. Final remarks

Information technology became strategically important for Estonia and lot of energy has been devoted to the development of IT (including educational projects on different levels). But no technology can be successful without people having an appropriate level of competence. Quick changes towards the information society create new demands to the educational system both in contents of education and in amount of "output".

Establishing a Graduate School is one possibility to provide a modern and profound education on the highest level and to achieve an international recognition of our MSc and PhD degrees in IT and CS. It also allows to reduce costs of teaching per student and to increase the number of students. As a result, the graduation process becomes more systematic but also more attractive.

Experience of this project indicates that institutes involved in teaching IT and CS are the most important factor in success or failure of any reform. The real Graduate School can be established only if these institutes find it useful to co-operate and search for the needed resources. It is to be hoped that current project has created productive atmosphere to achieve this goal.