Teaching Computing at Secondary Level
- the Turku Vision, Mission and Reality

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Abstract:

The principal objective of Finnish high schools is to prepare young students for further studies and life in general, but computing is nevertheless not recognized as an individual subject in the core curriculum of these schools. Due to gaps in tuition, common misunderstandings exist about the true nature of computing, which are especially problematic for secondary school students, who need a realistic view of the field in order to make advised decisions about their future studies. In this paper we present two initiatives taken by universities in Turku, Finland aimed at improving the possibilities for secondary school students to study. Our experience suggests that motivated students can be prepared for professional university training while completing their high school courses.

1 Background

Today's society requires citizens to have knowledge of information technology (IT). Strategy programs at national level define the skills needed in an information society and encourage people to learn these skills [1]. The Finnish government has issued an Information Society Programme, the aim of which is “to improve competitiveness and productivity, to promote social and regional equality and to improve citizens' well-being and quality of life through effective use of information and communications technologies.” (http://www.infosoc.fi) The program is based on close co-operation between public and private sectors. In this paper, we will use the term “computing” as an umbrella term encompassing computer science and IT.

1.1 The Finnish Educational System

In the Finnish educational system, high schools (HSs) are referred to as upper secondary schools. The principal objective of these schools is to provide students aged 16-19 with general, all-round education preparing them for further studies and life in general. Ben-Ari [7] states that a science can be taught at lower levels when it matures, and that the time has come for computing to be introduced at lower levels of education. For instance, in the USA [3] and in Israel [12], computing curricula for HSs were developed in the 1990s. In Finland, the situation has gone in the opposite direction: computing is not part of the HS core curriculum [2]. Computing has thus a completely different position than other sciences, such as mathematics and physics, which are compulsory at secondary level. Considering (1) the objective of HSs, (2) Ben-Ari's vision and (3) Finland being one of the leading nations in the field of IT, it can be seen as something of a paradox that computing is not included in the core curriculum of HSs; institutions that should provide all-round learning are not obliged to provide their students with tuition in perhaps one of the most important subject are as today.
1.2 Consequences of the Lack of Computing Education

When there are no formal requirements for instruction in computing, many HSs are not likely to expand the range of courses to include genuine computing courses; in the worst case, they will arrange no computing related courses at all. If such courses are given, they are largely practical and aimed at teaching the students how to use the computer and various software packages. Essential skills, such as algorithmic and logical thinking skills, are not developed when simply using the computer as a tool. At the same time, misconceptions of computing as focusing on computer hardware are reinforced. This has implications both for the general public and for future computer scientists; in particular, female students maybe intimidated by the stereotypical, nevertheless common, view of computing represented by a young male hacker sitting in front of his computer drinking soft drinks and eating pizza[18]. These misconceptions may also result in students enrolling in computing courses on false grounds, expecting the studies to be mainly practical [4].

Furthermore, researchers have studied factors predicting success in university computing, and many of them have found that pre-university computing courses increase the chances of students succeeding at university level [4, 15, 20]. Computing education at secondary level plays an important role preparing the students for the university computing curriculum: not only giving students basic computing skills, but also making them familiar with the genuine nature of the field. How are they supposed to be able to know if computing is something for them, if they do not know what studying it means in practice? Giving HS students a more accurate image of computing might also increase girls’ interest in the field, since the gender division seems to appear already at that level [19].

Given all of these aspects, the Finnish situation does not look too good.

1.3 Initiatives in Turku

In Turku, the importance of improving computing education on all levels is emphasized. Into ICT is a joint project between the universities in Southwest Finland, Turku Chamber of Commerce and Turku Centre for Computer Science, a joint research and education centre between the University of Turku (UTU), Åbo Akademi University (AAU) and the Turku School of Economics (TSE). The goal of the project is to create a web portal¹ that brings together and serves persons interested in the field of computing, students looking for a study position, new graduates and companies.

The director of Turku Upper Secondary and Adult Education Services, Esko Heikkonen, points out the importance of increased opportunities for collaboration between different levels of education. As a concrete example of active efforts made along these lines to improve the situation of computing education at HS level, researchers at the Department of Information Technology at UTU and the Department of Information Technologies at AAU have joined forces. The main agenda is to narrow the gap between universities and HSs. Professor Tapio Salakoski at UTU states that

[the] obvious and immediate goal of collaboration between university and HS level is an improvement in student recruitment. An indirect but important objective is, however, having a positive impact on society and securing the further development of the ICT field.

¹ The portal IntoICT (http://www.intoict.fi) was opened in January 2007.
In the following we will present two initiatives aiming at providing HS students with high quality education in computing.

2 Case Study 1: The ITM Program

At Kupittaan lukio, a HS in Turku, computing and media are an essential part of education. A special IT and Media (ITM) program was initiated in fall 2000, having an innovative goal: to provide computing related education to talented and interested students, thereby also producing future experts for the local ICT industry.

Students are enrolled in the program based on their final certificate from comprehensive school, with the grades in mathematics, the English language and the mother tongue being most important. Currently, thirty new student positions are offered annually. The program offers 40 applied courses related to computing and media, of which the students have to complete at least ten. All ITM students have to take a course resulting in a final diploma work.

The ITM program is a co-operation project between Kupittaan lukio and TUCS. Students who do well in the ITM courses have the possibility to enroll for studies at the Department of Information Technologies at UTU or the Department of Information Systems Science at TSE while still completing their HS studies. In fall 2006, all regional actors in tertiary computing education moved into new joint facilities as the ICT building was opened. To mark the importance of collaboration between secondary and tertiary level education, the building also hosts two lecture rooms for Kupittaan lukio, in which the ITM courses are given.

2.1 The ITM Curriculum

The ITM curriculum covers different areas of computing, ICT, media and contents production, and includes 40 courses on topics like programming, data structures, digital communication, multimedia, networking, media criticism, electronics and graphics and video editing. All courses are not 100% computing courses, but those that are not, target computing and media from other angles. For instance, in the media criticism course, students get acquainted with and learn to think critically about the information found on the Internet or seen on TV.

In 2008, a total of 260 ITM students had been selected to the program since it was initiated in year 2000. In the beginning very few of the students were girls, but putting more attention on the media courses seems to have improved the situation; today girls make up almost 20% of all ITM students.

2.2 Collaboration with Industry

The ITM program has many co-operation partners in the ICT industry. When the program was initiated, the number of collaborating companies was four, but over the years this number has more than quadrupled. All companies are either local independent companies or local subsidiaries of international companies.

Today the ITM program has a close relationship with seventeen companies, which is concretized as, for instance, company experts giving lectures at school and students visiting the companies on a regular basis. In their second study year, ITM students complete short training periods in a company, participating in an authentic industry setting project.
2.3 University Collaboration

In addition to maintaining close relationships with the ICT industry, the ITM program also co-operates with the IT departments of UTU and ÅAU. This collaboration is concretized by ITM students taking part in educational research conducted by researchers at the universities. Moreover, the universities develop new methods and material for teaching topics, such as mathematics and programming, and these are then tried out in suitable ITM courses. The collaboration was further strengthened in fall 2006, as the IT departments and the ITM programs now live under the same roof.

2.3.1 Special Mathematics

One of the specialties of the ITM program is the method used for teaching and learning mathematics. It is our belief that advanced mathematics courses at HS level lend themselves to make derivations and proofs more precisely; after all, the students taking these courses are likely candidates for future mathematics studies at university level. However, traditionally, very little attention has been given to the theoretical foundation in the advanced courses; using exact formalism in definitions and mathematical proofs is often avoided and, thus, the design of proofs also remains untaught. For instance, quantifiers have been found to be hidden in textbooks [16].

During the last decade the direction seems to have been to also make advanced mathematics more accessible to everybody, thus resulting in a drop of preciseness and formalism. Consequently, students’ mathematical reasoning and abstract thinking skills remain poor even after several advanced mathematics courses.

In the ITM program, using exact mathematical syntax is, however, a prerequisite, as this will provide a better basis for computer-supported mathematics. Starting in 2001, the advanced courses have been taught using structured derivations, with some computer assistance. Structured derivations are based on the calculational proof paradigm, put forward by Dijkstra and Scholten [10] in 1990, and which was originally developed for formal refinement and correctness proofs of computer programs. Back and von Wright [5] have developed the idea further, by extending the format with the possibility of connecting sub-derivations to long and complicated solutions. This method can be used in mathematics as a way of writing solutions to typical problems [6], which can also be nicely represented electronically. For instance, when presenting solutions on the web, subderivations can be hidden using hypertext links in order to make long solutions shorter. When needed a more detailed view of the partial solution is only a click away.

2.3.2 Programming in Python

Many different languages have been used in the ITM programming courses since the beginning (e.g. C++, Delphi, Java), but in 2004 we started using Python and have continued to use that ever since. The main problem with C++ and Java was the notational overhead generated by the complex syntax. In our opinion, when teaching programming as an all-round learning skill, focus should be on the general idea of programming, not on the specific syntax

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2 Using this approach, mathematical expressions are transformed step by step from the initial expression into a solution. Each new version of the expression is written on a new line separated from the previous one with a symbol denoting the relationship between the expressions together with a justification for why the step is valid [14].
of a certain programming language. Nevertheless, given our good experience from using Python [13, 17], Python is also used in the advanced programming course of the ITM program.

Students who have finished the ITM programming courses can take part in programming courses at UTU, while still completing their secondary education. This gives us the opportunity to make longitudinal follow-ups of students from their very first programming course at HS to specialized courses at the university level.

Every year, 5-15 ITM students take university level computing courses at UTU. All of these have, so far, completed at least the following university courses while at secondary school: “Introduction to IT” (2 ECTS), “Basic course in algorithms and programming” (5 ECTS) and “Foundations of object-oriented programming” (5 ECTS). Ever since the ITM program was initiated, students taking courses at the university have performed very well and placed in the best quartile. The majority of these students enrol at the same university for further computing studies after graduating from the ITM program.

3 Case Study 2: The DASK Model

Whereas the ITM program is local to Turku, the DASK model (DAtakunskap i SKolan, CS at School) aims at providing computing education to a larger audience by offering web based courses. DASK was initiated by the Department of Information Technologies at ÅAU in 2002, and has ever since offered university level computing instruction to HS students more than 400 kilometres apart using the Web.

DASK aims at giving the participants a realistic view of what it would be like to study computing at university level, and at diminishing the gap between HSs and the university. Establishing contacts with the schools, their teachers and students, makes it possible to market the department in a new way and to develop close collaboration with teachers in e.g. mathematics and physics. This is important, as teachers play a big role in the students’ choice of further studies.

The DASK curriculum consists of web-based versions of five basic computing courses3 (á 5 ECTS) and correspond to the courses taught at the university - no trade-offs have been made either in contents or difficulty level. The courses were originally offered to Swedish-speaking HS students, but starting in 2004, other interested persons may also participate in the courses via the Open University at ÅAU (Öppna Universitetet).4 This makes it possible for working adults and others to complete courses in computing without having to attend any lectures on a regular basis. This has also turned out to be a welcome alternative for university students who are not able to attend daytime lectures, e.g. due to lecture overlaps.

Each DASK course counts as two HS courses. In addition to this immediate benefit, the

3 Introduction to computer science, basic course in programming, continuation course in programming, computer technology and logic.

4 UTU has its own open university, which, similarly, provides anyone with the opportunity to complete university computing courses. These studies are, however, subject to charge also for HS students, except for the ITM students.
students also receive other advantages: they are accredited for each completed DASK course at ÅAU, and do not have to retake the courses corresponding to these if/when they enrol for further studies at the university. Moreover, HS students who have completed three of the five DASK courses (15 ECTS) with good results are accepted as students at the department without having to take the entrance exam.

The department does not receive any external funding, but provides the DASK courses free of charge to high school students. The only compensation in form of money comes from the Open University, and the amount is based on the number of students registering to the courses.

3.1 ActiWe – Active on the Web

In DASK, the main focus is on student activity, emphasizing the importance of continuous work throughout the courses. We have formulated the ActiWe (Active on the Web) principle based on the idea of active learning [8], and it has been the main guideline when designing, developing and giving the courses. The main aim of ActiWe is to engage the students in their own learning by having an activity-intense syllabus, including different types of activities in order to cater for different learning styles. Each course includes a final exam, but we have de-emphasized its importance and instead highlighted the significance of the continuous work done throughout the course.

John Dewey's [9] principle of “learning by doing” is at the core of all courses. The students are to submit assignments on a weekly basis, and the points scored in these play a substantial role for the final grade in addition to the exam. Furthermore, each course includes numerous optional activities, such as animations, exercises and interactive examples.

3.2 Course delivery

Instructors at the university are responsible for the courses in most ways (acting as the course lecturer, maintaining the material, marking assignments, taking care of the examination etc.). To minimize the risks of students feeling isolated, the university instructors also keep in touch with the students on a regular basis and give individual feedback on assignments. Depending on the number of students, additional assistants may be needed at the university for helping the instructor, in particular with checking assignments and giving feedback. Each high school has a contact teacher who supports the students locally, oversees exams and makes sure students have access to computers at school.

All course material is made available on the web using the course management system Moodle (http://www.moodle.org). Moodle is an open source platform well suited for our purposes, being flexible, customizable and featuring many different types of activity modules. Using the same system for all courses gives them a similar layout, and by using the same type of material and activities in all courses we ensure that students know what to expect when beginning a new course. Moodle serves as the classroom and the main communication medium between students and the instructor. The contents for each course are divided into smaller parts, each of which makes up one week in the course schedule. The weeks are illustrated as boxes on the course page, one box containing all instructions, reading material, assignments, visualizations, exercises, examples, and soon related to the topic to be covered during that week. This makes it easier for the students to get a clear picture of what is to be done during a specific week.
4 EVALUATION

Both the ITM program and the DASK model are continuously being evaluated and improved. In both cases, we are to some extent following the principles of action research as defined in “Computer Science Education Research” [11]. In action research, practitioners improve their practice by doing or changing something and then reflecting on the results. The main purpose is to collect data and experience that help in gaining a better understanding of the practice. In addition to questionnaires, informal discussions and emails, the ITM students are interviewed on an annual basis. Over the years we have received large amounts of both formative and summative feedback from students, teachers and companies; this has been very valuable, and has served as the basis for reflection and change.

Naturally, the ITM program and the DASK model have their strengths and weaknesses. Some of the benefits common to both initiatives are that they:

- give students a more correct understanding of the true nature of computing;
- provide students with an opportunity to see what studying computing at university level would be like;
- prepare students for further computing studies at university level, and
- give students the possibility to complete university level computing courses while still at school.

Further strengths and weaknesses are listed in Figure 1 below.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td><strong>ITM</strong></td>
<td><strong>DASK</strong></td>
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<tr>
<td>More precise mathematics</td>
<td>More demanding than &quot;normal&quot; upper secondary school studies</td>
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<tr>
<td>Familiarity with industry</td>
<td>Requires self discipline and time management of the students</td>
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<td>Great variety of courses</td>
<td>Increased workload for students on top of the compulsory school courses</td>
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<tr>
<td>Good results give opportunity to complete courses at the university (increased study motivation)</td>
<td>Costly for the arranging university</td>
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<tr>
<td></td>
<td>Resource intensive for the university (guidance, marking, feedback, administration, …)</td>
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Figure 1: Strengths and weaknesses of ITM and DASK.

Whereas the DASK courses serves as a potential recruiting channel for the university, the ITM program serves a common goal of both the collaborating companies and universities. These want to encourage talented students to study at local universities and to continue as employees in a local company after completing their university studies.

5 CONCLUSION

HS students should be guaranteed the opportunity to acquire the knowledge and skills in computing that they want and need. In our opinion, one of the responsibilities of universities
is to serve society and the community. If it becomes evident that some part of society is unable to offer necessary services, we find it completely justifiable for the university to assist in providing these services. This assistance will most likely also bring benefits to the university in return, or as professor Salakoski at UTU puts it:

As a welcome “side product”, collaborative efforts, like the ITM program with Kupittaan lukio, offers a working forum for interaction between high schools, universities and industry.

As the experience from both the ITM and the DASK initiatives has been mainly positive, it is our belief that motivated students can be prepared for professional university training while still completing their HS courses. Doing so will not only provide them with a solid knowledge base in computing, but also make them more motivated, confident and reassured about their choice of future studies. The Finnish National Knowledge Society Strategy [1] talks about the “successful trinity of education, research and product development” and states that the “interaction of services and structures that support education, research and product development should […] be made more effective” (p. 14). In our opinion, the initiatives presented in this paper are examples of such supportive structures.

ITM and DASK have the same aims and motivation, but are different in the way of delivery of instruction. In the future, it would be interesting to compare the results from the two initiatives; by developing a list of “best practices” from both projects, we could come up with a good overall design plan for how computing can be successfully introduced at HS level.

References:

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