Quo vadis, IT EDUCATION ?

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Abstract – Human society is rapidly growing into knowledge society, which is based on all-increasing use of Information Technology (IT).

Rapid development of IT technology has posed before the IT-education several challenges: rapid, all-increasing flood of new information (half of this what IT student learns in his/her first year of study is already obsolete after three years, and estimates show that we are only in the middle of the information revolution) and numerous ways for students to access this new information; very heterogeneous population of students – different ages, from different countries, from EU and from Far East, who nearly all are already working (full-time), thus having very different background knowledge; they record lectures (if they are present) with their iPhone/iPad images and videos and communicate with their mentors sending links to video clips in YouTube; changing nature of Universities, which are transforming into commercial enterprises (based on profit) and are forced to act correspondingly. Even the value of higher IT education is questioned – Bill Gates and Steve Jobbs both dropped out from college and many employers believe school-leavers make better workers than university graduates [1].

In the paper are discussed current developments in society and IT, challenges of IT education and considered changes what the IT education is currently having in our countries in the general context of EU efforts for promoting e-Skills and lifelong learning.

I. INTRODUCTION

With overall deployment of natural resources has the human resource – well-educated population - become the most important recourse of every country. Several studies carried out in various countries have shown that there is a positive and statistically significant correlation between education of the population and growth rates of per capita GDP [2].

Automation and introduction of various high-level technologies has rapidly increased demand for workers with higher levels of education, technical knowledge and skill. Rising skill requirements combined with a shortage of available skills is creating a growing mismatch between the skills of the workforce and the needs of the economy. This problem feeds itself - manufacturers in the USA report that they are forced to invest in automated equipment because of their inability to recruit sufficient number of people [3][4], but these new automata require even higher skills from their operators.

Talent - highly educated professionals - is becoming the key competitive differentiator. We are entering the Human Age, where human spirit and potential are the driving force behind enterprise and innovation [5]. European survey, covering responses of industry and government executives from 35 European countries found that managing talents is the top priority in Europe overall and in most individual countries and lack of talents is considered in all developed countries the most important issue of human resource (HR) management [6]. OECD predicts that growth in most EU countries will fall due to the lack of talents within the next 10 years when elderly people will dominate the population.

The disparity between what students learn in universities and the "real life" has raised serious concerns and doubt that even the graduate education will be a good base for future earnings. Successful investor Peter Thiel offers undergraduates $100,000 fellowships to drop out of college and work on some original ideas for a start-up enterprise [7].

II. STUDENTS

The current population of students, especially in IT specialties, is different and heterogeneous.

In Estonia, more than one third of students are older than 26 years. During the last five years many people disrupted their studies, but are determined to continue and often do so, but already in older age. Most of students already have an IT-related job. The role of university is for them complementary and less important than what's happening in their workplace. The IT industry is very vibrant and innovative, coming up with new ideas and exploring new things, therefore professional knowledge and practical skills of working students may exceed the university level in some areas.

Working has made students very conscious of time. Working students are motivated, self-contained, know what they want and are actively seeking information/knowledge which is essential for their work or related to their interests (the two are usually closely connected). And they want it just now, just-in-time, not just-for-case [8]. The current generation of digital natives [9] handles often many tasks at the same time (work in parallel), therefore they prefer information in small chunks, the way Internet provides it: in quickly changing portions, via short text messages, Twitter tweets and Facebook remarks rather than email or long passages of text; many simply can not read or create long literate passages of text (but can astonishingly quickly produce

pages of C# code). Their ability for concentration and contemplation is reduced [10]. They want their information to contain lot of multimedia elements – images, animations, soundclips, video, since ca 80% of them are visual, not verbal learners [11],[12].

They prefer many communication methods, which are totally new to their teachers. Instead of preparing a written report about their programming project they e.g. record with screen capture software a video clip showing how their program works, then put this up in YouTube and send to teacher link to the YouTube clip. Digital natives (still) can read, but many can write only using a programming language and (nearly) not any more using a natural language – Estonian, English etc.

Digital natives (still) can read, but many can write only using a programming language and (nearly) not any more using a natural language – Estonian, English etc. Numerous channels available for accessing information has significantly reduced importance of their professors as sources of new information, professors have to compete with their laptops, iPads/iPods to get their attention.

We are in an information-processing revolution based on electronic computers and optical communication systems. The previous information-handling revolution - the invention of moveable type - allowed the information in book to be accessible to millions. Widespread literacy and dissemination of information completely transformed society. The computer revolution - achievements in digital images, video and sound have made these previously only physically stored media predominantly digital and easy to use even in hand-held mobile devices. You do not need to write in order to describe, create a message – just record your speech with your mobile phone or turn your mobile phone to the subject and record a video clip. Mobile devices, YouTube and sound blogs are creating a new literacy based on video/sound clips and images and reducing the centuries-long importance of written text.

Rapid change, constant flood of new information and tasks has made digital natives extremely practical. They are always seeking concrete information needed for solving their current problems, are far less interested in general knowledge and not trying to memorize solutions – they know, that tomorrow there would be new problems.

The most important and widespread method of seeking information is googling. For digital natives Internet is already a religion - if it is not on Google it does not exist, if you are not in my Facebook circle I do not know you!

III. IT

Ten years ago "software engineer" was a distinct profession. Now programming and wrestling with Windows is becoming just another skill like writing -- something that any technical professional should be able to do, and many "digital natives" handle this skill far better than writing. Programming is essential for getting any kind of technical/mathematical job. And traditionally non-technological professions are also increasingly embracing some kind of programming as a way to advance their profession. Programming is becoming a much more fundamental piece of knowledge than reading or writing and IT specialists are getting the best salaries: "In Silicon Valley, annual tech salaries topped six figures" [13].

Once computers exterminated typists, currently they are exterminating many other professions. Today a new jaw bone for a patient and muscle tissue can be created with 3D printing [14],[15] – tomorrow 3D printers can create a whole outfit and footwear, sculptor can create a new masterpiece just typing into keyboard and all these can be delivered to customer by e-mail. No need for shopping and most possibly we also do not have time for shopping, our life is constantly accelerating. And estimates obtained by comparing the current Information Revolution with the previous revolutions show, that "we are not at the end of the information revolution. We are only partway into it" [16]. Next may/will be the Internet of Things [17], [18] – interconnection of smart network-enabled objects/robots and services on top of them. The next phase of offshoring – moving manufacturing work from USA and developed countries of Europe into China and far East – is off-peopling, transfer of jobs into complete oblivion through automation, leading to a future where manufacturing and routine service jobs account for less that 4% of the U.S. workforce [19]. Are we transforming into new species – informawore [20]?

Computers and Internet have created a new economy - a digital economy, where everything happens online, through exchange of information. Many values are nowadays considered purely as (digital) information – money (more and more banks are refusing to deal with "real", physical money), many kinds of art – music, literature (Amazon is currently selling more e-books than paper books [21]), even human jaw bones [14] and muscle tissue [15]. The digital economy has been the most innovative part of the economy over recent years, firms engaged in this industry have been growing dramatically, threatening many existing business models and existing professions. Lobbying for new protective laws will not help media companies with outdated technology.

Information has very different properties if compared to matter and energy. Information does not have conservation laws. Quite the contrary, information is like fire or nuclear reaction – it feeds itself. If you have more information, you can do more; doing more you can obtain new information, which enables you doing even more and thus obtain even more information. Introduction of computers in offices did not result in paperless office, did not reduce number of A4 pages printed there. Prepared with computers reports, tables and forms were much better, easier to handle and consolidate – create new, more general reports – that they put under question the need for many low-level managers, offices and government bureaucrats, whose job was previously to create them. Therefore in order to prove need for them they immediately wanted to know more and invented new reports, tables and forms.

Thus there is an exponentially growing need for more and more talented IT professionals.

IV. What are important IT skills?

Ten years ago was programming, more generally – Software Engineering (SE) considered as the most important IT skill. But in last ten years IT has come a long way. Many-many programs have been created (software application market is currently worth around 2.2 billion dollars, and growing at a rate of 85% annually [22]). All the time appear new software development tools which improve the productivity of human developers. Thus today success of any project in the IT world depends far more on ability to work with multiple technologies, integrate everything together, communicate and learn than on programming skills. IT technology develops all the time rapidly - IT is constant learning.

Ability to learn and communicate is very important skill in every profession; in IT this is critical. All the technical know-how can be obtained when needed from WWW, from manuals, co-workers etc, but these sources are useless without ability to communicate and learn.

Information has one more extraordinary property – it becomes worthless, if not used. As traditional jobs disappear, people will need to develop their non-automatable skills to be productive and succeed in the Hyper-Human Economy [23]. In many cases, workers won't go after existing jobs, but rather create new jobs and establish new enterprises. They identify problems to be solved and invent solutions using their hyper-human skills - discovery, creativity, ability to compare and generalize [24]. When Nokia announced in spring 2011 that 4000 software developers in Finland will be sacked, nobody of them complained, many announced right away, that now they will establish their own enterprise (and often mentioned game creation as their new field of operation).

The new jobs are based on new information, but this is in Europe not always used the best way. In EU are registered every year ca 65% more patent applications than in USA [25],[26], but Europeans have a great lag in creating new innovative products, services, enterprises. Americans have less patents, but use better than Europeans everything new, are more creative (and the start-up money is easier to get). To help students to get a grip of the USA entrepreneurship, the Tallinn University of Technology opened an office in Silicon Valley and is organizing in summer 2012 in Tallinn the European Innovation Academy 2012 [27]. The event is targeted to all Engineering, Science and Business students of Europe as well as professionals who are intending to pursue a career in innovative management and entrepreneurship.

V. How to Cope?

A. Curriculum

The classical idea of improving education is trough improvement of curricula. With current temps of IT innovations this is quite difficult. In order to teach something teacher himself should know the subject very well. Very few very talented teachers can be on forefront of IT technology, if half of the content becomes obsolete in three years [28]. While computing has evolved very significantly in the past 10 years, Computer Science curricula have been much slower to adapt to these changes [29]. Curriculum is an complex emerging system [30] and it evolves first of all from bottom up, by enthusiasm of innovative teachers and students, who often introduce very different, novel and non-standard courses [31],[32] – not from top-down directives, as many reformers of education want it to behave. Directives "you take this topic into your course" most often result in excuses [33]"Sorry, I don't know anything about this stuff, I can't teach it".

Fundamental programming principles and techniques are eternal, but nowadays they can be obtained from free on-line tutorials and courses. Children acquire basic computer skills already at their pre-school years when playing on-line games.

The Massachusetts Institute of Technology (MIT), the top of the latest Leiden ranking of universities around the word [34] has already for 10 years given free access to educational materials from all of its courses on the Internet. The MIT Open CourseWare (OCW) [35] is sharing materials from more than 2000 courses with an estimated 100 million individuals worldwide. Currently (winter 2012) the "Electrical Engineering and Computer Science" department offers 155 under-graduate and 97 graduate courses and these resources are extensively used, e.g. all 23 lectures of the MIT course 'Introduction to Computer Science and Programming' together have on YouTube over 2 million hits [36]; thousands of them come from mobile devices .

Success of on-line courses has encouraged MIT to create a non-profit online learning initiative MITx [37] (this is free only for full-time college or university students in New England). MITx offers a portfolio of MIT courses through an innovative online interactive learning platform.

The Stanford University Engineering school is offering on-line for free three of the school's most popular computer science courses [38]: *Machine Learning*, *Introduction to Artificial Intelligence* and *Introduction to Databases*. They are using technologies designed to enhance learning for Stanford students and extending them to a broad online audience. In the first four weeks after opening 300,000 students registered for these courses [39]. Lectures are delivered as short, interactive video clips which allow students to progress at their own pace. Together with courses are provided also live quizzes with instant feedback. Here are tested new technologies that allow students to rank questions that should be posed to the instructors.

The site 'Open Culture' [40], created in 2006 by group of enthusiasts leaded by Dan Colman, the Director and Associate Dean of Stanford's Continuing Studies Program brings together lot of free high-quality cultural and educational media for the worldwide lifelong learning community - audio books, online courses, movies, language lessons, eBooks. Currently (Jan 2012) they list over 40 Computer Science courses, which are both on very actual topic (*iPhone Application Development*, *Quantum Computing for the Determined*, *The Beauty and Joy of Computing* etc) and presented using very modern technologies (e.g. as iTunes video clips).

Use of video clips for educational content delivery has been strongly advocated already by R. Schank in his *Engines for Education* [41]. There are many positive examples, e.g. success of the Khan Academy [42], which explains math, science and humanities topics using over 2800 short videos; clips are augmented with automatically graded exercises. This simple approach was so compelling that by now more than 700 million videos have been watched by millions of viewers. Currently there is strong evidence ([43]) for positive effect of video clips in IT courses.

However, video technology has often been misused. Long recorded lectures are much more difficult to follow than corresponding material in text – with text it is easy to scroll to the interesting passage; with video to find just a short subsection is nearly impossible without watching the whole lecture. Video should be used as short clips which are dealing with one idea only, they should be technically good (in many educational clips are shown texts which are not readable) and the presenter/lecturer should have some actor's talent – monotone reading of written notes does not convey much message.

There are many other free resources which help to learn programming: Scratch [44] allows playfully experimenting, without dealing with syntax, create simple interactive stories, games, music and video and is suitable even for preschoolers; Alice [45] – innovative 3D educational programming environment allows to create an animated story, an interactive game, or a video to share on the web; Yenka [46] allows to simulate scientific experiments, create mathematical and statistical models, design electronic circuits and learn computer programming using visual control of animated characters by flowchart programs. One of the newcomers (from August 2011) is founded by Columbia University students Codecademy [47], which offers free interactive tutorials that guide users as they write and test lines of JavaScript code directly in their browser windows.

B. Pedagogy

"There's a difference between curriculum and pedagogy. Curriculum is all about what we teach. Pedagogy is about how we teach it." [48]

Even more important than IT technical skills are human skills: ability to learn, communicate and creativity – in the future we need creative, entrepreneurial IT specialists more than good programmers; many experts say that today are more relevant business skills [49].

These skills are far more difficult to develop.

The following suggestions have been tested in courses presented by the first author in Tallinn University of Technology. Most of participants of these courses work full-time, thus the epigraph on courses homepage is "We learn through experience and experiencing, and no one teaches anyone anything" (Viola Spolin), i.e. this is a message to students – if you want to learn, you have to work, just coming here does not make you wise.

1) Different style of lectures

Traditional university teaching is based on excessive use of lectures. But lectures can succeed only if audience is homogeneous and lecturer knows well the audience: "The success of a lecture requires the lecturer to be aware of the capabilities of all students and for all students to have a similar background" [50]. To be aware of capabilities and background of current diverse population of students is impossible , thus the style of lectures should change. In lectures should not be considered technical details of programming or software systems, but initiated communication with the whole group on higher level about significance of particular IT technologies, how something could be used and/or improved, what kind of technology is currently missing, but were good to have – such discussions greatly promote creativity and entrepreneurship and restore the style of Socratic dialogue, where teacher is the mentor, not a squawk box.

In our discussions come out some essential information. For instance, students do not value e-mail very high – mobile phone is more convenient; laptop and WiFi in the whole university are the most essential conditions for successful studies (94% students agreed, similar findings are described in [51]), students also agreed, that their attention span has decreased and they do/can not deal with long texts; their ability to deal in parallel simultaneously with several topics was also demonstrated – many worked on their laptops, but also actively participated is discussion. Students considered quite professionally state of common programs and revealed problems: programming languages and systems are very brittle, error prone and their syntax non-uniform (this problem was discussed already in [52]); many program editors are nearly useless (e.g. the Flash IDE), error reporting is very crude (many students said, that after using the free ActionScript editor FlashDevelop [53] they will never use the Flash IDE again, although their employer has expensive Flash licence). Microsoft come out in Windows 7 with several security innovations, which made use of folders and files rather confusing - even if there is only one user (computers have become a commodity and currently most computers are used by single person) he/she cannot have access to the folder "My Documents" (i.e. these are Windows/Microsoft documents?); every new version of the Office is accompanying with total overhaul of the menu system of all Office programs which usually make them more difficult to use and require re-learning while the functionality has not been improved – Word constantly creates junk files, PowerPoint looses media (sound, video) clips and if they are used, they are impossible to find; many www-pages allow to zoom to images and text (e.g. big tables) in order to show details, but in PowerPoint this is possible only with use of macros, but as default macros are disabled – students indicated Prezi [54] as a totally new style of presentation program which allows continuous zoom to subtopics.

Most students are using their laptops during the lecture/discussion and often find on the fly new facts/examples which were essential in the discussed topic - another example of their ability to deal simultaneously with several topics. Unfortunately our lecture hall

technology allows not (yet) switching student laptops to projector so that their findings were visible to the whole group, but even now students were quite satisfied. These discussions promote just the ability to discover, analyze, compare and generalize – skills, which are essential already today and even more tomorrow. Jeff Bezos, founder and engine of one of the world's most innovative companies Amazon [55] asks new hires, including senior executives, to tell what that they have invented [56]. Bezos wants to hire inventive and creative people – these are the most essential skills today and tomorrow.

2)Individual (or small group) projects.

Assessment of both courses is based on two individual projects, which are delivered by FTP and assessed on-line; face-to-face examination happens only if student wants to improve the mark or if there appear questions about the real work done by author (possibility of cheating). To minimize possibilities for cheating with project should be presented also all the "dirty" material, e.g. with game (the second project in the course *Games and Virtual Environments*) all sketches, sprites, recorded raw sounds etc; if something is taken from Internet then the source of those fails should be indicated and if the material has restrictions for use, there should be e.g. e-mail granting access.

3)Course materials on-line

All course materials should be 100% on-line – the student could be sent on his work to another end of the word. As much as possible should be used already existing free courses/tutorials on Internet. Usually it is not possible (yet) to get from there everything, something has to be created just for this course and because of rapid development, ca 30% has to be remade every year (some education apparatchiks think, that once an e-course has been created, the teacher is not needed any more – a total utopia!). Creating material just for your course is inevitable – it is easy to find programming tutorials or explanations of multimedia (e.g. sound, video) technology, but difficult to find suitable material which explains higher matters – connections with other topics, explains trends of development.

On-line should be also study plans (especially plans for practical exercises) – if student already knows the technology/program intended for an exercise, he/she can pass it.

4)Listen to students

As already said above, currently it is very difficult for a teacher to be aware of all new technologies and trends, students often know or discover something what is new to teacher. Therefore students are encouraged to use in their projects every suitable (free) technology or program. Exception are expensive commercial programming systems – with them student has to prove legality of use (he/she has license or the workplace has license and allows student to use the program).

Students often make very proper suggestions for topics of lectures and/or exercises – 'I saw tutorial of this technology, could we consider/try it in lecture/exercise' – always agree with such proposals (however many hours of sleep it takes to understand/master this new thing).

5)Try different methods, e.g. games

Videogames have become a very essential part of modern culture and production of videogames - a very significant sector of SE and world-wide economy. The last years showed decline in many areas of economy, but the game industry grow worldwide in last five years 16 percent [57],[58].

Games give players rich and challenging experiences, support search and discovery – the main components of creativity.

Many people still have outdated stereotype of the gamer. Today games are everywhere, and gamers are social, tech-savvy, goal-oriented people who want to improve themselves and also the world around them [59].

Game programming contains many important concepts of SE: UML, Patterns, Graphics and User Interface programming [60], and many rather abstract IT topics can be presented as games [61]. Game programming is the easiest way for a student to become independent developer (Indie game developer [62]) or to join some bigger game developing team.

VI. New IT Educational initiatives

To cope with need of IT specialists many new initiatives have been launched worldwide.

In New York City will in this fall open The Academy for Software Engineering [63] - the city's first public high school that will train kids to develop software. Anyone who is interested can apply; only their interest matters, not their grades and attendance record.

Several reports and surveys indicate that the whole Europe will face in the coming years shortages and mismatches in e-skilled people, but these skills are becoming central to boost innovation, productivity and employability and to respond to global challenges. Thus EU launched in 2007 e-Skills initiative [64]. During the first European e-Skills Week (March 1-5, 2010) were organised over 1160 events involving more than 445,200 participants from all over the Europe; the next e-Skills Week will be on 26-30 March 2012.

In Estonia, need for more IT professionals was recognized already in 2000, when was established a private non-profit higher educational institution The Estonian Information Technology College (UAS – University of Applied Sciences). It is owned by the Estonian Information Technology Foundation and public-private partnership: state, represented by the Estonian Ministry of Education and Research, two largest Estonian universities – Tallinn University of Technology and Tartu University, and private sector, represented by Estonian Telecom and Association of Information Technology and Telecommunications.

To cope with constantly increasing need of IT professionals in Estonia, in addition to The Estonian Information Technology College this autumn (2012) will start an IT Academy with two BCs and two international

master study programs; on 2015/16 the Academy is supposed to have already 12 study programs.

Under economical pressure, universities are more and more acting like international business enterprises, inviting foreign professors and accepting foreign students. The Tallinn University of Technology is preparing to accept much more students from East – from Russia, Ukraine, from former SU countries in Central Asia, from China and has already created a homepage in Chinese [65].

VII. STUDENT'S VOICE

The following is an excerpt (translated from Estonian) from an essay of one of our students:

"I may be wrong, but I think that many professors have forgotten one important issue: to explain to students the significance, importance of the considered issues in general context. Instead of this are presented lot of details, classifications and historical development – but anyone can get this from literature and Internet. If student does not understand, why this topic is important and how it is connected with issues considered earlier then there is no motivation to listen.

Thus a suggestion to professors – make students to think, not to memorize facts. Give them general understanding of issues in context and ability to use the right methodology in right place. Formulas and details do not vanish from literature and the head is not a garbage pin where you can drop whatever."

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