New Trends in Information Technologies and Their Integration in University Curricula: a Brief Study in the Context of the FETCH European Thematic Network

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Abstract: *Starting from general considerations about the fast evolution of Information Technology, in this paper we focus on the need for integrating new up-to-date topics in existing computing curricula. In particular, we summarize the data obtained from surveys developed within the FETCH European thematic network and directed to professors, alumni and industry representatives. We also provide suggestions derived from the FETCH European Strategic Framework for Computing Education and Training (ESFCET 2020), stressing the importance of computing curricula that incorporate timely technological targets.*

Key words: *Computing Curricula, Emerging Technologies*, *FETCH*, *Information Technologies.*

INTRODUCTION

The evolution of Information Technology (IT), fueled by research carried out in both academia and industry, is usually reflected in university curricula with a certain time delay. Furthermore, IT progresses are often subject to individual preferences and local constraints. These are significant problems today, as the current technology "revolution" implies fast changes rather than gradual and slow developments.

The market and industry require more and more fast and flexible adaption of computing education to their constantly increasing requirements. Even international organizations such as ACM and IEEE have, for years now, proposed authoritative IT curricula recommendations, but always with some delay (in the order of years). Moreover, these curricula cannot be updated very frequently, due to the complex procedures underlying their definition process.

In the framework of the FETCH project (*Future Education and Training in Computing: How to support learning at anytime anywhere*) of the European Lifelong Learning Programme, a consortium of 67 partners from 35 European countries has defined a *European Strategic Framework for Computing Education and Training 2020* (ECFCET 2020). In this paper we present some findings developed in the framework, which are connected with the problems of fast IT evolution and the need for up-to-date IT curricula in universities and higher education institutions. We also try to summarize the proposal of different actors to improve the curricula.

IT TOPICS AND THEIR EVOLUTION

The *ACM Computing Classification System* [1], published in 2012, ranks well-established technologies and topics in computing, whose top elements are the following:

1. General and reference
2. Hardware
3. Computer systems organization
4. Networks
5. Software and its engineering
6. Theory of computation
7. Mathematics of computing
8. Information systems
9. Security and privacy
10. Human-centered computing
11. Computing methodologies
12. Applied computing
13. Social and professional topic

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In the previous list we can distinguish both specific Computer Engineering and Computer Science main topics (e.g. *Hardware*, *Networks*, *Software and its engineering* and *Security* for the first group and *Theory of computation*, *Mathematics of computing* and *Information systems* for the second). These subjects are quite general and practically cover, at a "high level", all basic IT needs.

Instead of focusing on "deep-routed" technologies, the Gartner's 2015 Hype Cycle [2] analyses the attractiveness of current topics trends (Figure 1). In a sense, while the ACM classification reflects a pure engineering point of view, that of Gartner is more centred on applications.

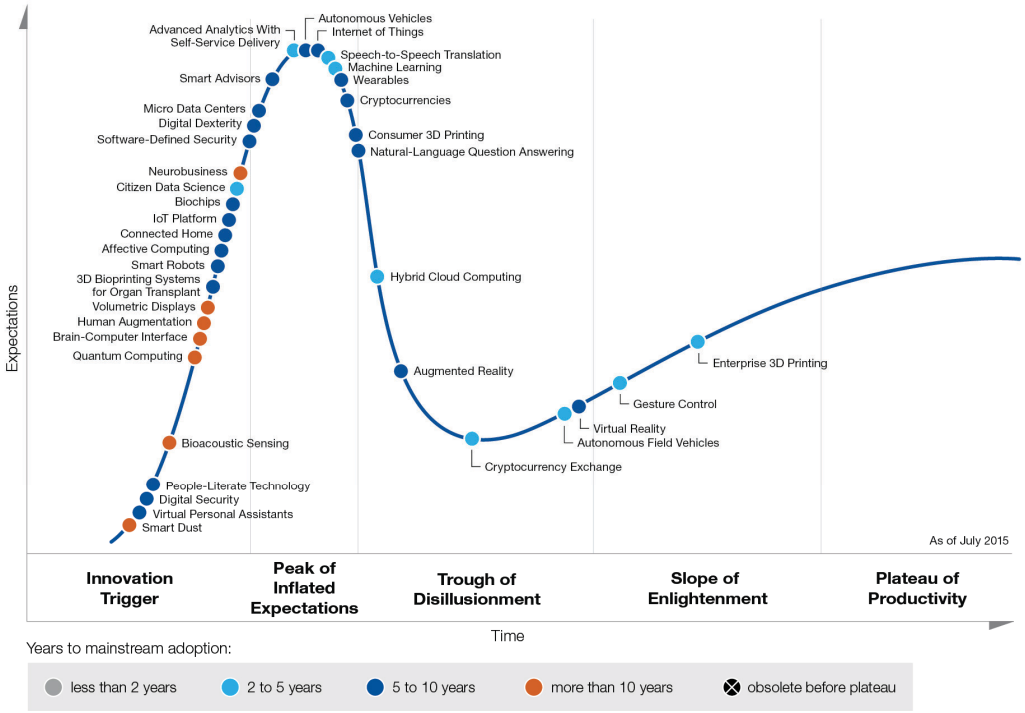
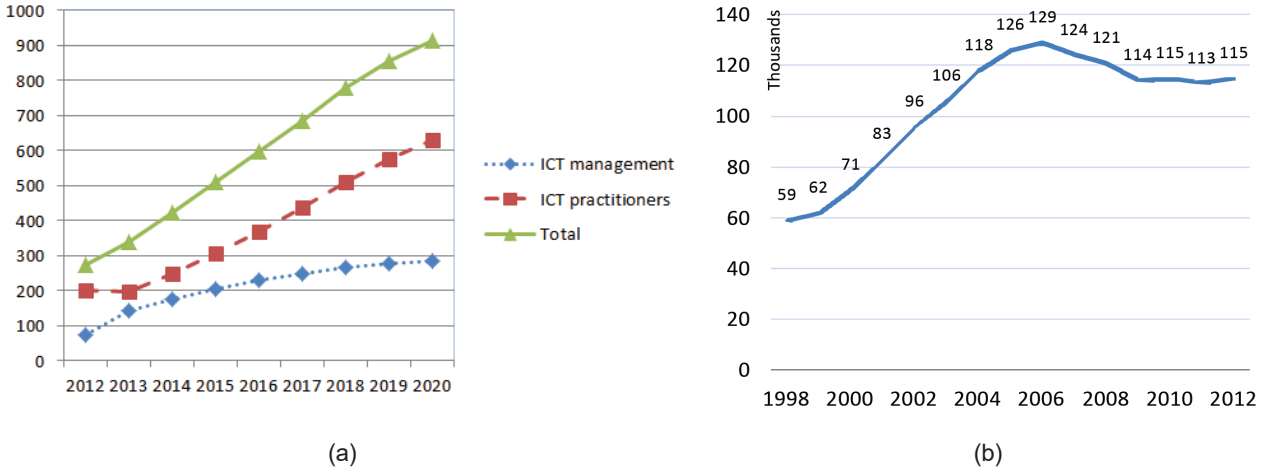


Figure 1. Gartner's 2015 Hype Cycle for emerging technologies [2]

Gartner's viewpoint seems to be more "politically oriented" when compared with the objectives of the "Europe 2020" initiative [3], which promotes "… delivering growth that is: smart, through more effective investments in education, research and innovation; sustainable, thanks to a decisive move towards a low-carbon economy; and inclusive, with a strong emphasis on job creation and poverty reduction". Gartner's perspective is also well related with ICT-education in Europe in quality and quantity, which, on the other hand, is interrelated with European ICT markets, research, technology trends and industrial activities. Simply put, Europe seems to be more interested in applicable tools than in tools by themselves.

As regards the forecast for ICT workforce demand in Europe in the next years, the situation is not very good to assure EU objectives. For instance, data from [4] show that the ICT workforce evolution in Europe in the years 2000 – 2012 is growing and will grow at a fairly constant rate (Figure 2a). At the same time, the reality of IT graduation in Europe is characterized by oscillations not matching with the growth of demand (Figure 2b). This fact implies the need for new policies to make IT more attractive, meeting at the same time the trends of technology development.

European goals related to education can be expressed with the aim to put "the knowledge triangle of research, education and innovation to work" [5]. EU policy is designed to support national actions and help address common challenges, such as



(a) (b)

Figure 2. (a): Forecast (in thousands) of ICT jobs demand in Europe in the years 2012 – 2020 (created from data published in [4]); (b) Evolution of the number of European ICT graduates in the years 1998 – 2012 (reproduced from [4])

ageing societies, skill deficits in the workforce, technological developments and global competition [6]. In this context, the European Commission especially requires "rethinking education" and "lifelong learning".

Innovation is related with a multitude of complex integrated disciplines. An example is given by reports of "The New Media Consortium" (NMC), which present typical IT trends that are of special interest for the education market and are expected to become widespread within few years. The "NMC Horizon Report > 2013 Higher Education Edition" [7] identifies directions such as: *tablet computing* (which may be considered as part of mobile IT), *games* (which involve a complex of IT disciplines), *analytics software* (including predictive analytics, forecasting, data mining and text analysis), *3D printing* (for industrial prototypes) and *wearable technology*. The "NMC Horizon Report > 2016 Higher Education Edition" [8] extends this list including: *development in heterogeneous environments* (the concept of "Bring Your Own Technology"), *learning analytics* (collection, analysis and reporting of data), *adaptive learning* (adaptive machine learning), *augmented and virtual reality* (2D-3D modelling and computer graphics), *affective computing* (recognizing, interpreting , processing, and simulating human emotions) and *robotics*. This list of "exotic" high-level directions defined by NMC confirms the need for curricula based on "low level" (i.e. "traditional") topics, which should, however, be combined with new application areas to produce "high level" products.

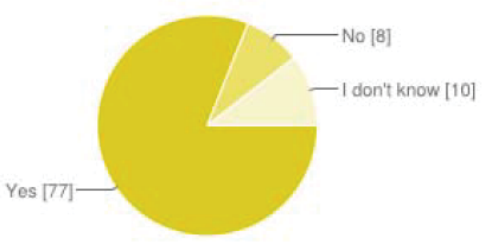
The position of university lecturers, alumni and employers from industry regarding the way universities should work and the content of curricula is a mixed one, which reflects the impact of individualism and locality.

A SURVEY STUDY CONNECTED WITH THE FETCH PROJECT

In the context of the European Thematic Network FETCH (*Future Education and Training in Computing: How to support learning at anytime anywhere* [9]), three surveys were implemented within Work Package 3. Each survey was directed to a different category of respondents, namely *Professors* (i.e. people involved in teaching activities in universities and/or higher institutions), *Alumni* (i.e. former students, especially those who graduated – either bachelor's or master's degrees – in the last few years) and *Industry Representatives* (i.e. employers or workers of companies in some way connected with the computing field). The specific fields taken into account are Computer Science (CS), Computer Engineering (CE), Software Engineering (SE) and Information Systems (IS). The survey was very extensive and included several sections, but here we will consider

only the questions related to university curricula and their possible improvement. Although we are aware that the data gathered through the questionnaires are limited and cannot be generalized (we received 95 answers from Professors, 69 from Alumni and 35 from Industry Representatives), we think that they can be useful for an informal analysis.

According to the answers provided to the Professors questionnaire, most respondents (81%) think that international standard curriculum guidelines should be extensively applied to define university curricula in the areas of CS, CE, SE and IS (Figure 3), mainly (about 65%) because it is important that all students in all countries acquire



Yes	**77**	81%
No	**8**	8%
I don't know	**10**	11%

Figure 3. Professors questionnaire: "Do you think that international standard curriculum guidelines should be extensively applied to define university curricula in the areas of CS, CE, SE and IS?"

comparable competencies.

The analysis of the Professors questionnaire showed also that possible courses or changes that should be included in CS, CE, SE and IS curricula, in order to enable them to better meet current and future needs of industry, include:

- Cloud Computing
- Mobile Software Development
- Computer and Information Security
- Big Data
- Web Programming and services
- (Considered less relevant) Agent-based Programming, Algorithms, Computer Science and Economy, Ethics and Laws, Functional Programming, Game Programming, Professional Java Programming and Social Media

Alumni answers about their current jobs threw light on the nature of occupation, i.e. on market requirements:

- Software developer
- Lecturer/Teacher
- Administrator/Coordinator
- Consultant
- Project manager
- Researcher
- Commercial/Marketing
- Manager
- Mobile developer
- Data analyst
- Database administrator
- Software analyst
- Web developer
- Application Engineer

Overall, former students who answered the Alumni questionnaire seemed to be satisfied about the preparation they received from university. Figure 4 shows the extent to which respondents agreed on the fact that university programs prepared them well for their current jobs.

When asked to suggest, based on their professional experience, any courses or changes that should be included in CS, CE, SE or IS programs in order to enable them to better meet current and future needs of industry, the answers of Alumni can be summarized as follows:

- Interpersonal relations, communication skills and soft skills
- Web technologies
- Mobile technologies
- Entrepreneurship and enterprise patterns and principles
- (Suggested by single respondents) Advanced oftware engineering and programming, Applied statistics, Business intelligence and Data mining, Change management, Client-side Web programming, Human-Computer Interaction, Information systems software (such as SAP), IT Project management, Law and business systems, Sales of IT products

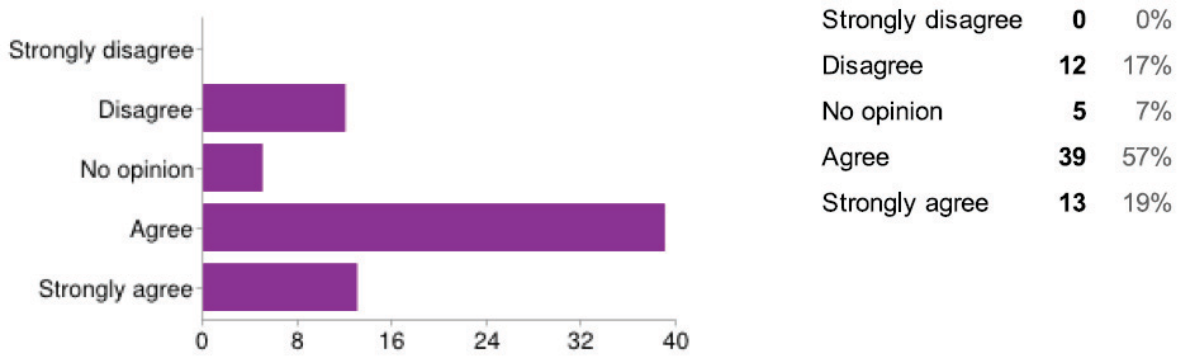


Figure 4. Alumni questionnaire: how much do you agree on the following statement "University programs have prepared me well for my current job"?

The top five courses that have mainly helped Alumni in their job (for each one of the four computing areas considered) are:

Computer Science

- Programming languages
- Algorithms and complexity
- Software engineering
- Software Development fundamentals
- Operating systems

Computer Engineering

- Algorithms
- Database systems
- Computer architecture
- Programming fundamentals
- Software engineering

Software Engineering

- Software design
- Software modelling and analysis
- Software management
- Software processes
- Software quality

Information Systems

- Systems analysis and design
- Data and information management
- IT project management
- Foundations of information systems
- Enterprise architectures

Although Industry Representatives were generally satisfied with the preparation level of their employees (Figure 5), their point of view was a little different from that of Professors and Alumni, as they stressed the need for specialists in:

- Object Oriented programming languages
- Communication and social skills
- Agile methodologies
- Design patterns
- English speaking and writing
- Mobile technologies
- Practical skills
- Project management
- (Suggested by single respondents) Agent-based programming, Databases, E-learning technologies, Ethical issues, Industry software solutions, Mathematical skills, Networking, Operating systems, Problem definition and modelling, Software engineering, Staying Up-to-date in technology, Strong theoretical grounding in computing subjects and Web technologies

Looking at the answers provided by respondents when asked to suggest any courses or changes that should be included in CS, CE, SE or IS programs to improve them, Professors, Alumni and Industry Representatives all cited *Programming skills* (especially with object oriented languages), *Web technologies* and *Mobile technologies*. Moreover, Professors and Alumni also mentioned *Big data*/*Data Mining* and *Information Security*.

The above presented combination of topics may serve as a "kernel" for recommendations of IT curricula. In order to achieve this objective, however, it is necessary to consider that:

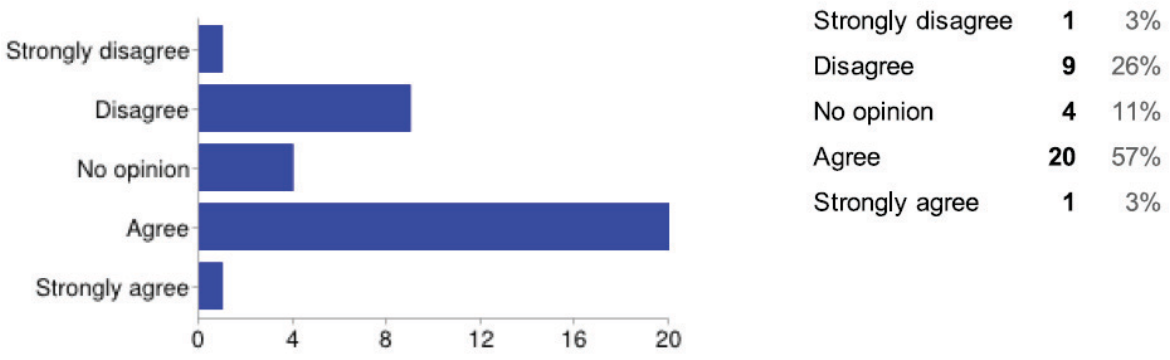


Figure 5. Industry Representatives questionnaire: how much do you agree on the following statement "University programs have prepared employees well for their current job"?

- The provided answers failed to cover all promising topics (at least according to the trends discussed in the previous section), excluding, for example, intelligent embedded systems (the core of the Internet of Things);
- Part of promising topics such as Big Data and Cloud systems are mostly a combination of traditional topics like Data mining, Pattern Recognition, Artificial Intelligence, Grids, Virtualization, etc.;
- Recommendations should offer the right elasticity to be applicable in different contexts, considering local differences in culture and economic development.

SUGGESTIONS FOR THE INTEGRATION OF RECENT RELEVANT TOPICS IN EXISTING STANDARD CURRICULUM GUIDELINES

The European Strategic Framework for Computing Education and Training 2020 (ECFCET 2020) [10] created within the FETCH network defines the strategic objective "Improving ICT education content quality by curricula enhancement". One of its priority areas proposes the adoption of international standard curriculum guidelines, and in particular it states that:

- The reference standard curriculum guidelines for bachelor's programs should be:
  - CS2013 [11] for Computer Science (by ACM and IEEE Computer Society)
  - CE2004 [12] for Computer Engineering (by ACM and IEEE Computer Society)
  - SE2004 [13] for Software Engineering (by ACM and IEEE Computer Society)
  - IS2010 [14] for Information Systems (by ACM and AIS)

- The reference standard curriculum guidelines for master's programs should be:
  - GSwE2009 [15] for Software Engineering (by iSSEc)
  - ACM-AIS Information Systems 2006 [16] for Information Systems (by ACM and AIS)

No official curriculum guidelines for master's programs in Computer Science and Computer Engineering are currently available.

A second priority area of the above mentioned strategic objective suggests the integration of recent relevant topics in existing standard curriculum guidelines, and in particular it states that special emphasis should be put on:

- *Web technologies*, which pervasively characterize the current computing scenario. The ability to create static and dynamic websites (using both client- and server-

side technologies) should be a strict requirement. Moreover, design issues related to usability, accessibility and device independence should be dealt with.

- *Mobile Technologies*, whose diffusion is exponentially increasing due to the availability of powerful and relatively inexpensive devices. The ability to create at least basic mobile-oriented applications should be a strict requirement.
- *Big Data*, Business Intelligence and Data Mining, as a consequence of the exponential increase of the amount of data produced nowadays. The capability of students to understand and use advanced data processing tools is a growing requirement in the market.
- *Cloud Computing* and *High Performance Computing*. There is an increasing demand for computational resources due to the rich set of new applications being developed every day. Most of these applications require resources which are available in the cloud only. In this context, high performance computing and cloud technologies are two faces of the same coin: the necessity for high computational resources.
- *Information Security*, as a consequence of the widespread use of Web and Mobile Technologies. Information storage on the Internet is becoming as common as traditional storage on physical devices, or even more. It is desirable that computing curricula include courses explicitly oriented towards the management of big amounts of data spread in the Internet, as well as towards their secure supervision.

CONCLUSIONS

In this paper we focused on the context and main drivers of one of the key objectives of the European Strategic Framework for Computing Education and Training 2020 (ESFCET 2020), that is "Improving ICT education content quality by curricula enhancement". Evolution of computing curricula towards timely technological targets needs to be based on well-established resources and approaches such as:

- Standard curriculum guidelines by international organizations (such as ACM and IEEE Computer Society) and the ACM Computing Classification System;
- Long-term European and national policies;
- ICT jobs market monitoring and extrapolations;
- Gartner's Hype Cycle for Emerging Technologies;
- Periodic surveys among key stakeholder groups in computing (Professors, Industry Representatives and Alumni).

One of the key outcomes of the presented approach is a set of recommendations concerning computing curricula guidelines and their integration with recent relevant topics.. These aspects have been incorporated within the priority areas of ESFCET 2020. Moreover, the modular structure of ESFCET 2020 makes it easily extensible – for example, with the addition of the TIOBE *Index of Programming Languages* [17].

A still broader perspective on improving ICT education processes is offered by two further strategic goals of ESFCET 2020, which focus on "Stimulating novel educational modalities, didactic approaches and models" and "Implementing an ICT education responding to qualitative and quantitative needs of European ICT employers".

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