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Software Engineering at PhDs: Societal Challenges, Technology Trends and Educational

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Software products, services, systems as well as the wide eco-system, the system of software-intensive systems, are the essence and the pillars of the digital economy and businesses today. The entire society and human life depend heavily on this worldwide eco-software system and the digital world it created. Without software systems, almost nothing from home appliances to travel and trade can work properly today. For example, IEEE Software's department editor Grady Booch reflects in his talks on the increasing responsibility of software engineering professionals in not only in the creation of software, but in a fundamental role in societal and ethical matters. As human endeavors from war to culture begin to involve software, so will software engineers be involved in this matters as well.

Software engineering emerged as a discipline at the crossroads of engineering, computer science and management. It has been defined by pioneers' research such Boehm as "the establishment and use of sound engineering principles (methods) in order to obtain economically software that is reliable and works on real machines", and SWEBOK defined SE as "the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software." The following are definitions that highlight the diverse perceptions of the software engineering by different communities:

- The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software. (2) The study of approaches as in (1) (IEEE Standard 610-1990).
- Software engineering is the technological and managerial discipline concerned with systematic production and maintenance of software products that are developed and modified on time and within cost estimates (Fairley, R. Software Engineering Concepts. New York: McGraw-Hill, 1985).

SEI software engineering definition from 1990 SEI Report on Undergraduate Software Engineering Education (CMU/SEI-90-TR-003):

- Engineering is the systematic application of scientific knowledge in creating and building cost-effective solutions to practical problems in the service of mankind.
- Software engineering is that form of engineering that applies the principles of computer science and mathematics to achieving cost-effective solutions to software problems.

In a special issue of the IEEE Software (Jan/Feb 2016 software engineering education was reported as one of the key challenges that the profession will face in the future. The software engineering community will need educators to train the millions of software developers that

are needed for developing and maintaining software systems. These educators, young researchers who will eventually end up software engineering professors, in turn need to be educated. PhDs programs are where this will occur systematically.

Programs in software engineering are recent compared to computer science programs and other related engineering programs. Accredited Bachelors in software engineering in North America can be traced in the early 2000. Most often, software engineering has been introduced as a track or a niche of specialization in computer science programs. PhD programs that are devoted specifically to Software Engineering are rare as of now despite the increasing need for them.

Educational programs in software engineering cover a large spectrum of topics. SWEBOK, the Software Engineering Body of Knowledge created by IEEE, defined 15 areas of knowledge. Beyond the technical perspective, software engineering education should also include a specific training on what are called soft skills, communication, team work as well as professional practices and ethics. Education at the PhD level also includes training on the creation of new knowledge, which involves research methods and tools, technical writing and communication, and the development of an academic portfolio.

Software engineering education at a PhD level is practically oriented and the candidates learn by doing, participating in research with more experienced researchers. For PhD level education, a research facility and a lab are essential. Large universities can cover a wide range of topics and provide PhD candidate with the infrastructure they need in research and education. By contrast, most of the time the field software engineering of software engineering in small universities relies on the expertise of a few professors in narrow sub-disciplines of software engineering. In emerging countries, this situation is complicated by the lack of adequate equipment and in some cases the lack of established tradition of research. These observations were the initial motivation for the book – to compile, advance and publish knowledge on software engineering education to promote quality education that will address the needs of the society and the professional community.

This edited volume investigates the current status of software engineering education at the PhD level. Questions we explore and answer with a pool of international experts include:

- What are the existing SE programs? What is the structure of the program, the most common courses and topics covered in those programs?
- What PhDs should know by the time they complete their PhD studies and what we should teach and provide during the PhD?
- What is the structure of the PhD programs? Pure programs or combined with something else?
- What are the learning strategies used at PhD level education?
- How emerging countries are creating their own PhD programs in software engineering and what are their unique challenges?
- How to combine SWE and related fields aspects at PhD level, such as SWE management practices and
- How to enable combining the unique strengths of various programs provided by diverse universities in different continents
- How ICT and especially social media and computer-supported collaboration can be used in SE education at the PhD level especially the education by research approach

The book answer these questions. It combines the results from an Erasmus+ project on developing software engineering PhD level education with the point of views of experts on the topic from abroad.

The book is useful for diverse audience, including PhD students, educators, administrators and professionals in the wider field of software engineering. We foresee the groups listed below benefiting from this book:

- For academic researchers in software engineering and computer science education, it is an essay on the state of arts status and the future of software engineering education
- For professors and PhDs enrolled in software engineering research and development, the book provides an in-depth overview of what software engineering education should be and how it works elsewhere
- For university administrators and PhD programs managers, the different chapters are a road map for the creation or development of a software engineering PhD program
- For industry professionals, the book is particularly useful for large companies that have research teams, or that are engaged in joint research projects with an academic entity.
- For public accreditation authorities and standardization organizations, the book can supplement (showing the ways) the existing SWEBOK in providing how this standard can be used for Ph.D. education

To a certain extent, the book will also benefit master's students and anyone interested in software engineering education and PhD studies in general.