

# Preparing Next Generation of Software Engineers for Future Societal Challenges and Opportunities

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## ABSTRACT

As a global community we are facing number of existential challenges like global warming, deficit of basic commodities, environmental degradation and other threats to life on earth, as well as possible unintended consequences of AI, nano-technology, biotechnology, and similar. Among world-wide responses to those challenges the framework programme for European research and technological development, Horizon 2020, have formulated the *Science with and for Society Work Programme*, based on *Responsible Research and Innovation* with a goal to support research contributing to the progress of humanity and preventing catastrophic events and their consequences. This goal may only be reached if we educate responsible researchers and engineers with both deep technical knowledge and broad disciplinary and social competence. From the perspective of experiences at two Swedish Universities, this paper argues for the benefits of teaching professional ethics and sustainable development to engineering students.

## Categories and Subject Descriptors

K.3.2 [Computers and Education] Computer and Information Science Education

## General Terms

Theory.

## Keywords

Social Software Engineering, Responsible Research and Innovation, Engineering Ethics, Research Ethics, Computer Ethics, Sustainable Development, T-shaped Engineer.

## 1. INTRODUCTION

*"The global community is facing Grand Challenges. The European Knowledge Society must tackle these through the best analysis, powerful actions and increased resources. Challenges must turn into sustainable solutions in areas such as global*

*warming, tightening supplies of energy, water and food, ageing societies, public health, pandemics and security. It must tackle the overarching challenge."* The Lund Declaration, 2009 [1]

Our time is often characterized as the *age of complexity*. Increasing capability to deal with complexity is a direct consequence of the development of computing machinery and the ability to program it. Ubiquitous use of information processing (computational) devices that are programmed to control, predict or simulate variety of processes enables us to face complexity and better understand and anticipate the behaviors of complex systems. There is however a significant difference between calculating offline a mathematical function "in abstracto" and controlling a paper mill in practice. The difference is in level of complexity, context dependence and social embeddedness of technological solutions for practical problems.

However, education of new generations of software engineers often focus on training abstract skills without careful consideration of the role of embeddedness of technology into context. It shows considerable inertia when it comes to introducing new views of computing and in particular new understanding of how in the best way software engineer can prepare for his/her future professional work in the real-world context of application and its different aspects, especially social side of it. Recently this aspect of research and innovation attracted considerable attention, through the notion of *Responsible Research and Innovation (RRI)*, [2-4], defined as:

*"a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)." Von Schomberg [2]*

This requirement and expectation of responsible research and development is connected to the concept of the *Triple Helix*, where universities stand for knowledge that is applied in industry in accordance with societal needs. The university-industry-government mutually interconnected relationships in the form of triple helix are described in Leydesdorff [5], and Ranga and Etzkowitz [6], that capture the transition from an industry-government relation characteristic for the industrial society to an increasingly tripartite relationship between industry-government-university in the emerging data-information-knowledge society.

The expectations are increasing for integrative, responsible research and innovation, aligned with societal needs through challenge-driven research and innovation, where scientific progress is connected to the sustainable development. The novelty in this approach is that societal involvement is present during the whole process, which is particularly important for the ICT,

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biotechnology, robotic, nanotechnology and similar emerging fields.

Societal challenges for the framework for European research and technological development Horizon 2020 are formulated in the *Science with and for Society Work Programme*, which is meant to “help build effective cooperation between science and society, to recruit new talent for science and to pair scientific excellence with social awareness and responsibility” (Science with and for Society Work Programme 2014-2015). This new approach encourages all stakeholders (involved citizens, researchers, business, policy makers, etc.) to interact throughout the research and innovation process and to coordinate and align both the process and its outcomes with societal values and needs, in accordance with Responsible Research and Innovation (RRI).

Process includes identification and prioritizing of research and innovation goals, accountability, values and transparency, where products are in accordance with societal values and needs (such as sustainability, safety, privacy, equity, diversity, etc.)

## 2. ORGANIZATIONAL ADAPTATION IN THE ERA OF COMPLEXITY AND CONTINUOUS CHANGE

As a consequence, on a systemic level there is a necessity of defining *social/organizational responsibility* in addition to customary *personal responsibility* [7]. We should take into account both intended and unintended consequences of research and technology in a preferably *anticipatory and learning process* that will in the first place prevent incidents and accidents and in the worst case *mitigate* their consequences, [8-13]. Present day dominantly *reactive policies* must be replaced by *anticipatory practice* based on scenario analyses, and foresight grounded in experiences (social learning) collected on a systemic level [7].

The dominant underlying structure of contemporary global society is its organisation in networks of networks of interacting agents. Each individual belongs to a variety of networks, which define their different roles as stakeholders in various aspects of research and technology. In this context complexity and trans-disciplinarity /inter-disciplinarity comes as an important aspect of research and development.

This new triple-helix type of relationship between research, society and industry/business necessitates *shared* ability of a broader view – socially aware researchers, engineers, citizens, politicians and businessmen. Interdisciplinary literacy and inclusion of “soft” aspects that promote pro-social value systems are becoming necessary.

To start with, the new understanding of the role of research and innovation as defined in Responsible Research and Innovation (RRI), Von Schomberg [2,3] must permeate education in the first (Bachelors), second (Masters) and third (PhD) cycle programmes. One of important components of the development of RRI is to educate engineers with shared professional goals and value systems.

## 3. THE UNIQUENESS DEBATE AND ENGINEERS TEACHING ETHICS

Even though ethics has an essential socio-cultural dimension the *basic principles* of ethics are constant, no matter in which area they might be applied. Thus the *fundamental principles* of medical ethics, legal ethics, and computer ethics are not different from one another. However, new situations related to the computers do

raise new questions about *how* these principles are to be applied, phenomenon defined by Moor [14] as *policy vacuum* (that is the lack of previous experiences of similar situation and absence of best practices and policies) as elaborated in Johnson [15], Tavani [16] and Barger [17]. The important question was raised whether ethics of computing/ computer science/ software engineering is *unique* or simply an application of general ethical principles, known as the *uniqueness debate*. The notion of *uniqueness* is based on the comparison. Similarity and difference are *relative concepts*. *Uniqueness* is a matter of focus and context. Looking at the set of all possible ethical problems, different patterns can be recognized permitting their grouping into medical ethics, political ethics, environmental ethics, business ethics etc. The criteria for grouping problems within certain fields are several, and one of them is the *importance* of the ethical problem. The other is its specific and *unique* character. Moreover, Tavani [16] argues that the computer ethics issues are both philosophically interesting and deserving our attention, no matter whether those issues are unique ethical issues.

As a consequence of the uniqueness debate predominant understanding have emerged that ethics of computing/ computer ethics/ engineering ethics are unique ethics fields founded and lead by engineers and computer scientists with interests in ethics (such as J. Moore, H. Tavani, K. Miller and many others) and the opinion prevailed that it would be appropriate for engineers and researchers to teach courses in the subject.

## 4. EXPERIENCES FROM PROFESSIONAL ETHICS COURSES AT MÄLARDALEN UNIVERSITY

In the year 2003 I have developed the first course in Professional Ethics at Mälardalen University, intended primarily for Science and Engineering students, especially within CS, SE and Robotics. Its outline was based on equivalent courses at other universities worldwide. The course has been taught continuously since then for the first, second and third cycle programmes. The emphasis is on *cultivating ethical sensibility*, the development of *moral autonomy*, *ethical pluralism* and *critical thinking*.

Course includes lectures, with guest lectures given by researchers or practitioners with relevant experiences, individual presentations of students on the approved topic of interest, class discussions, and mini-conference where research papers are presented. Students are expected to write class notes containing their own reflections in connection to each lecture. Results of experiences with those courses have been published in a number of publications; where [8] is presenting social, ethical, and professional issues of computing curricula, [9] argues for the importance of teaching professional ethics to computer science students, [10] discusses professional ethics in software engineering curricula, while [11] focuses on professional ethics in computing and intelligent systems. References [19]-[25] are articles written in collaboration with my students who participated in Professional Ethics courses.

At present, course is given as a PhD course. It provides an insight into the ethical problems important for professionals in Engineering and Science. It forms a framework in which professional and ethical issues can be analyzed, and builds up an awareness of various views of ethical issues as well as the ethical responsibilities of professionals. The topics include, among others, the social context of a profession, conflicts between loyalties to different principles such as safety and economy, precautionary principle and environmental impact, integrity,

privacy, ownership, etc. Fundamental moral theories are presented as the introductory part of the course.

We discuss Codes of Ethics (such as IEEE, ACM, Responsible Conduct of Research, SE Code of Ethics), and examine a series of case studies, which have led to ethical problems. At the same time we develop critical thinking and argumentation techniques.

Number of articles produced in the course since 2003 have been published at international conferences, journals and as chapters in Licentiate and PhD theses.

In sum, our experiences of the course have been very positive. Students have participated actively in discussions, case studies and research on chosen topics. Even predominantly technically minded students were able to assimilate and use ethical concepts and develop ethical argument. The examination forms for the course are the writing of a research paper on an ethical topic of interest and an oral presentation of a chosen topic (such as safety, security, intellectual property, environmental ethics, privacy and personal integrity, etc.) followed by an in-class discussion led by the students responsible for the actual presentation. Course evaluation results show that students experienced the course as useful and relevant for their future professional activities.

Three industrial PhD students have included their articles written in the course as specific chapters on ethical aspects of their thesis work: Larsson M. [23], Larsson S. [24], and Kade [25]. One more Phd Student, Jägemar [22] is planning to do so. They have investigated ethical consequences of software testing practices, effectiveness of the software development teams related to different ethical attitudes, ethical aspects of motion capture and ethical and cognitive sustainability aspects of mobile devices. A number of other students have published their articles written in the course on professional ethics in international journals and at CEPE and E-CAP conferences.

A more detailed description of professional and ethical issues of software engineering curriculum applied in Swedish academic context of Mälardalen University can be found in [12]. Apart from the courses in professional ethics we also included Professional Ethics lecture as a part of courses in Research Methodology and Computing and Philosophy [13]. In hindsight, we can argue that ethics courses provide considerably better and more long lasting effect in teaching social aspects of engineering, than isolated lectures on ethics in other courses, which inevitably bring a lot of repetition and never reach necessary depth and scope.

## 5. COURSES IN ETHICS AND SUSTAINABLE DEVELOPMENT AT CHALMERS UNIVERSITY OF TECHNOLOGY

Interesting to mention, at the Software Engineering in Society (SEIS) track of the recent ICSE 2015 conference question was discussed about how many institutions, that participants were affiliated with, have courses teaching social aspects of software engineering, and specifically how many ethics courses. Surprisingly, there were very few such courses. If the vision of RRI is to become reality, there should be adequate education in social aspects of software engineering in all cycles of education.

The Swedish Higher Education Authority requirements that are defined in the Higher Education Act, include three qualitative targets for all courses and programmes: *knowledge and understanding, competence and skills and judgment and approach*. Courses in social aspects such as courses in ethics and

sustainable development are definitely contributing to the category of *judgment and approach* with their explicit focus on values and broader societal context of research and engineering.

Some of the important questions when including social (and in particular ethical) aspects in engineering education are: Should ethics be a part of other courses (one lecture in every course, like Ethics and Cyber-Physical Systems) or should it be taught as a separate course? Would it be better if professional ethicists and philosophers (or environmental professionals in case of sustainability) would be engaged to teach courses like professional ethics or sustainable development, respectively, instead of professionals in computing? I would like to argue, based on the outcome of the *Uniqueness debate*, and formulations in *Social and Professional Issues in Computing Curricula 2103* [26], that we engineers and researchers can and should be teaching social aspects of engineering, including ethics and sustainable development, to our students. It requires an initial effort, but experiences show that it is possible to do appropriately.

The development and implementation of the third cycle course Research Ethics and Sustainable Development at Chalmers University of Technology can be instructive in this context. The course is compulsory for all PhD students at Chalmers and consists of lectures with in-class discussions, guest lectures and group work, including peer review of individual essays that present each participant's thesis research project from the perspective of research ethics and sustainable development. As a framework as a basis for discussions we provide ethical review protocol with a list of possible ethical concerns and instructions on stakeholder analysis. Essays are discussed in groups and presented at a mini-conference at the end of the course, both individually (in a form of lightening talk) and then also in a group, which analyses individual essays on a more general level, searching for commonalities and differences, patterns and possibilities for improvements. Essays are written so that they can be published as a part of a PhD thesis. Present course that is centered around individual PhD research projects is a result of the development of a previous version of the course where group work consisted in discussion of specific general topics such as diversity, equity, publishing ethics, etc. Our experiences indicate that students show much more interest and engagement when starting from their own work and then critically think and relate to the research of their colleagues then when discussing in abstracto.

## 6. CONCLUSIONS

*"With respect to system thinking, a T-shaped person is one who has technical depth in at least one aspect of the system's content, and a workable level of understanding of a fair number of the other system aspects. Many pure computer science graduates are strongly I-shaped, with a great deal of depth in software technology, but little understanding of the other disciplines involved in such areas as business, medicine, transportation, or Internet of Things. This leaves them poorly prepared to participate in the increasing numbers of projects involving multi-discipline system thinking."* [18]

Boehm and Koolmanojwong Mobasser [18] address the necessity of the system thinking and educating of T-Shaped software engineers, which includes social aspects of software engineering.

*The Science with and for Society Work Programme*, with the requirement of Responsible Research and Innovation are supporting research process and products of research that will contribute to the advancement of humanity and avert catastrophic events or in the worst case mitigate their consequences. They

necessitate education of engineers with developed sensitivity to social aspects of engineering, including courses on research and engineering ethics and sustainable development.

This paper offers positive experiences from two ethics courses given at two different Swedish universities – Mälardalen University and Chalmers University of Technology, developed and taught by the author.

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