The Need for Soft Skills for Ph.D.'s in Software Engineering*

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ABSTRACT

Ph.D. students within the area of Software Engineering often work in very confined and focused subareas. However, studies show that if the Ph.D. student aims at working in industry later on, the need for the so-called soft skills is high. This paper concludes on two surveys made to understand whether Ph.D. students within the 'Erasmus +' project Joint Programs and Framework for Doctoral Education in Software Engineering perceived the soft skills to be of importance for them to learn. The conclusions are that the students are aware of the soft skills but often do not consider it to be of importance to formally train these.

CCS CONCEPTS

•Software and its engineering •Software creation and management •Collaboration in software development •Programming teams

KEYWORDS

Global Software Engineering, Ph.D. Training, Soft Skills

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1 Introduction

Over the past decades, software development with distributed teams across a region, country, or around the globe has become an established pattern named Global Software Engineering (GSWE) (Hawthorne and Perry, 2003; Monasor, et al., 2010). With some benefits such as reduced time and cost of development due to "follow the sun" strategy, GSWE also presents several types of challenges associated with geographical, temporal, and socio-cultural distances (Hoda et al., 2017; Ågerfalk et al., 2005; Lanubile, et al., 2003). As GSWE is a relatively new model of software development, most of practice software engineers usually do not have the required experience of working in global teams, hence they usually face a large number of problems in GSWE arrangements some very similar to the challenges seen in outsourcing of projects (Smite et al., 2010).

GSWE is not still specifically taught in University degree Software Engineering, so firms are forced to train SWE professionals directly in GSWE work environment. Therefore, it has become important for academic degree programs to train their Software Engineering graduates for working in GSWE settings. Due to the increasing popularity and reported challenges of GSWE, some academic institutes have started to offer GSWE courses, the level of which can vary widely, depending on the target audience and the level of course complexity (Fortaleza, et al., 2012). Most of such courses incorporate project-based work (Doboli, et al., 2009) and soft skills training, such as cultural sensitivity and working in a team (Monasor, et al., 2010; Richardson, et al., 2009).

The purpose of this paper is to conclude on what expectations and views Ph.D. students in SWE area have to the soft skills they need to acquire to enter the demands initiatives such as GSWE. This is done through a case study of a project in which international group of Ph.D. students have classes in traditional Software Engineering areas but also in methods for obtaining soft skills, following earlier reported surveys (Gadasina et al., 2016; 2017).

The case study was related to the 'Erasmus +' project Joint Programs and Framework for Doctoral Education in Software Engineering, PWs@PhD (Knutas at al., 2017), that has the purpose to develop guidelines for target countries such as Russia and Jordan with respect to setting up programs for Ph.D.s in Software Engineering. The project works through production of content and material on 7 areas of knowledge related to the SWEBOK (Bourque et al., 2014) and it defines a set of courses to potentially include in a Ph. D. program. As part of these courses, soft skills are taught by use of Problem Based Learning method (Askehave et al., 2015). With 11 universities partners distributed over 6 countries, the PWs@PhD has held 7 intense courses in areas such as for example math and computing, human computer interactions, engineering methods and tools, business perspectives and Problem Based Learning[1].

The intense schools were organised through two weeks of training in one field with Ph.D. students from the partner countries

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[1] fase.it.lut.fi

CEUR-WS.org/Vol-2256/SWEPHD18_paper_03.pdf

(Russia, Jordan, Finland, UK, Germany, Denmark) and Ph.D. students could participate in one or several of the schools dependent on their interest and availability. The schools have been running over the three years from 2015 to 2018. The peculiarity of this group of Software Engineering students is a high level of training in the specialty, i.e. in the field of hard skills. This is usually the result of individual long-term work in basic university with the scientific adviser in a narrow field of research and development. This means that a number of the students lack soft skills which are demanded in industry and through international cooperation.

The paper has the following sections. In section 2, the concept of soft skills is described in more detail as a background. Section 3 describes the methodology of the paper. Section 4 includes a description of the survey carried out and the analysis made of the results. In section 5, the conclusions are presented.

2 Soft Skills for Software Engineering

For a software developer in Microsoft, a number of soft skills are required (Orsted, 2000). Amongst others Orsted (2000) points to skills in change-management, stress management, problem solving skills, self-development, communication and interpersonal skills. Also, in Sedelmaier et al (2014) it is stated that "soft skills are equally important" for a software developer to accomplish the needs of modern teamwork and communication with stakeholders. Generally, soft skills are seen as the complementarity of technical skills when referring to software engineering (Ahmed et al, 2012). This includes personality traits, attitudes that drive the persons' behaviour and competences in interacting with peers in teamwork.

The traditional worldwide view of the set of competencies required for software engineers assumes the mandatory study of technical, or hard skills as the baseline. In the most general case, these are STEM subjects and programming. It is known that in countries seeking to dominate the field of information technology but lacking qualified personnel in high-tech areas such as China, STEM education has recently become more popular (Wolfe, 2018). However, it turns out that these competencies are not enough at higher levels of software development management (Wheadon & Duval-Couetil, 2014). The research Project Oxygen conducted by Google in 2013 (Strauss, 2017) showed that among the eight most important qualities of the best Google managers seven are soft skills, and all the competencies of the STEM group are in the last eighth place. In 2017 another study by Google (Project Aristotle, Strauss, 2017) showed that the best teams in high-tech environments demonstrate many Soft Skills, among which emotional safety dominates.

A systematic approach to the study of this phenomenon was applied in the study of the University of Washington (Li et al., 2015). In this study, 59 leading executives and developers from 13 departments of Microsoft identified a variety set of 53 characteristics, which definitely should be attributed to soft skills. At a high four levels they are following: Personal Characteristics (improving, passionate, open-minded); Decision Making (sees the forest and the trees, knowledgeable about people and the organization, update mental models, handling complexity); Engagement with Teammates (creating shared context, creating shared success, creating a safe haven, honest); Software Product (elegant, creative, anticipating needs).

Russian universities have thoroughly elaborated methods of teaching hard skills, created State Educational Standards and educational programs in their specialties (Terekhov, 2001; Taran et al., 2007; Khalin et al., 2017). Methods of mastering soft skills at different educational levels have appeared for a long time; however, in the universities of Russia they have not yet received system development. The most effective of them, in our opinion, are various types of project and problem-based learning (PBL) that are actively used in Western European universities, including inverted class and peer-to-peer technologies (for example, French École 42 and Danish Aalborg University).

PBL is a learner-centred pedagogical methodology in which students are assessed on their ability to go through a problem-solving process usually based on real-life situations (Askehave et al, 2015). Several authors (Capraro, 2013; Freemen, 2014) confirmed in their studies the benefits of PBL for STEM students such as: considerable improvements in critical, lateral and creative thinking, problem solving strategies intrinsic motivation, entrepreneurship, group collaboration communication skills, and collaboration with society.

3 Methodology

Very little research has been carried out to understand the views of the students themselves about the skills they need acquire for future work, and almost none asked opinions of Ph.D. level students specialized in Software Engineering. This paper extends and is based on earlier works by Gadasina et al (2016, 2017) reporting on surveys made with a group of 31 high level Ph.D. students who are currently engaged in the doctoral programs in Software Engineering at the international PWs@PhD Project. In both surveys, the students were asked about their views towards acquiring soft skills as part of their future work competence. In Gadasina et al. (2016) processing and statistical analysis results of the written survey allowed identifying groups of the most significant for student's professional skills for future work; to find out the Ph.D. students level of knowledge and mastering these skills; to evaluate the student's intention to obtain them.

At the very beginning of the 21st century three largest software and hardware companies Microsoft, Cisco and Intel set up an 'XXI Century Skills' Project[2] to develop a new educational system because they were concerned that universities were not producing graduates that could fit best into the digital work places and the new manufacturing system. In a short time, researchers of education from all over the world define what was meant by XXI century complex skills, such as a collaborative problem solving (Kozma and Voogt, 2003; Trilling and Fadel, 2009). The 'XXI

[2] http://atc21s.org

Century Skills' framework postulates that as the share of manual and routine cognitive labour is declining, and of no routine cognitive labour increases now, education process should be reformed to provide students with skills more appropriate in the new economy. Right now, the project is at the stage of being able to define a template that allows those sets of skills to work. That's why in the second stage of the study (Gadasina and Voitenko 2017) the 4 groups of skills from the 'XXI Century Skills'Project were selected as basic soft skills and were explored the importance of owning them the same international group of 31 Ph.D. students who received Software Engineering training in the PWs@PhD Project..

These four groups of XXI Century Skills are*: Ways of Thinking* (effectively reasoning, critical and systems thinking, judgement and decision making, problem solving, creativity, innovations implementing, learning to learn); *Ways of Working* (communication, collaboration, teamwork); *Tools for Working* (media-, information- and ICT-literacies); *Ways of Living in the World* (flexibility and adaptability, initiative and self-direction, productivity and accountability, leadership and responsibility, social and cross-cultural skills). First two groups of XXI Century Skills compose Learning and Innovation skills. Presence of these skills separates those students who are prepared for increasingly complex life and work environments in modern fast changing world. The descriptions of the skills according universal list from the website of the Partnership for the skills of the 21st century[3] were incorporated into the text of the questionnaire at the request of the respondents. In survey the students were asked two key questions for every skill from the all 4 groups:

(1) Please rate your overall level of mastery that you have achieved during training at the university in the skills below;

(2) Please rate how likely it is that you take part in training the skills below, if it were available to you as part of your high school program of education.

4 Results

As mentioned, two surveys have been carried out to understand the students' perception of their needs in soft skills. In the study by Gadasina et al. (2016) the list of skills named and ranked by students was compared with a list of skills required by employers in the areas close to the Software Engineering. According to the Burning Glass Technologies report, in 'Project Management, Research and Strategy Cluster' of required skills "research, project management, negotiation and analytic skills are in particular demand among high-skill, high paying jobs in families such as management and research. These jobs have experienced wage growth and expanded employment opportunities in recent years." (Burning Glass Technologies, 2015).

The skills of this cluster, such as managing project, research methods and negotiation, have the highest evaluation scores in students list of desired skills as well. In general, correlation between the ranked sets of skills mentioned by students and required by employers in the area of 'Research, Planning and Analysis' is equal to 0,41 (Gadasina et al. 2016). This result show that, despite that complete lists of skills required by employers and desired by students differ considerably, Ph.D.-students quite well understand the basic soft skill sets necessary to engage in higher positions corresponding to level of their qualification. See details in Appendix A.

In the second survey described in more detail in (Gadasina and Voitenko 2017), a somewhat different approach was gained. For every 4 group of XXI Century Skills the difference between the scores of the answers to the question (2) and to the question (1) (i.e. 'What skills I would like to train?' mines 'What skills I really mastered in my University?') was calculated.

The results were subjected to statistical and cluster analysis. Cluster analysis was carried out by the modified method of Ward with Manhattan distance for each of these two questions. Two clusters were discovered to be statistically significant for all four groups of XXI Century Skills. These clusters can be conditionally called 'acting students' and 'dormant students'.

Statistical analysis showed, that maximum value of residuals (+0,89) in the first Ways of Thinking group is for Implement Innovations skills, with that such kind of skills is absent in the list of skills elaborated by this group members themselves. It may mean students do not see innovations in pedagogical process at their universities, and it could be supposed that attention to Implement Innovations skills are absent in University courses. However, it does not mean that they are on big demand on the labour market for Software Engineering positions.

A high need for mastering Creativity and Decisions Making skills (+0,64 & +0,43) is expected. The traditional educational process in the academic style pays little attention to the development of these skills, which are obviously in demand among employers. On the contrary, respondents believe that they are in good standing during their studies at the university in Learning to Learn (−0,29), Critical Thinking (−0,11) and, to a lesser extent, Problem Solving (+0,21) skills. This, apparently, is due to the fact that for Software Engineering specialty this soft skills are more related to technical hard skills whose mastering is somehow included in the curriculum.

To avoid loading the text by clustered dendrograms and diagrams cluster analysis results presented below in 4 summary tables for the four XXI Century skills groups. Each table summarizes the results of processing responses in the form of an estimate of the percentage size of the following 4 groups of students who believe:

- that they *have* the skills and *intend* to master them,
- that they *have* the skills and *don't intend* to master them,
- that they *don't have* the skills but *intend* to master them,
- that they *don't have* the skills and *don't intend* to master.

For the 1st group of skills *Ways of Thinking*, summary table is:

[3] http://www.p21.org

	Have skills	Don't have skills
Intent to master	**57%**	**32%**
Don't intent to master	**04%**	**07%**

The intent of the most of respondents to master and develop this group of skills even if they already have it, means that the *Ways of Thinking* group of skills is highly important for Software Engineering students.

Second *Ways of Working* group imply skills to Communicate clearly and to Collaborate with others effectively. Certainly, the ability to express clearly own thoughts and ideas for others effectively is important for any specialist. Typically, it involves the exchange of information between people in a face-to-face meeting, such as negotiating between developers and business consultants and managers, more often between developers themselves, or discussing problems at a workshop etc. However, in Global SWE projects such direct communication between developers from different countries of the world is usually impossible due to their separation in space and time, therefore communication is carried out mainly in written form. Distributed Linux GSWE development is an excellent example[4].

Communicating programmers mainly is discussing and reviewing code, sometimes simply viewing comments on the repository without explicit conversation, but you necessarily need good skills in clear writing and properly understanding e-mails. It follows from the answers, that Collaboration (+0,35) and especially Teamwork (+0,55) have a weak presence in respondents' training, in less degree it concerns Communication (+0,29) skills. Again, traditional classical training programs at universities do not contribute to the development of the skills of this group, while PhD-students themselves feel the need for their development. This should be noted, as these skills are in high demand.

For the 2nd *Ways of Working* group of skills the table looks so:

	Have skills	Don't have skills
Intent to master	**68%**	**13%**
Don't intent to master	**00%**	**19%**

All respondents who believe, that they have Communication and Collaboration skills intent to enhance them. As for the previous group of skills, it means that they understand the importance of continually improving skills significant for them.

The next third group *Tools for Working* contains Information, Media and ICT literacies. Media literacy (+10) shows students had not mastered it at universities. ICT literacy (−0.03) and Information literacy (−0.13) are evidently the important skills for SWE specialities so in Universities they are learned more. That's why the students consider them to be known enough and is not interested in further learning. This makes sense in the case when these subjects could be learned and extended by himself.

The table for the 3rd group of skills *Tools for Working*:

	Have skills	Don't have skills
Intent to master	**45%**	**19%**
Don't intent to master	**13%**	**23%**

It should be noted that despite of Software Engineering specialty about half of the respondents consider that they do not possess these crucial literacies.

The forth group of skills *Ways of Living in the World* directed to develop thinking skills, content knowledge, and social and emotional competencies to navigate complex life and work environments. This and earlier (Gadasina et al 2016) surveys show that Leadership (+0.77) and Initiative (+0.58) skills are in demand regardless of age, country and university. Relevance of Social (+0.48) and Cross-Cultural (+0.39) skills require introducing in universities collaborating projects and programs for students from different faculties, universities and countries. Results also show that study programs in universities allow in big amount develop such skills as Flexibility (−0.35), Accountability (−0.16), Responsibility (−0.10) and Adaptability (−0.03).

For the 4th group *Ways of Living in the World*, the table is:

	Have skills	Don't have skills
Intent to master	**49%**	**03%**
Don't intent to master	**16%**	**32%**

Almost a third part of respondents don't intend to master this type of skills despite they don't have an experience in these skills. We can suppose that respondents may believe that these skills are innate and it is impossible to learn them. Again, the most of respondents who believe to have such skills are intent to develop them and vice versa.

Here it is appropriate to provide some comments from the side of experienced specialists: Leadership can be a factor preventing getting an ordinary job position in some companies; Social and Cross-Cultural skills can be obtained and improved on a job place as most developers usually share common professional set of skills; Self Direction for sure is one of the key skills, and Productivity is one of the key skills for assessment by management.

Mastery of 21st Century themes and Core subjects (English, world languages, arts, mathematics, economics, science, geography, history, government and civics) is essential for all students in the 21st century. In addition to these Core subjects, schools and universities should move to promote the mastery of academic content at much higher levels by integrating the Interdisciplinary themes of the 21st century into the core subjects. The interest of the respondents to the skills of this Interdisciplinary group can be the sign not of the lack of studying these themes in the universities but of the importance of the skills in general. For the professionals within the area of Software Engineering following Literacies are very important: Health (+1.10), Entrepreneurial (+0.94), Environmental (+0.90), Financial (+0.68), Civic (+0.61) and Business (+48).

As a result of the research conducted within the framework of the PWs@PhD Project, it has been experimentally established that in addition to mastering the hard (technical) skills, it is necessary to

[4] https://www.kernel.org/doc/html/v4.15/process/2.Process.html

pay attention to the development of the soft skills in order to increase the competitiveness of graduates. Carried out studies have shown that Software Engineering PhD-students understand the need to master the soft skills competencies as personal qualities that enable them to interact effectively and harmoniously during training process and on the working place, and they are ready to study them. Students emphasize the following skills as the most important: leadership, interdisciplinary collaboration, communication, critical thinking, career preparation and planning, entrepreneurship, responsibility.

It should be noted, that although soft skills are important for an IT specialist (software engineer, software developer or R&D), they do not have a big value without professional level of hard skills which are primary and necessary for a high specialist. The set of soft skills plays important but supplementing role.

5 Conclusion

To develop software for competitive product software engineer must first of all have the required set of hard skills – such as to design, write, maintain, and test code, and necessary knowledge of Mathematics, Computer Science and related subject. Modern Software Engineering also includes such activities as project management, establishing the development process, communicating with the team and other teams in cross cultural and/or distributed environment. Delivering the code only is insufficient in modern complex contextual technical conditions, the appropriate level of soft skills is also necessary for a good software engineer and R&D, especially for a manager position.

The above results of our current field of study of the PWs@PhD Project international group of highly qualified in hard skills software engineers show that Ph.D. students understand the need to master soft skills and are ready to learn them in university.

Novice Software Engineers are often low proficient of how to become professionals. Papers Gadasina at al. (2016, 2017) itemizes a set of skills that they might aim to achieve from trainings, projects at work, mentoring, or self-regulation for enhancing personality qualities and target areas for improvement. It is well known that the adaptation of the software engineer to the project is critical, novices may also use these results to find the right fit with prospective employers and teams, in terms of the skills they value as different teams emphasize various skills differently. Learning skills from the lists of skills, mentioned above, may also help novices better present themselves to employers. They might demonstrate to employers that they possess or can develop those hard and soft skills which experienced engineers and managers value. Also, that extends to highlighting substantial skills when authoring resumes or presenting themselves in interviews.

The results of the study also have significant value for curriculum choices, teaching methods, and learning objectives in traditional Software Engineering educational process. First of all, university educators' staff may consider adding courses on new topics not found in their current curricula. For example, it is generally recognized that decision making is a key part of software engineering, but this specific topic is not a part of the ACM's "Software Engineering 2014 Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering"[5]. Meanwhile special decision-making courses might be helpful to software engineering students and postgraduates.

Software Engineering educators might also use results of Gadasina et al. (2016, 2017) and cited above investigations to examine usually used teaching methods. Most key software engineer soft skills, such as communicative and creative skills, focus on how to do rather than what to do, whereas most teaching instructions focus on teaching only cognitive skills and acquire knowledge. In this direction educators might consider moving their attention on the processes of how and in what ways software engineering goals are attained. For example, existing Problem Based Learning approach and Project Based Courses might use skills presented here to help students evaluate each other's behaviour, as well as train communicative and creative soft skills simultaneously with cognitive hard skills referring to the ultimate goal of the skills – ability of a team to produce a quality software in time and budget. Moreover, educators can consider explicitly discussing what students will not be capable to learn in academic settings, allowing them to be aware of potential skills and knowledge gaps and enable them to seek out opportunities outside of the Universities where they might be better learned through mentorship on the job, distance MOOCs, internships or global open-source projects.

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APPENDIX A

XXI Century Skills	***Students List of Skills***
Ways of Thinking:	
Effectively Reasoning	*Quality evaluation*
	Ability to formulate ideas clearly
Critical and Systems Thinking	*Critical thinking*
Judgement and Decision Making	
Problem Solving	*Persistence*
Creativity	
Innovations Implementing	
Learning to Learn	*Grant writing*
	Academic writing
	International publishing
	Teaching abilities
	Educational assessment
Ways of Working:	
Communication	*Public speaking*
	Communication
	Foreign language communication
	Intercultural communication
	Negotiation
	Ability to convince
Collaboration	*Interdisciplinary collaboration*
	Ability to work collaboratively
Teamwork	
Tools for Working:	
Media Literacy	
Information Literacy	*Ability to find relevant information*
ICT Literacy	*Software development*
	Program administrating
Ways of Living in the World:	*Interpersonal skills*
Flexibility and Adaptability	*Adaptation to situation changing*
Initiative and Self-Direction	
Productivity and Accountability	
Leadership and Responsibility	*Leadership*
	Social responsibility
Social and Cross-Cultural skills.	*Intercultural communication*
Core Interdisciplinary themes:	
Global Awareness	
Financial Literacy	
Economic Literacy	
Business Literacy	*Managing people*
	Managing business
	Managing projects
	Time management
	Career preparation and planning
	Intellectual Property Managing
Entrepreneurial Literacy	*Entrepreneurship*
Civic Literacy	
Health Literacy	
Environmental Literacy	