Soft Skills of Developers in Software Engineering: View from the PhD Students' Side*

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Abstract. The paper presents the results of a survey of opinions Software Engineering (SWE) PhD-students enrolled in the international program at the Erasmus+ *PWs@PhD Project* of eleven universities from five European countries, Russia and Jordan. The main intent of the research is to learn more about the ways in which PhD-students in the SWE field can prepare themselves for careers in modern exacting and fast changing job market. First results of the investigation allowed for PhD-students themselves to identify groups of the most signicant for them professional skills, to find out the level of mastering these skills and to evaluate intention to obtain them. Processing and analysis results of the new survey and comparison the lists of soft skills ranked by students with list of 21st century skills and lists of skills required by employers allowed to give nontrivial recommendation for universities administrations, those who strive to democratize the intellectual labor and to help economic development at the same time.

Keywords: soft skills · software engineering · PhD training · survey

1 Concept of Software Engineering

Software Engineering (SWE) is a relatively new area of activity. The origins of the term 'software development' refer to different sources. Officially it was first used in 1968 as the title of the World Conference on Software Development, supported by NATO. The conference was attended by international experts on software who agreed on defining prime practices for software grounded in the application of engineering. The result of the conference is a report[1] that defines how software should be developed.

Modern, generally accepted best-practices for Software Engineering have been collected by the ISO/IEC JTC 1/SC 7 subcommittee and published as the Software Engineering Body of Knowledge (SWEBOK, ISO/IEC TR 19759:2005. Retrieved 2012-04-01).[2]

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[1] http://homepages.cs.ncl.ac.uk/brian.randell/NATO/nato1968.PDF

[2] https://www.iso.org/standard/33897.html

Recall here the classical definitions: "SWE is the application of engineering to the development of software in a systematic method" [1]. "SWE is the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software" [8]. According to the survey[3] only about 40 percent of software developers have degrees in computer science, and almost no degrees in SWE. So, it would not be surprising that people are confused about the difference between Software Engineering and Computer Science. The principal distinction between science and engineering in software is the same as the distinction in other fields. Following [15], [17] we remind significant differences.

Scientists learn what is true, how to test hypotheses, and how to extend knowledge in their field. Engineers learn what is true, what is useful, and how to apply well-understood knowledge to solve practical problems. Those who are doing science can afford to be narrow and specialized, and those who are doing engineering need a broad understanding of all the factors that affect the designing product. And what is more important for Employers and Professors, an undergraduate science education prepares students to continue their studies while an undergraduate engineering education prepares students to enter the workforce immediately after completing their studies.

In other words, classical Computer Science is helpful to Software Engineering, but will never be enough. Good Software Engineering also includes creativity, vision, multi-disciplinary thinking, and humanity. This observation frees Software Engineering researchers to spend time on building up a body of collected wisdom for future practitioners. Professors should not try to make Software Engineering into an extension of mathematically-based Computer Science [5].

From the other side, requirements of employers from the Computer Scientist are waiting for ability to solve important, but highly applied, narrowly focused tasks, and from the Software Engineer – a creative approach, universal knowledge and *soft skills*. Employers expect university programs to create fully developed experts who have the ability to be leaders in their fields and are capable of creating real-world values from their knowledge. At the same time professors and academics more than two decades are trying to reduce the gap between the skills that contemporary employers expect, and the actual skills that many traditional educational programs continue to equip graduate and PhD students [11], [14], [16], [20], [22], [23], [26].

2 Education for Software Engineer in Russia

System and level of training of Software Engineers varies in different universities and has a significant impact on demand for graduates on the employment market. In the Russian higher school, the Federal state educational standards for the training of Bachelors and Masters in SWE were developed and approved by the RF Ministry of Education and Science only in 2011. This allowed starting the training of Bachelors and Masters in SWE in 91 universities of Russia. Saint

[3] https://insights.stackoverflow.com/survey/2017

Petersburg State University (SPbSU) by the Federal Law has right to develop their own sets of educational standards, determine the structure and content of educational programs at their own direction at all levels of higher education. SPbSU own educational standard[4] is set up for each direction of SWE training – Bachelor, Specialist, and Master (the last one in academic, academically-oriented and practice-oriented forms). Nevertheless, the educational standard at the level of training of highly qualified personnel in SWE – PhD-doctorate – in the SPbSU is currently missing.

Therefore, University uses various forms of international cooperation for the preparation of highly qualified specialists, such as the Agreement for Double Doctoral Degree between Lappeenranta University of Technology and Saint Petersburg State University signed in 2016 (including SWE specialties). Moreover, international cooperation in the field of higher qualification scientific personnel training is supported by the *PWs@PhD Project* [18] in the European Union Erasmus+ Program Capacity Building in Higher Education. This activity aims for the inclusion of the new specialty *Software Engineering* in the *RF Nomenclature of Specialty of Scientific Workers*, that will allow Russian universities to organize the preparation of postgraduate and doctoral students, as well as carry out the defense of candidate and doctoral dissertations. And in the perspective of introducing in Russia, following the Bachelor's and Master's degrees, the PhD degree as the third level of the Bologna system, it will also provide opportunities for opening a PhD-students training and for defending PhD theses in the field of SWE [9], [25].

3 Education for Software Engineer – World trends

A classic example of a worldwide Software Engineering Center Silicon Valley formed around a traditional learning institution, Stanford University. That school has changed with the times, integrating with the tech business it has helped spawn. Nowadays software industry is known for its indifference to formal qualifications – few companies ask about a job applicant's education, but all will test specialized knowledge and teamwork qualities.

Recently Stack Overflow, a question and answer site for programmers, released the results of their 2017 annual survey[5] of more than 64000 developers. Among current professional developers globally, 76,5% of respondents said they had a Bachelor's degree or higher, such as a Master's degree or equivalent, and only 2,2% had a Doctoral degree. More than half (54,2%) of professional developers who had studied at a college or university said they had concentrated their studies on computer science or software engineering. On the question 'What kind of learning do you recommend?' more developers (64,5%) answered 'should take an online course than any other method' followed by 'getting a book and working through the exercises' (50,2%).

[4] http://spbu.ru/structure/documents/mm19xm7g.html
[5] https://insights.stackoverflow.com/survey/2017

This approach gave birth to a new educational model, the extreme manifestation of which is the École 42, which does not have any professors, does not issue any diploma or degree, and is open 24/7. According to official site[6], École 42 is a high quality, computer-programming training program, which provides its curriculum completely free-of-charge to its students. The training is inspired by new modern ways to teaching which include inverted class technology, peer-to-peer pedagogy and project-based learning. The basic idea of École 42 is to place all the students into a single building in the heart of Paris, give them Macs with big Cinema displays, and provide them increasingly difficult programming challenges. The students are given a very little direction about how to solve the problems, so they have to turn to each other and to the super-fast Internet to figure out the solutions [2]. École 42 activity is a good example of the fact that programming is mainly a skill of solving problems that should be trained, rather than a set of knowledge in Computer Science. This idea is a key to understanding on how to learn programming. Of course, École 42 will not destroy traditional universities, but certainly can accelerate the growth in the number of people who do not believe in the need to obtain a university degree.

Online SWE education become increasingly popular among learners, therefor classical universities have long begun to investigate the quality of such kind learning [19]. Nevertheless, their quality has not been sufficiently studied. As for recent results, in the interesting article [13] authors first time provide an overview of flipped classroom studies through the analytical lens of de Bono's 'Six thinking hats' model [3]. In another review article [10] authors sampled 30 popular and diverse online coding tutorials, and analyzed what and how they taught learners. It was found that tutorials largely taught similar content, organized content bottom-up, and provided goal-directed practices with immediate feedback, but few were tailored to learners' prior coding knowledge and only a few informed learners how to transfer and apply learned knowledge.

The same basic question is at the foundation of rapidly growing world's software ecosystem: employers want to hire and retain great engineers, universities want to train great engineers, and young engineers want to become great. But understanding of what characteristics define software engineering expertise still lacks specificity, breadth, and rigor, in many respects because it is a new area of knowledge and new industry. We can mention that as one of the main factors to explain the situation. The authors of the article [12] believe that Software Engineering expertise is much more about *personality*, *interpersonal skills*, and *decision-making* expertise than about technical knowledge and ability, against the background of incomplete, indirect, and abstract knowledge about Software Engineering expertise in general. We, however, believe that strong technical competence is the necessary base for the great Software Engineers. Nevertheless, in the work [12] among all possible attributes authors identified the set that practice expert software engineers viewed as important for the engineering of software and provided a contextualized understanding of why these attributes are impor-

[6] https://www.42.us.org

tant in real-world practice. Their analysis identified a diverse set of 53 attributes of great software engineers, at a high level they are:

(A) Personal Characteristics – *Improving, Passionate, Open-minded*;

(B) Decision Making – *Knowledgeable about People and the Organization, Sees the Forest and the Trees, Update Mental Models, Handling Complexity*;

(C) Engagement with Teammates – *Creating Shared Context, Creating Shared Success, Creating a Safe Haven, Honest*;

(D) Software Product – *Elegant, Creative, Anticipating Needs.*

In January, 2016, by surveying the chief HR officers at some of the world's leading companies, the World Economic Forum has released *The Future of Jobs* [27] report revealing the top 10 skills person shall need by 2020. Report highlights the changing nature of work, which became more trans-disciplinary, increasingly collaborative and focused on solving complex problems in creative ways.

Table 1. Comparing lists of skills for 2020 and 2015

Place in List for 2020	Skills	Place in List for 2015
1	Complex Problem Solving	1
2	Critical Thinking	4
3	Creativity	10
4	People Management	3
5	Coordinating with Others	2
6	Emotional Intelligence (new)	Quality Control (old 6)
7	Judgment and Decision Making	8
8	Service Orientation	7
9	Negotiation	5
10	Cognitive Flexibility (new)	Active Listening (old 9)

Key skills for 2020 emerging to Job Family for Software Developers and Analysts are *Complex Problem Solving*, *Critical Thinking*, *Cognitive Flexibility*, *Active Learning and Mathematical Reasoning.* The last one is absolutely necessary skill at all time, we believe.

With many studies like mentioned above we following the authors come to understanding Software Engineering not just as a purely technical discipline, but a sociotechnical one, with individual contributors and their collaborations supporting software developing. As a consequence, we come to the need to learn Software Engineers *soft skills* as personal qualities that enable them to interact effectively and harmoniously.

But very few investigators interested in the views of the SWE students themselves about the skills they need to future work, and almost none asked opinions of SWE PhD-level students. That is why in this work we choose the group of 31 high level PhD students who are currently engaged in the modern preparation process at the *PWs@PhD Project* [18] and focused on the study of the

importance of exclusively *soft skills* for software developers. To this end, we have chosen the so-called XXI Century Skills as a universal list of *soft skills*.

In general, we understand and emphasize it here – although soft skills are important, they are still secondary, while technical skills are primary and necessary. The main aim of the software developer is to write and maintain code (or even only maintain in some cases), without these skills other does not have a big value. As if the carpenter did not know how to work with hammer and plane, but would have good communicative skills.

4 Education for Software Engineer – PhD Level

Doctoral education generates new knowledge by closely linking specialized education and hands-on research experience. The results are important for the society as a whole and for country competitiveness in a global knowledge-based economy. Doctoral education prepares a new generation of researchers in academia, industry, government, and nonprofits, as well as a highly skilled workforce for other sectors of the economy. Decades-long participation of large and growing numbers of temporary visa holders in US attests to the attractiveness of this model. United States and Japan have long-standing private higher education sectors, and Western Europe has an almost completely public higher education sector. Eastern and Central Europe and several African countries have recently seen growth in private higher education.

According to the report of US National Science Foundation 'Science and Engineering Indicators 2016' the number of S&E doctorates conferred annually by U.S. universities increased steadily between 2002 and 2008, declined through 2010, and increased by 14% through 2013, to nearly 39000. The growth in the number of S&E doctorates between 2000 and 2013 occurred among U.S. citizens and permanent residents as well as temporary visa holders. The largest increases in S&E doctorates were in engineering and the biological sciences. Graduate enrollment in computer sciences grew rapidly in the early 2000s, then decreased through 2006, but it has generally increased since then.

The time required to earn a doctoral degree (as measured by time from graduate school entry to doctorate receipt) and the success rates of those entering doctoral programs are concerns for those pursuing a degree, the universities awarding the degree, and the agencies and organizations funding doctoral study. Longer times to degree mean lost earnings and a higher risk of attrition. Time to degree increased through the mid-1990s but has since decreased in all S&E fields from 7,7 to 6,9 years. The physical sciences and mathematics had the shortest time to degree, whereas the social sciences and medical and other health sciences had the longest. Time to degree was shortest at research universities with very high research activity (6,7 years in 2013, down from 7,2 years in 1998) and it was longer at universities that were less strongly oriented toward research.

The aim of this research is to explore the degree to which students realize that international doctoral programs are providing them skills that will be on demand on the current job market.

At the first stage of the study [6] a written survey was conducted of a group of PhD students of eleven universities currently involved in the doctoral programs in SWE at the international *PWs@PhD Project* [18]. Processing and statistical analysis of the survey results allowed identify groups of the most significant professional skills for student's future work, to find out the PhD-students level of knowledge and mastering these skills and to evaluate the student's intention to obtain them.

Particularly, we compare the list of skills ranked by students with a list of skills required by employers in the areas close to the SWE. According to the report [4], strategy and project management skills *Research*, *Project management*, *Negotiation* and *Analytic* are in particular demand among high-skill, high paying jobs in such fields like management and research. These jobs have experienced wage growth and expanded employment opportunities in recent years. Developing the skills in this cluster can be particularly advantageous to job seekers looking to advance their careers and take on additional responsibilities.

The skills of this cluster have the highest scores in student's evaluation of desired skills: *Managing Project*, *Data Analysis*, *Research Methods* and *Negotiation*. In general, the correlation between the ranked sets of skills required by employers and compiled by students in the area of Research, Planning and Analysis is 0,41. These results show that, despite the fact that the complete lists of skills required by employers and desired by students differ considerably, students can see quite well the basic skills necessary to engage in higher positions corresponding to their level of qualification.

In the present study, we selected the XXI Century skills as *basic soft skills* and explored the importance of owning them for students undergoing preparation for the PhD-thesis on SWE. Just a decade ago three large software and hardware companies Microsoft, Cisco, and Intel set up a project XXI Century Skills 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 five years, researchers of education from all over the world define what was meant by XXI century skills, such as a complex skill collaborative problem solving [24]. The XXI century skills framework has captured imagination of teachers and politicians around the world. It postulates that the share of manual and routine cognitive labor is declining, and the share of non-routine cognitive labor increases. Therefore, the society must reform education to provide students with skills more appropriate in the new economy. Right now, the project is already at the stage of being able to define a template that allows those sets of skills to work.

There are 4 groups of XXI Century skills[7]:

(I) Ways of Thinking – *Creativity & Innovation*, *Critical Thinking*, *Problem Solving*, *Decision Making*, *Learning to Learn*, *MetaCognition*;

(II) Ways of Working – *Communication*, *Collaboration*, *Teamwork*;

[7] Partnership for the twenty-first century skills, http://www.p21.org, Assessment and Teaching of twenty-first century skills (ATC21S), http://atc21s.org

(III) Tools for Working – *Media Literacy*, *Information Literacy*, *ICT (Information and Communication Technology) Literacy*;

(IV) Ways of Living in the World – *Citizenship Local* & *Global*, *Life* & *Carrier*, *Personal* & *Social Responsibility*, *Cultural Awareness* & *Competence*.

Developing the skills in this cluster can be particularly advantageous to job seekers looking to advance their careers and take on additional responsibilities.

Analysis of the quantitative survey results using *R* application package consist not only of standard comparing the mean scores, standard deviations and correlation of the responses, but also the cluster analysis of the responses using the method of Ward with manhattan distances between objects and other data mining techniques. Statistical significance of differences when comparing the responses of various groups of respondents performed using the Mann-Whitney *U*-test and variance analysis methods.

The same international group of 31 doctoral students who received training in the *PWs@PhD Project* [18] were asked 12 general and two key questions. Of the answers to general questions, the following two about the university role in career preparation are of interest.

Table 2. The university role in career preparation

Questions	Mean values for Russia	Mean values for other countries
How have you been informed before entering the university about career prospects after graduation in the chosen field of activity?	2,80	3,29
To what extent do educational university program prepare you for a successful career after graduation in the chosen field of activity?	3,40	3,79

The table 2 shows that Russia stands out at first glance. The average level of ideas about the future career in Russia is lower than in the average for other countries by 18% before and 12% after the university. In Russia, it increases during the time of study at the university by 21%, and in other countries only by 15%. However, according to the Mann-Whitney criterion, the difference in answers to both questions for Russia and other countries is not statistically significant (and it is also not significant in terms of age and sex).

For each of the groups (I)-(IV) of the XXI Century skills the respondents answered two main questions:

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

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.

The results of the answers to these questions were subjected to statistical and cluster analysis.

Cluster analysis, carried out for each skills group, allowed to identify two well-separated groups of respondents who answered the first and second questions:

- respondents, who rate their level of mastery in this group of skills as a sufficiently high;
- respondents, who rate their level of mastery in this group of skills as a low;
- respondents, who are interested in mastering this group of skills;
- respondents, who are not interested in mastering this group of skills.

A more detailed analysis of these results is beyond the scope of this article.

On the next diagrams for every group of skills one can see the residual after averages of the answers for the 1st question have been subtracted from the averages of the answers for the 2nd question. In other words, difference between *'What skills I would like to train'* and *'What skills I really mastered in my University'*.

First two groups of skills – Ways of Thinking (I) and Ways of Working (II) compose *Learning and Innovation skills*. They separate students who are prepared for increasingly complex life and work environments in today's world from those who are not prepared properly. In the first turn, effective scientists and engineers must be able to exhibit a range of functional and critical thinking skills.

The descriptions of the skills are given below according to the website of the Partnership for the skills of the 21st century[8]. They were incorporated into the text of the questionnaire also at the request of the respondents.

Ways of Thinking (I) imply among other *Effectively Reasoning, Critical and Systems Thinking, Judgement and Decision Making, Problem Solving, Creativity, Innovations Implementing* and *MetaCognition*.

Effectively Reasoning means following skills: use various types of reasoning as appropriate to the situation; effectively analyze and evaluate evidence, arguments, claims and beliefs; analyze and evaluate major alternative points of view; synthesize and make connections between information and arguments; interpret information and draw conclusions based on the best analysis; reflect critically on learning experiences and processes.

Critical Thinking supposes using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.

Systems Thinking is ability to analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.

Judgement and *Decision Making* mean considering the relative costs and benefits of potential actions to choose the most appropriate one.

Metacognition is awareness and understanding of one's own thought processes.

Problem Solving signifies skills to solve different kinds of non-familiar problems in both conventional and innovative ways and identify and ask significant questions that clarify various points of view and lead to better solutions.

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

Creativity supposes skills to Think Creatively (use a wide range of idea creation techniques; create new and worthwhile ideas; elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts) and skills to Work Creatively with Others (develop, implement and communicate new ideas to others effectively; be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work; demonstrate originality and inventiveness in work and understand the real world limits to adopting new ideas; view failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes).

Learning to learn is the ability to pursue and persist in learning, to organize one's own learning, including through effective management of time and information, both individually and in groups. This skill includes awareness of one's learning process and needs, identifying available opportunities, and the ability to overcome obstacles in order to learn successfully.

At last, *Implement Innovations* means to work on creative ideas to make a tangible and useful contribution to the field in which the innovation will occur.

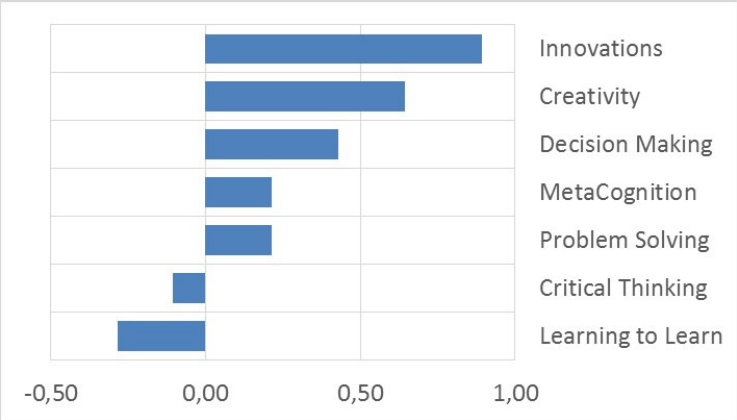

Fig. 1. Mean values of points for Ways of Thinking group

Analysis. Maximum value of residuals we can see for *Implement Innovations skills*. With that even mentioning of the implement innovations are absent in the list of skills elaborated by this group members themselves [6]. It means they do not see innovations in pedagogical process at their universities, we can suppose that attention to *Implement Innovations* skills are absent in University courses at all. However, it does not mean that they are on big demand on the market for SWE positions.

A high need for mastering *Creativity* and *Decisions Making* skills 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 learned quite well during their studies at the university in their *Learning to Learn*, *Critical Thinking* and, to a lesser extent, *Problem Solving* skills. This, apparently, is due to the fact that for SWE specialty they can be more related to *hard skills* whose mastering is somehow included in the curriculum (see Figure 1).

Ways of Working (II) imply skills to *Communicate Clearly* and to *Collaborate with Others* effectively.

That means specialists must be able articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts; listen effectively to decipher meaning, including knowledge, values, attitudes and intentions; use communication for a range of purposes (e.g. to inform, instruct, motivate and persuade); utilize multiple media and technologies, and know how to judge their effectiveness a priori as well as assess their impact; communicate effectively in diverse environments (including multi-lingual); demonstrate ability to work effectively and respectfully with diverse teams; exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal; assume shared responsibility for collaborative work, and value the individual contributions made by each team member.

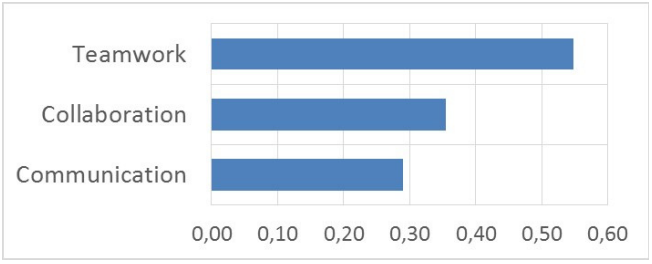

Fig. 2. Mean values of points for Ways of Working group

Analysis. Certainly, ability articulate thoughts and ideas effectively is important in any case. We see from the answers, that *Collaboration* and especially *Teamwork* have a weak presence in respondents training, in less degree it concerns *Communication* 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, since these skills are in high demand (see Figure 2).

The next group **Tools for Working (III)** contain *Information, Media* and *ICT literacies*.

Information Literacy suppose handle information efficiently in time and effectively in sources; evaluate information critically and competently; manage the flow of information from a wide variety of sources; use information accurately and creatively for the problem solving; apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information.

Media Literacy means ability to *analyze media* (understand how and why media messages are constructed, and for what purposes; examine how individuals interpret messages differently, how values and points of view are included or excluded, and how media can influence beliefs and behaviors; apply a fundamental understanding of the ethical/legal issues surrounding the access and use of media) and to *create media products* (understand and utilize the most appropriate media creation tools, characteristics and conventions; understand and effectively utilize the most appropriate expressions and interpretations in diverse, multi-cultural environments).

Information, Communication and Technology (ITC) Literacy requires use technology as a tool to research, organize, evaluate and communicate information; use digital technologies, communication/networking tools and social networks appropriately to access, manage, integrate, evaluate and create information to successfully function in a knowledge economy; apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.

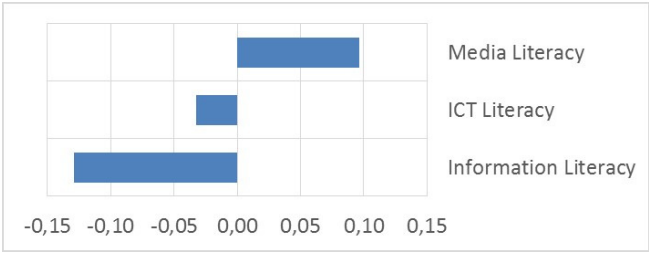

Fig. 3. Mean values of points for Tools for Working group

Analysis. *Media Literacy* usually is not present at university. *Information and ICT literacies* are the important skills for SWE so they are learned more in universities. That's why the students consider them to be known enough and are not interested in further learning. This make sense in case these subjects could be learned and extended by a person himself (see Figure 3).

The group **Ways of Living in the World (IV)** directed to develop thinking skills, content knowledge, and social and emotional competencies to navigate complex life and work environments. It contains *Flexibility* and *Adaptability*, *Initiative* and *Self-Direction*, *Productivity* and *Accountability*, *Leadership* and *Responsibility*, *Social* and *Cross-Cultural skills*.

Flexibility supposed to incorporate feedback effectively; deal positively with praise, setbacks and criticism; understand, negotiate and balance diverse views and beliefs to reach workable solutions, particularly in multi-cultural environments.

Adaptability is understood as ability to adapt to varied roles, jobs responsibilities, schedules and contexts together with proficiency to work effectively in a climate of ambiguity and changing priorities.

The *Initiative* expects the ability to work independently – to monitor, define, prioritize and complete tasks without direct oversight, and to manage goals and time, i.e. to set goals with tangible and intangible success criteria; to balance tactical and strategic goals; utilize time and manage workload efficiently.

Self-directed students are those who are able to go beyond basic mastery of skills and/or curriculum to explore and expand ones own learning and opportunities to gain expertise; demonstrate initiative to advance skill levels towards a professional level, demonstrate commitment to learning as a lifelong process; reflect critically on past experiences in order to inform future progress.

Productivity and *Accountability* here consist of two skills – the first is to Manage Projects, i.e. to set and meet goals, even in the face of obstacles and competing pressures, and to prioritize, plan and manage work to achieve the intended result. The second – to Produce Results, i.e. to demonstrate additional attributes associated with producing high quality products including the abilities to: work positively and ethically; manage time and projects effectively; multitask; participate actively, as well as be reliable and punctual; present oneself professionally and with proper etiquette; collaborate and cooperate effectively with teams; respect and appreciate team diversity; be accountable for results.

Leadership means here ability to guide and lead others, particularly, to use interpersonal and problem-solving skills to influence and to guide others toward a goal; leverage strengths of others to accomplish a common goal; inspire others to reach their very best via example and selflessness; demonstrate integrity and ethical behavior in using influence and power.

Responsibility is understood primarily as responsibility for others, which is ability to act responsibly with the interests of the larger community in mind.

Social and *Cross-cultural skills* include the ability to Interact Effectively with others, particularly, to know when it is appropriate to listen and when to speak, and to conduct themselves in a respectable, professional manner. The second significant group of skills is ability to Work Effectively in Diverse Teams with respect cultural differences; to work effectively with people from a range of social and cultural backgrounds; to respond open-mindedly to different ideas and values; to leverage social and cultural differences to create new ideas and increase both innovation and quality of work.

Analysis. This and earlier surveys show that *Leadership* and *Initiative* skills are in demand regardless of age, country, and university. Relevance of *Social* and *Cross-Cultural* skills require introducing in universities collaborating projects and programs of students from different faculties, universities, and countries. Results also show that study programs in universities allow in big amount develop such skills as *Flexibility*, *Adaptability*, *Responsibility* and *Accountability*.

Here it is appropriate to give a few comments from the side of experienced software developers: *Leadership* can be a factor preventing getting an ordinary job position on some job markets; *Social* and *Cross-Cultural* skills are not so

Fig. 4. Mean values of points for Ways of Living in the World group

hard to achieve in practice as most workers 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 (see Figure 4).

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 subjects, schools must move to include promote understanding of academic content at much higher levels by weaving 21st century **Interdisciplinary Themes** into core subjects. They are:

Global Awareness. It is learning from and working collaboratively with individuals representing diverse cultures, religions and lifestyles in a spirit of mutual respect and open dialogue in personal, work and community contexts; understanding other nations and cultures, including the use of non-English languages, using 21st century skills to understand and address global issues.

Financial, Economic, Business and *Entrepreneurial Literacy*, that means at least knowing how to make appropriate personal economic choices; understanding the role of the economy in society; using entrepreneurial skills to enhance workplace productivity and career options.

Civic Literacy, which signifies participating effectively in civic life through knowing how to stay informed and understanding governmental processes; exercising the rights and obligations of citizenship at local, state, national and global levels; understanding the local and global implications of civic decisions.

Health Literacy. It contains obtaining, interpreting and understanding basic health information and services and using such information and services in ways that enhance health; understanding preventive physical and mental health measures, including proper diet, nutrition, exercise, risk avoidance and stress reduction; using available information to make appropriate health-related decisions; establishing and monitoring personal and family health goals; understanding national and international public health and safety issues.

Environmental Literacy. It requires to demonstrate knowledge and understanding of the environment and the circumstances and conditions affecting it, particularly as relates to air, climate, land, food, energy, water and ecosystems; demonstrate knowledge and understanding of society's impact on the natural world (e.g. population growth, population development, resource consumption rate, etc.); investigate and analyze environmental issues, and make accurate conclusions about effective solutions; take individual and collective action towards addressing environmental challenges (e.g. participating in global actions, designing solutions that inspire action on environmental issues).

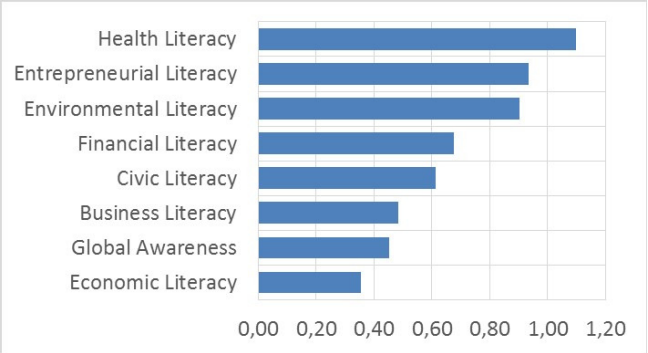

Fig. 5. Mean values of points for Interdisciplinary Themes group

Analysis. Skills of this group are of general view so the interest of the respondents can be the sign not of the lack of it studying in the university but of the importance of these skills in general. From the SWE professionals side *Health Literacy*, *Financial*, *Economic*, *Business and Entrepreneurial Literacy* are very important (see Figure 5).

The framework of 21st century skills looks blameless, in assumption that in the future most adults are still hired employees. Nevertheless, this approach does not justify itself in more distant future, when most people will not work for wages. Their creative and productive impulses will be transmitted through various new kinds of human practices, which can be summed up as *Optional Labor*. The emergence of societies with low employment rates will create new problems to education. In this direction education should move away from the mastering skills to the developing of meaning and motivation to prepare students for the world of optional labor. Following the work [21] we consider three kinds of *Optional Labor*: *Prosumption*, *Volunteerism* and *Self-Design*.

Prosumption means *Production* and *Consumption* simultaneously. The author of this new term argued that the separation of production from consumption was a temporary aberration. It did not exist in pre-capitalist societies and will not exist in the future economies. In the narrowest sense means creation content within the Web 2.0 framework (Facebook, blogs, Wikipedia, twitter, Instagram).

Volunteerism. Volunteers are someone's susceptible to the moral pressures, moved by ethical considerations, and capable of empathy. At the same time, they must be able to extract enough pleasure from their work to make it motivating. They can do it through social contacts, or simply by engaging their minds and creative impulses.

Self-Design is a whole new, larger meaning of a monumental art piece, created out of one's own entire life. The identity we produce is a life-long project, a continuous memoir. *Self-Design* no more and no less than a new quest for the meaning of life (e.g. Facebooking as a careful construction of the self-image and a profoundly social activity).

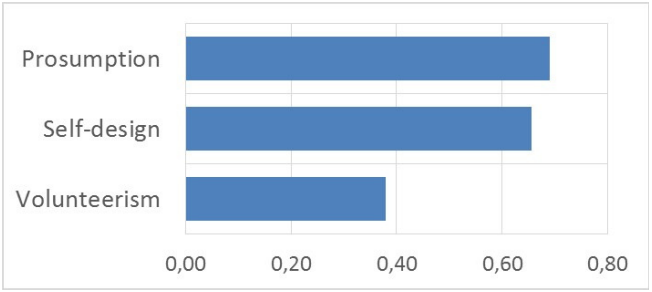

Fig. 6. Mean values of points for Ways of Optional Labor group

Analysis. This group of skills is quite innovative for the modern universities. Currently the universities do not have exact understanding of their development. This may be the reason for the high relevance of this group among the respondents (see Figure 6).

5 Conclusions and Recommendations

To develop a competitive software product Software Engineer must possess the key *hard skills* – the ability to write and maintain code and necessary knowledge of Computer Science and related technologies. But SWE is not just concerned with the technical processes of software development and proficiency to create simple and intuitive designs that another person (or themselves later) could easily understand, but also with activities such as software project management and with the development of tools, methods and theories to support software production.

With results of our and many mentioned above studies we come to understanding that SWE undoubtedly is a sociotechnical discipline and undertaking, with individual contributors and their collaborations supporting software development. As a consequence, Software Engineers come to the need to possess *soft skills* as personal qualities that enable them to interact effectively and

harmoniously. Also, although the ability to learn new skills (i.e. continuous improvment) and to make decisions in increasingly more complex and ambiguous situations on the high level in general is more important than any individual technical skills, in some cases an employer may prefer a candidate with strong experience in required specific area.

From the side of *hard skills* possessing, though, delivering the code only is insufficient in conditions of complex contextual technical considerations, nevertheless delivering production quality code that considers error handling, memory consumption, performance, security, and style, and is proper covered by unit tests stays the main responsibility of a software developer.

In a more rigorous mathematical formulation, it can be argued that confident possession of *hard skills* is a necessary condition for the successful work of a Software Engineer, and the possession of developed *soft skills* is still only sufficient. In other words, the presence of developed *hard* and *soft skills* is necessary and sufficient for a good Software Engineer.

In a whole the above results of our current field study of the international group of highly qualified in *hard skills* Software Engineers show that they understand the need to master *soft skills* too and are ready to learn them in their universities.

Novice Software Engineers are often low proficient of how to become professionals. Present paper 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 Soft 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. Mentioned above lists of skills 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 study also have significant value for curriculum choices, teaching methods, and learning objectives in traditional SWE educational process.

First of all, university educators staff may consider adding courses on new topics not found in their current curricula. For example, generally recognized decision making to be a key part of Software Engineering, but this specific topic is not a part of the ACM's 'SE2004 Software Engineering Curriculum' (retrieved 2012-03-25)[9]. Meanwhile courses specifically about decision making or case studies of software engineering decisions might be helpful to SWE students and postgraduates.

SWE educators might also use results of our and cited above investigations to examine usually used teaching methods. Most key skills of Software Engineers focus on how to do rather than what to do, such as communicative and creative skills, whereas most teaching instructions focus on teaching only cognitive

[9] http://sites.computer.org/ccse/SE2004Volume.pdf

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 behavior, as well as train communicative and creative *soft skills* simultaneously with cognitive *hard skills*.

Finally, educators can consider explicitly discussing what things 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 open-source projects.

Surely this paper is only a start for better understanding of educational problems in preparing of software engineers. There are many opportunities for further work, such as examine of the combinations of key or dominant skills. Each specific skill enumerated in this study could also be the subject of future studies to provide deeper assessments of their impacts on SWE outcomes and provide more insights into the unique qualities of the Software Engineering phenomenon.

References

1. Abran, A., Moore, J. W., Bourque, P., Dupuis, R., Tripp, L. L.: Guide to the Software Engineering Body of Knowledge. *IEEE*, 2004. ISBN 0-7695-2330-7.
2. Bershidsky, L.: Bloomberg View. A French Billionaire Wants to Disrupt Silicon Valley, 2016.
3. de Bono, E.: Six thinking hats. *London: Penguin*, 2000.
4. Burning Glass Technologies 2015. The Human Factor: The hard time employers have finding soft skills. Burning Glass Technologies Report. November 2015, 20 p.
5. Connel, Ch.: Software Engineering $\neq$ Computer Science. Dr.Dobb's The world of software development, June 4 2009.
6. Gadasina, L., Voitenko, S., Yurkov, A.: Research of Student Prospects on Developing International PhD Program in SWE, *Ural-PDC 2016 – Proceedings of the 2nd Ural Workshop on Parallel, Distributed, and Cloud Computing for Young Scientists*, 2016, pp. 56-65.
7. Gould, J.: How to Build a Better PhD, *Nature*, 528, 2015, pp. 22–25.
8. IEEE Standard Glossary of Software Engineering Terminology, *IEEE std* 610.12-1990, 1990.
9. Khalin, V., Kosov, Yu., Voitenko, S., Yurkov, A.: Training of PhDs in Software Engineering in Russia: A Proposal for New Specialty, InnoCSE 2017 – Proceedings of the 1st International Workshop on Innovative Approaches in Computer Science within Higher Education, 2017, pp. 20-25.
10. Kim, A. and Ko, A.J.: A Pedagogical Analysis of Online Coding Tutorials. ACM Technical Symposium on Computer Science Education (SIGCSE), 321-326, 2017.
11. Lethbridge, T.C.: A survey of the relevance of computer science and software engineering education, *Conference on Software Engineering Education and Training*, 1998, pp. 56–67.
12. Li, P., Ko, A.J., and Zhu, J.: What Makes a Great Software Engineer. International Conference on Software Engineering, 700-710, 2015.

13. Lo Ch. K., Hew, K. F.: A Critical Review of Flipped Classroom Challenges in K-12 Education: Possible Solutions and Recommendations for Future Research, *Research and Practice in Technology Enhanced Learning*, 12.4, 2017.
14. Loksa, D., Ko, A.J., Jernigan, W., Oleson, A., Mendez, C., Burnett, M.M.: Programming, Problem Solving, and Self-Awareness: Effects of Explicit Guidance. *ACM Conference on Human Factors in Computing*, 2016, pp. 1449–1461.
15. McConnell, S.C.: Professional Software Development: Shorter Schedules, Better Projects, Superior Products, Enhanced Careers. 241 pages, Boston, MA: Addison-Wesley, 2004. (Chapter 4)
16. Murray, B.: The Growth of the new PhD. *Monitor on Psychology*, 31, 24–27, 2000.
17. Parnas, D. L.: Software Engineering Programmers Are Not Computer Science Programmers. *IEEE Software*, November/December 1999.
18. Project PWs@PhD "Joint Programs and Framework for Doctoral Education in Software Engineering", 2016-18, http://fase.it.lut.fi/
19. Sackman, H., Erikson, W.J., Grant, E.E.:Exploratory experimental studies comparing online and offline programing performance, *Communications of the ACM*, vol. 11, no. 1, pp. 3–11, 1968.
20. Shea, A. A.: It's time for graduate science programs to get real, *Chronicle of Higher Education*, 59, 31, 2013.
21. Sidorkin, A.M.: Education to Jobless Society. Studies in Philosophy and Education. *Springer Science + Business Media Dordrecht*, 2016.
22. Taylor, M.C.: Reform the PhD system or close it down. *Nature*, 472, 261, 2011.
23. Trauth, E.M., Farwell, D.W. and Lee, D.: The IS expectation gap: industry expectations versus academic preparation. *MIS Quarterly*, vol. 17, no. 3, pp. 293307, 1993.
24. Trilling, B., Fadel, Ch.: 21st Century Skills, Learning for Life in our Times. *John Wiley and Sons*, 2009.
25. Voitenko, S., Vyunenko, L., Yurkov, A.: Trends and Opportunities of Training Highly Qualified IT Specialists in Accordance with International Standards. *Proceedings of the 2nd International Conference on Applications in Information Technology (ICAIT-2016)*, 2016, pp. 1–4.
26. Wheadon, M., Duval–Couetil, N.: Student Perspectives on Developing More Relevant Ph.D. Programs in STEM Disciplines through Professional Skills Training, *American Society for Engineering Education Annual Conference*. 24, 1, 2014. Paper ID No. 10495.
27. World Economic Forum 2016, Global Challenge Insight Report: The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution, Shareable Infographics, January 2016.