Research of Student Prospects on Developing International PhD Programs in Software Engineering

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Abstract. The main intent of the research is to learn more about the ways in which PhD doctorants in the Software Engineering field can prepare themselves for careers in modern exacting and fast changing job market. Results of first diagnostic stage of the study are presented based on materials of a simple quantitative survey of a group of PhD-students, a significant part of which is developing in the field of parallel, distributed and cloud computing. This group is currently enrolled in the international program at the Erasmus+ project of eleven universities from five European countries, Russia and Jordan. Processing and statistical analysis results of the survey allowed to identify groups of the most significant professional skills for future work, to find out the PhD-students level of knowledge and mastering these skills and to evaluate the students intention to obtain them. Conclusions and recommendations presented on the base of comparison the list of skills ranked by PhD students with a list of skills required by employers in the areas close to the Software Engineering.

Keywords: professional skills · PhD students · international PWs@PhD project

1 Introduction

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 this study a written survey was conducted of a group of PhD students of eleven universities currently involved in the doctoral programs in Software Engineering (SWE) at the international project "Joint Programs and Framework for Doctoral Education in Software Engineering" (PWs@PhD project). The overall aim of this project in the European Union Erasmus+ Program "Capacity Building in Higher Education" is to support the development, modernization, and internalization of Software Engineering higher education according to the SWEBOK [1] international standard. The global aim of capacity building would be to change the composition of staff at Higher Education Institutions to make this more representative [2].

1.1 Western Problems

The current postgraduate education system in many countries is still based on an XIX century discipleship model, where elder researchers train younger ones in the craft of research. Although the scientific corporation has changed cardinally since then, the PhD education system mostly has not [3]. Over the past few decades occurred rapid and transformative changes occurred of society and in the institutions created to respond to these needs. As economy changes from based on the production of goods to economy based on the production of knowledge and information, it creates a demand for new types of learners and innovators in every level of education. Employers and administrators in every sector now expect doctoral programs to create well-rounded disciplinary experts who have the ability to be leaders in their fields and are capable of creating real-world value from knowledge and discovery [4].

In spite of these economic realities, university doctoral programs largely continue to view PhD training as a means of reproducing the status quo. Postgraduate study, in an attempt to produce experts, has traditionally recommended doctoral students to dive deeply into a narrow area of specialization over the course of their research [5]. On this way, some may be left with autonomous and narrow areas of expertise at a time when the changing market is demanding specialists who have well-rounded education and integrative skills that have experience with interdisciplinary researches, leadership, and communication skills [6].

1.2 Russian Problems

The situation in Russia is quite different from overproduction of PhD's in Western countries. The reform of higher education in Russia implemented in accordance with the Bologna system had almost no impact on the third level of the Bachelor-Master-Doctorate system. Domestic post-graduate school – especially speaking about the applied disciplines – is considerably less effective than the doctoral training institution of PhD [9]. In accordance with the Federal Law "On Education in the Russian Federation" today only a few of the leading Russian universities (incl. Moscow and St. Petersburg State Universities, Ural Federal University etc) have the right to develop their own educational standards establishing the structure and content of educational programs of their specialization at all levels of higher education. However, the training standard at the level of post-graduate students and PhD students in St. Petersburg State University is currently missing and the University therefore makes efforts to train Russian post-graduate students based on the international standards, especially in the IT-field. In particular, international cooperation is carried out within the framework of the PWs@PhD project aimed at the capacity building in the field of doctoral programs of software development. One of the SWEBOK international standard's areas of study is SWE from the economic and business point of view, which is widely represented in the Faculty of Economics of St. Petersburg State University [7].

1.3 Actuality

The mismatch between the professional skills which contemporary employers expect, and the actual skills with which many doctoral-level programs are equipping PhD students, need to be better investigated and understood. Quantitative data collected by many investigators in previous studies document the existing inconsistencies between the disciplinary skills acquired during doctoral education and the professional skills of demand by the contemporary employers; see for example [6–8], [10]. Researchers studying the roles of postgraduate education in career preparation have commonly relied on questionnaires and surveys as the predominant means of determining PhD graduates' assessments about how well their former doctoral programs prepared them for their current careers. What is almost absent in the literature until this moment (see, however [4]), there are the voices of the PhD doctorants who are currently engaged in the higher level preparation process. The answers following questions of contemporary SWE doctoral students can help to fill this gap and better understand their expectations and representations: which professional skills are PhD students interested in acquiring and how do they feel their programs could be improved.

2 Research Methods

In this first diagnostic stage of the study, we use approach involving a simple quantitative survey of a group of PhD students, a significant part of which is developing in the field of parallel, distributed and cloud computing, who are currently enrolled in SWE-related international programs at the PWs@PhD project of eleven universities from five European countries, Russia and Jordan. The purpose of the quantitative survey is to gather data from participants as well as evaluate their interest to various aspects of professional development.

As the initial stage of the search PhD students themselves under supervision of researches created and presented the list of professional skills outside of their major area of study which will be necessary for them after their complete PhD (Appendix A). The 27-questions survey was drawn up based on the obtained skills list and PhD Focus Group Participant Information Survey for American doctorants from the paper [4]. The survey questions were combined and designed to gather numerical rating scales intended to draw out more specific information about the student's career goals, expectations about being prepared for the job market during postgraduate school, perceived proficiency in various professional skills and interest in gaining additional supplemental skills training. Each of the participants was asked to fill out the survey individually.

Survey items ask participants to rank the types of jobs they will seek after completing their degrees and how prepared they feel for their respective careers. The survey also asks doctorants to describe their proficiency in professional skills and the likelihood they would participate in additional training in those same skills if it were provided.

Analysis of the quantitative survey results consist of comparing the mean scores, standard deviations and correlation of the responses, also the cluster

analysis of the responses using the classic method of Ward. Statistical significance of differences when comparing the responses of various groups of respondents performed using the standard Mann-Whitney U-test [11].

3 Results

The main themes that discovered during the analysis of the received data are presented here in an effort to address the research questions posed by this study.

3.1 Skills Possess vs Skills to Obtain

On the basis of an independent group work 22 PhD students of 11 European universities in the framework of participation in the PWs@PhD project compiled a list of the skills they need for further work, but are not directly related to their course of study and research on SWE specialties (Appendix A). As a result of association without repetitions this list with the similar list for 44 students enrolled in STEM-related PhD programs at a large American university [4], a questionnaire was compiled intended to elicit perceived proficiency in mentioned professional skills and interest in gaining additional skills training.

On the basis of the survey of participants PWs@PhD project, conducted with the help of the developed questionnaire, the skills collected were ranked on the importance in future and on the degree of the present mastering.

Processing and statistical analysis of the results of a survey of PhD-students opinions allowed to identify groups of the most significant skills, to find out the students level of knowledge and mastering these skills and to evaluate the students intention to obtain them.

Fig. 1 shows a diagram that allows to compare the mean values of points for skills that PhD-students possess, and skills they want to acquire in the course of training in the framework of the international PWs@PhD project.

3.2 Skills Desired vs Skills in Demand

It is a common interest to compare the list of skills ranked by students with a list of skills required by employers in the areas close to the SWE. The table "The Most in Demand Skills in 15 Business functions" from [12] shows a ranked list of top baseline skills by career area, highlighting those skills which are more commonly requested, and thus more valued, for each particular group of jobs.

The most suitable for our purposes skills group is highlighted by the authors of the report [12] "Project Management, Research and Strategy Cluster". According to the report, strategy and project management skills such as Research, Project management, Negotiation and Analytic skills are in particular demand among high-skill, highpaying 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

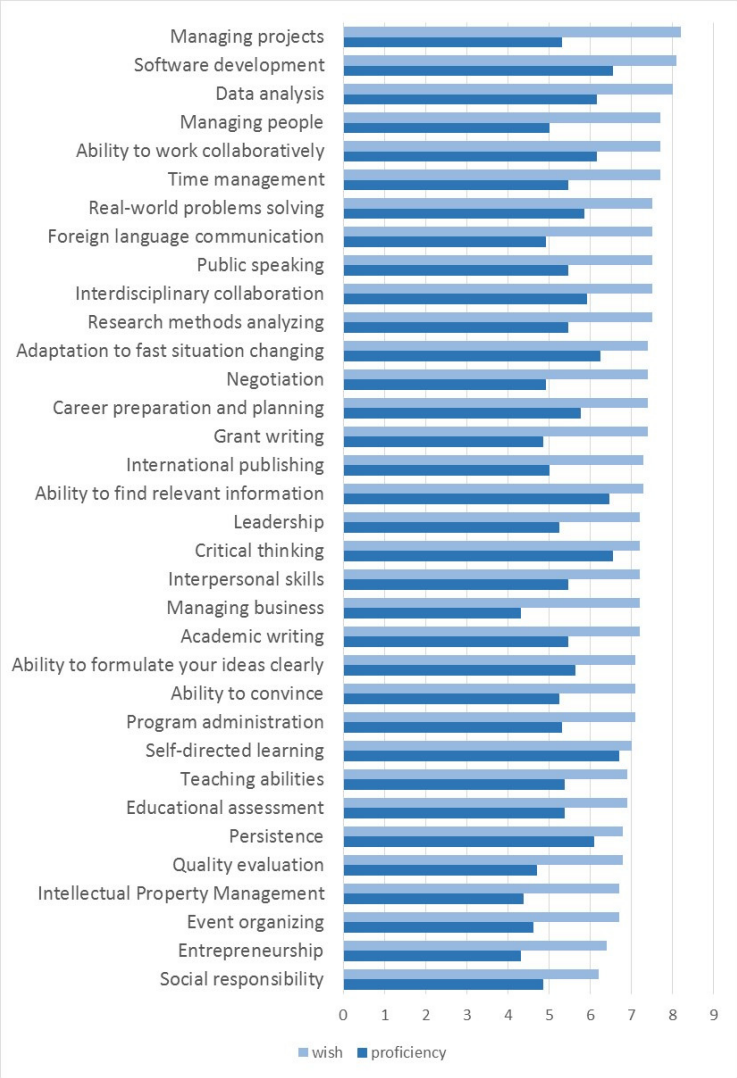

Fig. 1. Mean values of points for every kind of wishing and proficiency skills

on additional responsibilities. Surprising findings for the authors turned that Negotiation skills and Analytical skills, which are not particularly similar skills, cluster closely together in the job market.

Surprising findings for the current study are that skills of this Cluster have the highest scores in students evaluation of desired skills, as one can directly see from the Fig. 1: Research Methods – 7.5 points, Managing Project – 8.2 points, Negotiation – 7.4 points, and Data Analysis – 8.0 points. In general, the correlation between the ranked sets of skills required by employers [12] and

compiled by students (Fig. 1) is: for occupations in the career area of Engineering – 0.37, in the area of Information Technology – 0.34, in the area of Research, Planning and Analysis – 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.

3.3 Advanced Students vs Ordinary Students

Further, cluster analysis of the responses to the survey question number 16 (see Appendix B) allowed to distinguish two groups, which can be called "advanced" and "ordinary" students. The group of "ordinary" students appreciated their existing skills by an average of 3.65 points, a group of "advanced" – by 6.29 points, i.e. almost twice as much. Fig. 2 is a diagram shows the mean values of marks on several skills from the students list for the two groups described above.

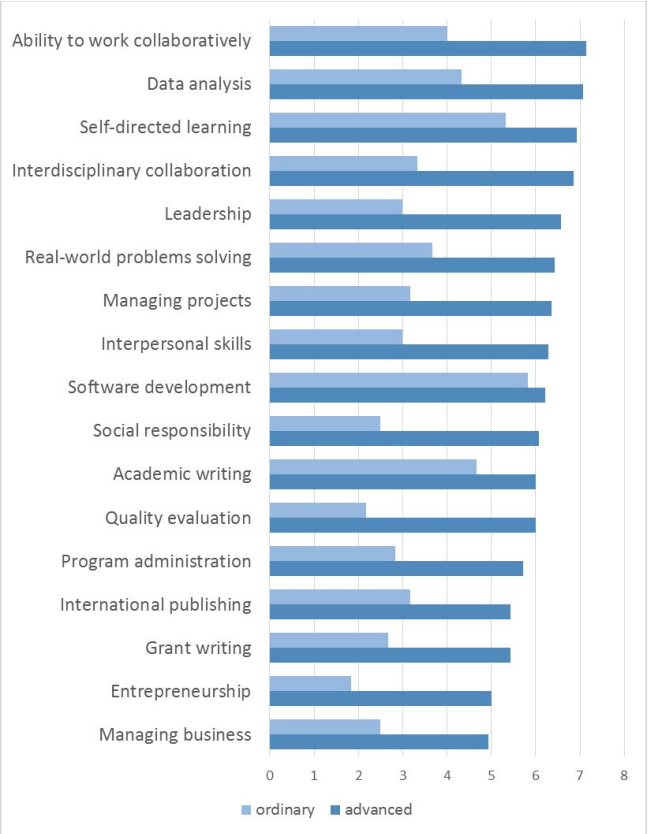

Fig. 2. Difference of two clusters

3.4 Self-Motivated Students vs. Students in Good and Bad Standing

The same cluster analysis of the responses to question 17 of the skills that the PhD-students would like to receive during the international training program (see Appendix B) has revealed three clusters:

1. students in good standing, who interested in all skills,
2. self-motivated students, who interested only in several types of skills,
3. students in bad standing, who do not interested in the most skills.

Averages of mean values of marks for all skills are equal to for the first group – 8.37, for the second – 5.66, for the third – 2.46. Fig. 3 is a diagram showing the average student marks affixed on several skills from the list for three clusters described. This result on the one hand reflects the differential structure of any learning group, on the other hand shows the difference between the perfectionists who want to have excellent grades in all subjects, and experts, which are clearly much focus in the direction of their work and the problem area of their research.

Fig. 3. Difference of three clusters successful, self-motivated and poor students

3.5 All Are Equal

In addition, we compared the marks exhibited by doctorants from Russia and from other countries. The result is that for each skill difference the responses between Russian and foreign students are statistically not significant either as a result of the responses to question 16, nor on the results of the responses to question 17. Moreover, a set of skills that students possess, and a set of skills that they would like to acquire, is the same for all countries.

4 Conclusions

According to the results of the study, we formulate the following conclusions.

1. The Lists of professional skills outside of the major STEM area of PhD studies which will be necessary for further work are significantly different for European doctorants (Appendix A), American doctorants [4] and American employers [12].
2. Students have practical sense to pay attention to the knowledge and skills not directly related to the special disciplines taught. It could be recommended to teachers to include in the process of preparation PhD students additional forms of work and activities which are not directly related to traditional academic learning process but allow to develop the necessary skills for postgraduate work.
3. Skills such as Supervision, Negotiation, Analysis, Research, and Project management become increasingly critical for graduates who want to advance into management. Developing experience in these areas will help PhD students prove to employers that they have the required skills.
4. International training programs for PhD students similar to PWs@PhD project increase the development of practically useful skills outside the scope of academic activities.

Further examination of these themes seeks to develop a better understanding of student perceptions about which skills will be most useful in their future careers, and which factors affect their learning and career preparation behaviors and influence the kinds of knowledge and skills they actively seek to acquire during international schools of the PWs@PhD project.

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A The Skills

List of professional skills outside of the major Software Engineering area of PhD studies which will be necessary for further work.

1. Leadership
2. Managing people
3. Managing business
4. Managing projects
5. Time management
6. Software development
7. Program administrating
8. Interdisciplinary collaboration
9. Grant writing
10. Public speaking
11. Communication
12. Foreign language communication
13. Intercultural communication
14. Quality evaluation
15. Negotiation
16. Academic writing
17. International publishing
18. Interpersonal skills
19. Persistence
20. Critical thinking
21. Ability to formulate ideas clearly
22. Ability to convince
23. Ability to find relevant information
24. Adaptation to fast situation changing
25. Ability to work collaboratively
26. Career preparation and planning
27. Intellectual Property Managing
28. Entrepreneurship
29. Social responsibility
30. Teaching abilities
31. Educational assessment

B The Survey

16. Please rate your proficiency in the following professional skills outside of your major area of study which you are acquiring in your university during PhD program, on a scale of 1-10:
    (1) – Not proficient at all, (10) – Extremely proficient.
17. Please rate how likely you would be to participate in training related to the following professional skills, if it were made available to you as part of your doctoral program, on a scale of 1-10:
    (1) – Unlikely, (10) – Extremely likely.