Industry Feedback on Skills and Knowledge in Real-Time Software Engineering

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***Abstract*—Rapid progress of computing technologies is the major reason that the programs like electronics, computer and software engineering, robotics and control engineering need continuous updates. This paper is related to the development of an international curriculum in real-time software engineering. It focuses on identification of skills, attitude and knowledge the students need to acquire to become efficient engineers working in the field. To facilitate this objective, a survey administered to industry representatives in four countries is described and its results are discussed.**

I. Introduction

Technology progress has significant impact on engineering curricula which require continuous modification designed to prepare students for technological challenges of the modern workplace. Rapid progress of computing technologies is the major reason that the programs like electronics, computer and software engineering, robotics and control engineering need continuous updates.

The faculty experience allows them to design curricula considering the fundamental concepts and basic principles of the discipline. However, the feedback from future student employers is critical to design modern curriculum fully matching continuously changing job market demands. A survey was designed to get this feedback from specific sector of industry regarding what the employers expect graduates to have in terms of skills and attitudes as well as knowledge of technical topics. This internet-based survey was solicited from a representative sample of industry engaged in real-time software-intensive control systems. The collected data were analysed and the results will be used to help identify academic program educational outcomes and objectives thus preparing a base for creation of a new curriculum framework. The presented paper describes the background, the survey administrations and results.

II. Survey organization

The survey was designed as result of discussion among the ILERT project partners.

The survey was placed on the web server and the participants were invited via e-mail, phone, and personal contact to login to the survey site and provide their responses. The survey data were collected in a data base for subsequent processing.

The respondents reflected international composition of the ILERT project representing four countries: Czech Republic, France, Poland and USA. It needs to be noted, that we had relatively weak response rate upon the initial e-mail solicitation. The reason was that in many cases the mailing was intercepted by spam filters, the respondents were too busy to commit about 15-20 minutes to fill the survey. Occasionally, the survey reached individual who was not prepared to provide required information. Repeated contacts and follow-ups allowed us to receive enough data to consider the results as valid.

Eventually, as a response to over 370 solicitation we received 43 responses (11% response rate). We are grateful for the companies who took part in the survey and provided us with a valuable feedback. The names of companies are listed in Table I.

TABLE I
ILERT Survey Companies

Country	Company Name
USA (12)	Avidyne, Raytheon, Hawker Beechcraft Corporation, Stuart W. Law Company, Boston Scientific, Teledyne Controls, Boeing, Honeywell Aerospace, Hamilton Sundstrand
Poland (14)	CSN-STANEL Automatyka, ABB Corporate Research, Astor, Abis, RAControls, InTeCoFEV Polska, Pumpa, Tarbonus, Multiprojekt, Computer Systems for Industry, ComArch, INVENTIA, MPL Technology
Czech Republic (10)	Tescan, ANF DATA, B+R Automatizace, Honeywell, Freescale Czech Republic, ADC Czech Republic, CAMEA, Flextronics Design, ANeT Ltd., Schneider Electric CZ
France (7)	CIRTEM, National Research and Safety Institute, ST Microelectronics, IRSN Radioprotection and Nuclear Safety French TSO, Leroy Somer, Airbus S.A., Euro-Systems

The final version of the survey included two main categories:

Part A - General Skills and Attitudes (10 items)

Part B - Technical Knowledge Areas (15 items)

In Part A the issue was to find importance of general skills, capabilities and attitudes of engineering school graduates when they enter the job market. The items in Part A were:

1. *Work as a part of a multidisciplinary team*
2. *Analyse, understand and define the problem*
3. *Think independently and search for solutions*
4. *Make oral presentations*
5. *Write technical reports and papers*
6. *Communicate with people and present arguments*
7. *Communicate in a foreign language*
8. *Lead a team*
9. *Understand value and cost*
10. *Experience international, social, cultural and political issues*

Similarly, Part B included items related to specific technical areas and skills. The items were:

1. *Good background in mathematics*
2. *Familiarity with a specific application domain*
3. *Knowledge of control theory, algorithms and applications*
4. *Knowledge of system specification and design methods*
5. *Knowledge of hardware design and development concepts, methods and tools*
6. *Knowledge of software design and development concepts, methods and tools*
7. *Knowledge of formal methods applied to system development*
8. *Experience with hardware development platforms (e.g. FPGA, PLC, microcontrollers, I/O devices)*
9. *Knowledge of networking components, topologies and communication protocols*
10. *Proficiency in software program construction (programming language)*
11. *Understanding the concept of real-time systems (timing, scheduling, RTOS services)*
12. *Familiarity with software development tools and development environments (integrated development environment - IDE, compilers/interpreters, simulators, emulators, code/test generators)*
13. *Knowledge of system development process and project management*
14. *Experience with hardware/software integration, including testing and verification*
15. *Knowledge of quality control, validation, verification, and certification (e.g. for dependable systems)*

In both Part A and Part B, the responses could be selected as: *Essential*, *Important*, *Unrelated*, and *Unimportant*, with a possibility to provide comment.

In addition to selecting responses in Parts A and B, the survey included Part C, where responders were asked to create a "wish list" i.e. to rank the first three items in each category according to their importance for the need of their company. In Part D, the survey asked respondents to fill information regarding the company profile, size, type of projects, etc. This information is treated confidentially to be used only to analyse and create aggregated results.

III. Results

Results of our survey will be presented in two parts: the first one – general – answers to part A and B will be presented and summarized, and the second one – detailed to countries – answers will be grouped by the company location. To support the analysis the following indices were computed:

$$J_1 = \sum_{i=1}^{4} N_{\{i\}} W_{\{i\}} \quad (1)$$

$$J_2 = \sum_{i=1}^{2} N_{\{i\}} \quad (2)$$

$$J_3 = \sum_{i=3}^{4} N_{\{i\}} \quad (3)$$

where: $N_{\{.\}}$ - is the number of selected Essential {es}, Important {imp}, Unimportant {unimp} and Unrelated {unrel} answers, $W_{\{.\}}$ – is the answer weight specified with the following rule: Essential [5], Important [1], Unimportant [–1] and Unrelated [–1], i : {1≡es, 2≡imp, 3≡unimp, 4≡unrel}.

Distinguishing between two "positive" responses (Essential, Important) and two "negative" (Unimportant, Unrelated) and computing separate sums (J_2 and J_3) it is easy to notice which of the survey items are critical, which is not so clearly visible when considering only total sum (J_1).

The objective of ranking part of the survey was to assess which of the items are the most critical for a specific company. The ranking identifies what the employers look in potential job candidates in terms of knowledge, skills and personal attitudes.

For the ranking analysis, the score points were specified as: rank 1 – 10 points; rank 2 – 8 points; rank 3 – 6 points. It was necessary to introduce total factor due to same number of selections for many questions. The first place in the ranking was analysed separately due to summarized fuzziness.

A separate analysis was done by the country of responders. The computed percentage ratio shows the ranking across the countries. Ranking was computed as

$$S_i = 10N_{i,I} + 8N_{i,II} + 6N_{i,III}$$

where $N_{i,j}$ identifies the frequency of i-th item be placed on j-th position (j = I, II, III).

For each of the items (N_a=10 from Part A and N_a=15 from Part B) the total was computed as:

$$J_{4,i} = 100\frac{S_i}{\sum_{j=1}^{Na} S_j}$$

IV. Survey Analysis - part A

A. Computed Index Table (Part A)

The key items identified as the result of analysis (see table II) were:

- A2 - Analyse, understand and define the problem
- A6 - Communicate with people and present arguments
- A3 - Think independently and search for solutions

- A1 - Work as a part of a multidisciplinary team

The items identified as low priority were:

- A10 - International social, cultural and political issues
- A8 - Lead a team
- A9 – Economics, value and cost

TABLE II
INDEX TABLE PART A

Item \ Quality	J_2	J_3	J_1
1	1	42	97
2	0	43	**155**
3	1	42	**121**
4	16	27	31
5	5	38	57
6	0	43	**131**
7	13	30	69
8	23	20	5
9	23	20	5
10	28	15	-1

B. *Ranking (Part A)*

TABLE III
RANKING TABLE PART A

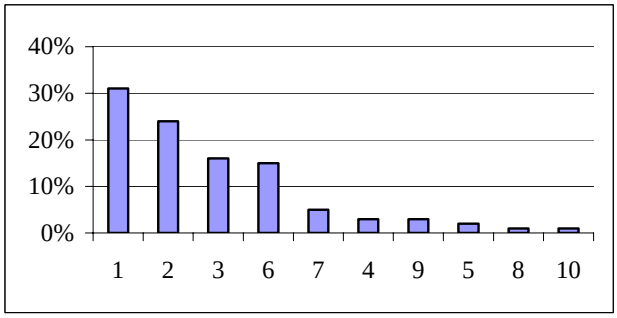

Fig. 1 Items sorted according to their ranking score $J_{4,i}$ (part A)

The highest score received items related to understanding, problems solving, creativity and teamwork. The responses underscore the need for employees capable of communicating and using modern technologies.

C. *Country oriented analysis (Part A)*

TABLE IV
COUNTRY PREFERENCE TABLE PART A

Country	J_1	Questions in order		
USA	Positive	1, 6	3	2
	Negative	7	10	8
PL	Positive	2	3, 6	1
	Negative	10	9	8
CZ	Positive	2	7	3
	Negative	10	8	9
FR	Positive	6, 2	7	1, 5
	Negative	9	10	

The country-based analysis presents the responses based on index J1. Country ranking shows that the highest ranking are consistent with these identified in earlier analysis: multidisciplinary teamwork, problem solving, and creative thinking and communication skills. USA and France responders put slightly more stress on the multidisciplinary and team aspects of the work. European countries seem to weight more in problems solving skills.

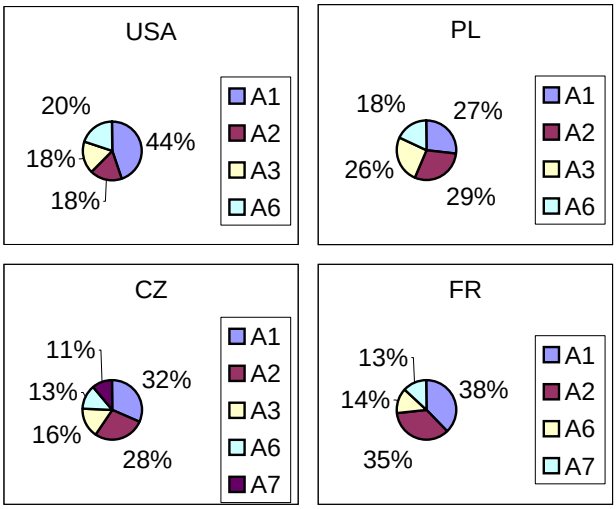

Fig. 1 Country oriented ranking (items from part A)

V. SURVEY ANALYSIS - PART B

A. *Computed Index Table (Part B)*

TABLE V
INDEX TABLE PART B

Item \ Criterion	J_2	J_3	J_1
1	29	14	43
2	26	17	29
3	36	7	61
4	37	6	**99**
5	30	13	61
6	36	7	**113**
7	26	17	13
8	32	11	53
9	32	11	45
10	36	7	**85**
11	28	15	61
12	34	9	65
13	35	8	63
14	39	4	79
15	36	7	61

The key items identified as the result of analysis in technical domain area (Table V) were:

- B6 - Software design and development concepts, methods and tools

- B4 - System specification and design methods
- B10 - Software program construction
- B14 - hardware/software integration, including testing and verification

The items identified as low priority were:

- B7 - formal methods applied to system development
- B2 - specific application domain familiarity

B. *Ranking (Part B)*

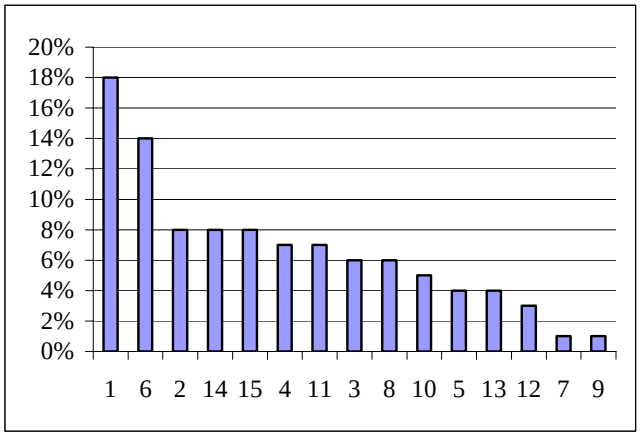

Fig. 2 Items sorted according to their ranking score $J_{4,i}$ (part B)

The highest score received items related to knowledge of methods and techniques related to software and system design and development. The responses underscore the industry need for employees capable of "hitting the ground running" when facing new project and adapting to new development environment.

C. *Country oriented analysis*

TABLE VI
COUNTRY PREFERENCE TABLE PART B

Country	J_1	Questions in order		
USA	Positive	6	10	11
	Negative	2	5	7
PL	Positive	4	5	6
	Negative	1	7	11
CZ	Positive	10	6	11
	Negative	13	7	5, 10
FR	Positive	15, 4	13	5,6, 13
	Negative	2	10	11, 12

In the technical domain area, country ranking shows slight inconsistency. The highest ranking was related to knowledge of software design and development concepts, methods and tools. However, close second was knowledge of mathematics not showing high in earlier analysis. These two items are leading in responses from USA and Czech Republic. French and Polish responders have selected variety of items not giving clear preferences to particular one.

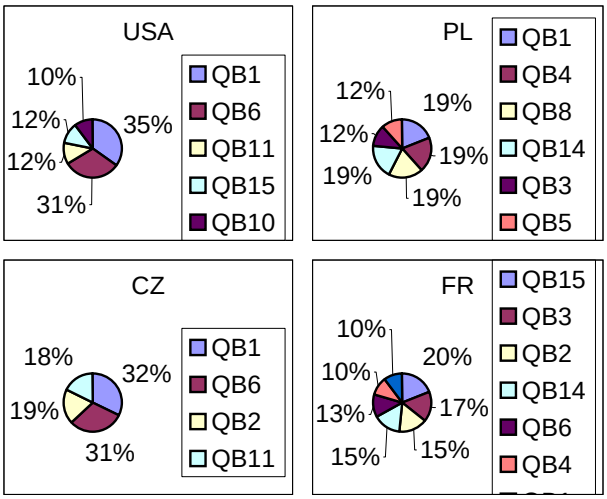

Fig. 3 Country oriented ranking (items from part B)

VI. CONCLUSIONS

It is interesting to note that USA companies are in favour of multidisciplinary teams, while for Europeans the issue does not seem to be critical.

Another interesting result shows the difference between Eastern Europe and France regarding the item "analyse, understand and define the problem". Could we draw conclusion how well elementary and high schools are preparing students in the fields of mathematics and physics. Howe well are they prepared for university challenges of logic problems solving, presentation and individual creative thinking?

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