

ENGINEERING STUDY PROGRAM COMPLIANCE EVALUATION TO GUIDELINES FOR SOFTWARE ENGINEERING CURRICULUM

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Abstract. Improvement of engineering study programs in relation to constant changes to company and organization wishes, association guidelines, student demands, university policies, etc. raise various difficulties. Information and communications technology (ICT) industry is developing in a fast pace and requirements for skills and knowledge expected from graduates are constantly changing. The leading ICT Association for Computing Machinery (ACM) and the Institution of Electrical and Electronic Engineers (IEEE) joined forces to develop multiple documents that are regularly revised, published and available to public and include guidelines for development of undergraduate level study programs curricula. These documents cover such ICT fields as computing, computer engineering, computer science, cybersecurity, information systems, information technology and software engineering. In this article software engineering undergraduate study program compliance with ACM and IEEE guidelines executed at the Latvia University of Life Sciences and Technologies (LLU) has been evaluated and compared to similar programs at the University of Ostrava, the University of Malaga and the University of Debrecen. Compliance is evaluated using ACM and IEEE defined knowledge areas that must be included in the curricula, including computing essentials, mathematical and engineering fundamentals, software modelling and analysis, requirements analysis and specification, software design, software verification and validation, software process, software quality and security. The study program knowledge area share compliance with ACM/IEEE guidelines is calculated and association by the Spearman's rank correlation coefficient is presented. The results show that the Latvia University of Life Sciences and Technologies, the University of Debrecen and the University of Ostrava study program design is in compliance with ACM/IEEE guidelines.

Keywords: engineering study, ACM guidelines, software engineering.

Introduction

Information and communications technology (ICT) field takes a significant role in business processes around the globe. There is a lack of employees in the field and demands in certain countries are higher than average. Latvia is one of the countries where industry demand for ICT degree graduates is increasing and according to the Europe Commission Skills Panorama data [1] future employment growth average in Latvia over the period 2016-2030 is estimated at -1.6 %. However, maximum growth is 50.1 % for ICT services. The ICT services' index is considerably above the other sectors and highest estimated in the European Union. Universities face challenges to meet industry and government demands for the amount of graduates in the ICT field. According to the Latvia Ministry of Education and Science data annually all Latvia higher education institutions (HEI) provide 670 ICT field bachelor level graduates and it is necessary to increase the amount of graduates up to 3000 per year [2]. Besides, industry emphasizes various skills that need to be acquired during studies. These skills also relate to technologies that are used by certain companies. To meet the industry demands the biggest engineering associations ACM and IEEE have joined forces to develop curricula recommendations for ICT education starting from kindergarten until undergraduate and Master degree [3]. These guidelines have been used in the research to examine the study course compliance [4] and to develop a technology stack design for study purposes [5]. Curricula recommendations are also for accreditation purposes to develop criteria for accreditation of undergraduate programs in the United States [6]. In 2017, ACM and IEEE developed a curricular report titled Information Technology Curricula 2017: Curriculum Guidelines for Baccalaureate Degree Programs in Information Technology, known also as IT2017 [7], which are widely discussed and considered a solid foundation for Information Technology program development [8]. Curricula recommendations are kept in constant update. At the moment there is a project to prepare ACM Computing Curricula 2020 [9]. Following certain curriculum design guidelines can improve student mobility program execution, as institutions could easier perform matching of subjects and credit point transfer between universities. An example could be ERASMUS program for student mobility, where protocol of intention and protocol of mobility recognition can be developed easier, if partner programs follow international guidelines for curriculum development.

Software engineer is one of the most demanded specialists from the group of ICT specialists. Also in Latvia software engineer is the most demanded specialist for the past 3 years based on the data from the Employers' Confederation of Latvia surveys [10]. In the field of Software Engineering the latest curricula recommendations are published in 2015 [11].

The aim of this paper is to analyze undergraduate study program compliance to ACM and IEEE Software Engineering curricula recommendations.

Materials and methods

In this research the undergraduate study program Information Technologies for Sustainable Development, executed at the Latvia University of Life Sciences and Technologies (LLU) compliance to ACM and IEEE guidelines for Software Engineering is analyzed. The study program is 4 year program that awards the bachelor degree in computer science with profession Software Engineer. We also analyze 3 more ERASMUS partner university Software Engineering programs compliance to discuss the possible similarities to ACM and IEEE guidelines.

The following undergraduate study programs were chosen for this comparison:

- Software Engineering, University of Malaga (UMA).
- Computer Science and Technology, University of Ostrava (OSU).
- Computer Science, University of Debrecen (UNIDEB).

These programs are selected based on Information Technologies for Sustainable study program student mobility frequency using ERASMUS program.

ACM and IEEE Software Engineering curricula guidelines [11] define the knowledge areas that must be included in the curricula:

- Computing essentials.
- Mathematical and engineering fundamentals.
- Software modelling and analysis.
- Requirements analysis and specification.
- Software design.
- Software verification and validation.
- Software process.
- Software quality.
- Security.
- Professional Practice.

Guidelines define hours that must be present for each of the knowledge areas. Each knowledge area is described in detail, mentioning the topics that must be discussed in each area. Based on these topics we mapped the study course of each study program to ACM/IEEE knowledge areas using the course content and learning outcomes.

Professional practice and graduation thesis preparation are avoided in this research, because of ambiguous definition by universities and ACM guidelines. ACM guidelines consider Professional Practice more as communication skills improvement, team work, etc. For universities typically Professional Practice is more internship in a company where students work on real projects, which also involve the skills defined by ACM, but not fully cover them. Graduation thesis can be mapped to multiple knowledge areas so for more clear result representation graduation thesis is avoided.

To further investigate the compliance we introduced three META knowledge groups and arranged the knowledge areas in these groups:

- Computer Science Foundation knowledge group, consists of Computing essentials, Mathematical and engineering fundamentals.
- Software Development knowledge group, consists of Software modelling and analysis, Requirements analysis and specification, Software design.
- Software Quality Verification knowledge group, consists of Software verification and validation, Software process, Security, Software quality.

Compliance is calculated as share in percents by the META knowledge areas and ACM/IEEE guidelines. Spearman's rank correlation is applied to test the study program knowledge areas share. The Spearman's rank correlation coefficient is non-parametric test used to measure the strength of association between two variables.

Results and discussion

Table 1 shows the study program knowledge areas share in percents and compliance with ACM/IEEE guidelines. It can be seen that some knowledge areas are not covered in certain study programs. The programs that fully cover all knowledge areas include Information Technologies for Sustainable Development at LLU and Software Engineering at the University of Malaga.

Table 1
Study programs knowledge areas share (%) compliance with ACM/IEEE guidelines

Knowledge areas	ACM/IEEE guidelines	LLU	UNIDEB	OSU	UMA
Computing essentials	34.7 %	57.9 %	44.6 %	61.6 %	41.9 %
Mathematical and engineering fundamentals	18.3 %	11.4 %	16.1 %	15.1 %	7.0 %
Software modelling and analysis	6.4 %	4.7 %	0.0 %	2.7 %	4.7 %
Requirements analysis and specification	6.8 %	5.1 %	3.6 %	3.4 %	4.7 %
Software design	11.0 %	7.6 %	21.4 %	11.6 %	25.6 %
Software verification and validation	8.4 %	3.8 %	5.4 %	0.0 %	2.3 %
Software process	7.5 %	1.9 %	1.8 %	2.7 %	4.7 %
Security	4.6 %	3.8 %	5.4 %	2.7 %	2.3 %
Software quality	2.3 %	3.8 %	1.8 %	0.0 %	7.0 %

Figure 1 shows that all study programs analyzed cover META knowledge groups. The University of Ostrava has most emphasis on Computer Science Foundation with 76.71 % from all study courses while the University of Malaga has most emphasis on Software Quality Verification (16.28 %) and Software Development compared to other universities. At the same time the LLU study program has similar META knowledge group share distribution as UNIDEB and OSU study programs.

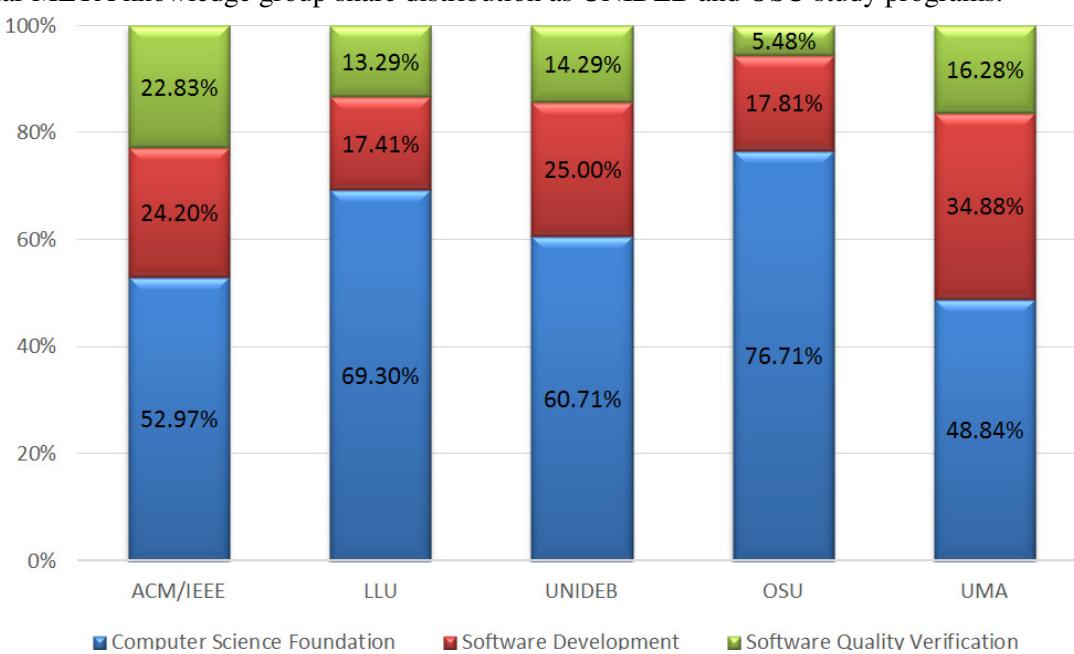


Fig. 1. ACM/IEEE guidelines and study program META knowledge areas share (%) by groups of knowledge areas

The hypothesis about the study program compliance with ACM/IEEE guidelines has been put forward and the distribution of knowledge groups and knowledge areas for all study programs has been checked. LLU study program's Computer Science Foundation knowledge areas are similar to OSU study programs and have higher impact to curricula comparing to ACM/IEE guidelines (Fig. 2).

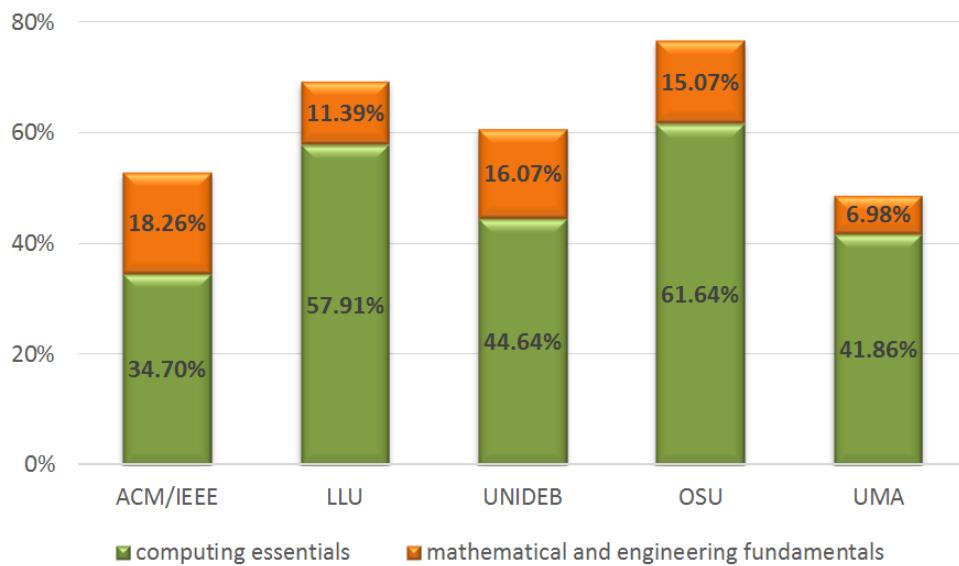


Fig. 2. ACM/IEEE guidelines and study program Computer Science Foundation META knowledge areas share (%)

In turn, LLU study program Software Development knowledge areas are more similar to ACM/IEE guidelines in comparison to other universities study programs, where UNIDEB study program has not the software modelling and analysis knowledge area at all, but UMA and UNIDEB study programs have significant share of the software design knowledge area (Fig. 3).

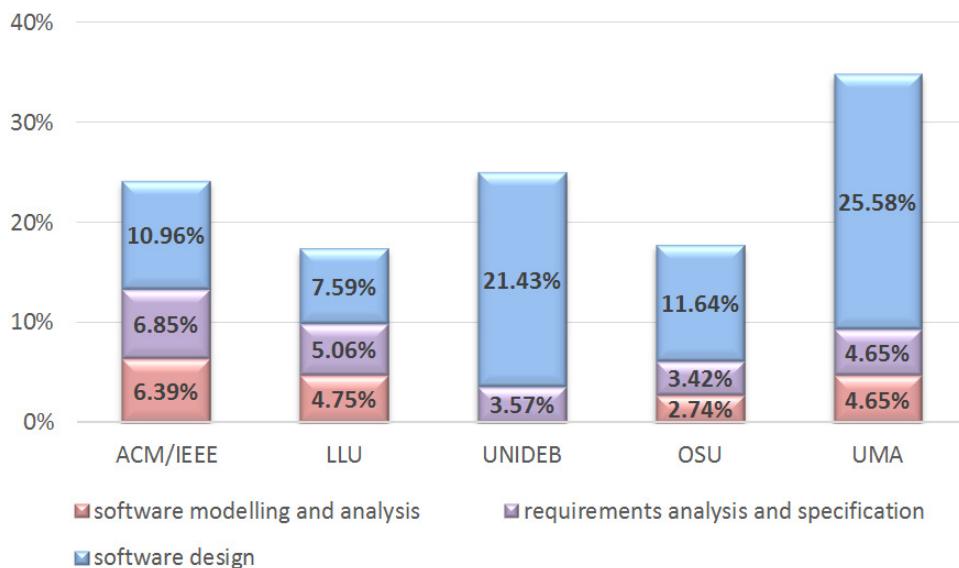


Fig. 3. ACM/IEEE guidelines and study program Software Development META knowledge areas share (%)

Software Quality Verification knowledge areas distribution shows that the LLU study program is more similar to UNIDEB study program, but compliance with ACM/IEEE guidelines is under the question (Fig. 4).



Fig.4. ACM/IEEE guidelines and study program Software Quality Verification META knowledge areas share (%)

In total 9 knowledge areas are distributed between 3 knowledge groups by different shares for all analyzed universities study programs and the hypothesis about the study program compliance with ACM/IEEE guidelines can be tested using the Spearman's rank correlation coefficient. The higher is the value of the correlation coefficient, the higher is the association between the knowledge areas shares of two study programs or ACM/IEEE guidelines (Table 2).

Table 2

Study program knowledge areas share (%) association by Spearman's rank correlation coefficient

Parameter		LLU	UNIDEB	OSU	UMA
ACM	Correlation Coefficient	0.678*	0.773*	0.741*	0.522
	Sig. (2-tailed)	0.045	0.015	0.022	0.150
	n	9	9	9	9
LLU	Correlation Coefficient	-	0.684*	0.866**	0.704*
	Sig. (2-tailed)	-	0.042	0.003	0.034
	n	-	9	9	9

Notes:

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The Latvia University of Life Sciences and Technologies ($r_s = 0.678$), the University of Debrecen ($r_s = 0.773$) and the University of Ostrava ($r_s = 0.741$) study programs have a similar knowledge areas share (%) to ACM/IEEE guidelines, besides, the similarity between the Latvia University of Life Sciences and Technologies and other universities is higher to the University of Ostrava study program ($r_s = 0.866$).

The results show that there is significant association of the Latvia University of Life Sciences and Technologies ($p\text{-value} < 0.05$), the University of Debrecen ($p\text{-value} < 0.05$) and the University of Ostrava ($p\text{-value} < 0.05$) study program knowledge areas share (%) to ACM/IEEE guidelines, except the University of Malaga study program ($p\text{-value} = 0.15$).

Conclusions

1. The Latvia University of Life Sciences and Technologies, the University of Debrecen and the University of Ostrava study program design is in compliance with ACM/IEEE guidelines. Compliance is evaluated using ACM and IEEE defined knowledge areas that must be included in the curricula, including computing essentials, mathematical and engineering fundamentals, software modelling and analysis, requirements analysis and specification, software design, software verification and validation, software process, software quality and security.
2. Study program knowledge areas share compliance with ACM/IEEE guidelines is evaluated by the Spearman's rank correlation test and the results show that compliance is significant for the Latvia University of Life Sciences and Technologies, the University of Debrecen and the University of Ostrava study programs.
3. The highest similarity is between the Latvia University of Life Sciences and Technologies and the University of Ostrava study programs with the Spearman's rank correlation coefficient $r_s = 0.866$.
4. The applied method of program evaluation in regards to compliance with ACM/IEEE guidelines can be applied in further research, analyzing study course contents and to prepare study programs for accreditation.

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