Enhancing the Software Engineering Curriculums: A Case Study of the Jordanian Universities

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Abstract

Software Engineering is about creating high-quality software in a systematic, controlled, and efficient manner. Although the Software Engineering discipline had been recognized since 1968, there is still no agreement among the Universities worldwide about what should be included in the Software Engineering curriculums or study plans. This problem has resulted in that different knowledge areas are being taught to the Software Engineering students in different universities. Also this problem has resulted in that many universities now include courses in the Software Engineering curriculum that are not related to Software Engineering. A case study of the Jordanian Universities had proved that more than 60% of the courses taught at the Software Engineering departments of the Jordanian Universities are non Software Engineering related courses. An analysis had been conducted to compare the current Software Engineering courses taught at the different Jordanian Universities and the guidance provided by the ACM/IEEE about what should constitute an undergraduate Software Engineering education. Also an analysis of the Software Engineering courses taught at different countries such as UK and USA had been conducted where these countries were chosen because they contain many of the top ranked Universities in the world. The analysis had resulted in determining the knowledge areas that should be added to the curriculum of each Jordanian University. Enhancing the curriculum will result in a SE graduates that are equipped with the needed knowledge to join the software market.

1. Introduction

Software plays a central role in almost all aspects of our daily lives such as in banking, education and medical fields. This great role increased the demand of the market for Software Engineering (SE) skilled graduates; based on the authors long experience in the SE education field in Jordan; only small portion of those graduates engaged in the SE market and the others are discovering soon that they are not prepared enough for filling software engineering jobs. There are many causes of this problem and these problems will be specified in details in Section 2.

The case study that will be used throughout this research is the Jordanian Universities; Jordan has a total of 18 universities. All of these universities have computer science departments but only 13 universities have SE departments. The remaining universities are about to open a SE department in the near future because this branch of science is gaining lots of interest among the students and academic staff recently. Only 3 of the 18 Jordanian Universities has departments that afford Master's degrees in SE; however, many Universities will open such departments in the near future.

After analyzing the courses taught at the 13 SE departments in the Jordan Universities it was noticed that more than 60% of the courses are not SE related courses but rather Computer Science (CS), Mathematics and non computers related courses such as languages, humanity, social, health etc.

Jordanian Universities SE departments suffer also from the inconsistency problem where different SE related topics are taught in different universities, besides many of the SWEBOK knowledge area are not covered by these departments.

The previous problems, among other problems such as not including real projects from the software market, are increasing the chasm between the SE graduates and the needed qualifications by the SE market.

In this research the percentage of the SE courses to the non SE courses will be analyzed for the different Jordanian Universities (Section 3.1). Also the same analysis will be conducted for a sample of the SE department in UK and USA; where these countries were used specifically because they contain many of the top ranked universities around the world (Section 4 and 5). It must be mentioned here that this research will only consider the SE curriculums and the CS's.

For each SE department at the Jordanian Universities; the SE knowledge areas that are specified by SWEBOK and that are not covered by this University's curriculum will be analyzed in order to conclude the courses that should be added to the SE curriculum at each department (Section 3.2).

This paper makes the following main contributions:
- Analysing the percentages of the SE courses to non SE courses in the Jordanian as well as a sample of UK and USA universities.
- Analysing the uncovered knowledge areas by the Jordanian universities depending on the SWEBOK.
- Addressing the SE education weaknesses in Jordan and suggesting solutions accordingly.

2. The Problems

The main problems that are facing the SE education in Jordan are the following:
- More than 60% of the courses taught at the SE departments are non SE courses.
- None of the 13 SE departments at the Jordanian Universities cover all of the knowledge areas suggested by SWEBOK.
- There are great inconsistencies among the SE courses taught at the different universities.
- Most of the learning is theoretical and there is no incorporation of real projects or case studies from the Jordanian or global software market.
- Most of the academic staff teaching the SE courses are of non SE education background such as CS or even mathematics.
- The accreditations committees of the Jordanian Universities imposes many of the courses that should be taught in the SE departments and many of these courses are non SE related courses.
- There is no clear understanding of what the term "Software Engineering" means; some of the academics and students relate it to CS and others to Engineering.

3. Jordanian Universities SE Analysis

The proposed solutions to the problems in Section 2 will depend on the following activities.
- Analyzing the percentages of SE courses to non SE courses at each SE department at the Jordanian Universities as well as a sample of UK and USA universities.
- Analyzing the Software Engineering curriculums for the Jordanian as well as the sample of UK and USA universities in order to conclude the courses that must be added to the curriculum to cover all the knowledge areas suggested by SWEBOK.
- Comparing the SE courses at Jordan Universities with the courses taught at sample of the UK and USA universities.
- Reviewing the literature related to SE education in order to know the ideas and the needed courses in SE that are suggested by the experienced people in the field of SE education.

These activities will be discussed in the following sections:

3.1 Analyzing the Percentages of SE Courses at the Jordanian Universities

Table 1 below summarizes the percentages of the obligatory and selective SE courses to the non SE courses at each of the SE departments of the Jordanian Universities.

Jordanian universities SE departments have both obligatory courses as well as selective courses; the best scenario for SE occurs when the student selects all of his/her selective courses as SE core courses while the worst scenario to SE occurs when a student selects all of the selective courses as non SE core courses. In Table 1 the percent of the SE courses is the average of the best case scenario and the worst case scenario.

Table 1: Percentages of SE to non SE courses in the Jordanian Universities

University	Percent of SE Courses	Percent of CS Courses	Present of other courses
Philadelphia	0.455	0.227	0.318
JUST	0.432	0.295	0.273
Petra	0.284	0.307	0.409
Alhussien bin Talal	0.307	0.400	0.293
Applied Science University	0.352	0.330	0.318
Jadara	0.364	0.295	0.341
Alzaytoneh	0.341	0.318	0.341
Princess Sumyah	0.307	0.330	0.363
Alzarqaa	0.295	0.307	0.398
Al-Balqaa	0.364	0.364	0.272
Hashimit	0.364	0.300	0.336
Amman Alahlia	0.318	0.330	0.352
Israa	0.352	0.307	0.341
Average	0.349	0.316	0.335

Table 1 reveals the following results:
- The percentages of SE and CS courses at SE department at Jordanian University are almost the same as the percentage of the non computers related courses.
- For many Universities the percentages of non computers related courses are even higher than the SE courses percentage.
- In most Universities the CS courses have the highest percentages.

Shortly, SE departments at the Jordanian Universities emphasize the non Computer related course and give these courses the same or even higher percentages comparing to the SE and CS courses. This issue will result in producing SE graduates that are not equipped with the needed SE knowledge to join the software market.

3.2 Analyzing the SWEBOK Knowledge Areas That Are Not Covered by the Jordanian Universities

It was concluded in Section 3.1 that the percentages of non computers related courses are very high comparing to the SE and CS courses; this section will discuss the knowledge areas of SWEBOK that are not covered by the Jordanian Universities and that can be added to the curriculums of each of these Universities instead of the non computer related courses in order to reduce the chasm between the graduates and the market needs.

Table 2 below summarizes the SWEBOK knowledge areas that are not covered by each of the different SE departments at the Jordanian Universities.

The (✓) character indicates that this specific knowledge area is not covered by a university.

It must be noted that some knowledge areas could be covered by more than one course; however, this research only compares the name of the knowledge area with the names of the courses in the SWEBOB with the names of the courses in the SE curriculums.

Table 2: Unsupported knowledge areas in SE in the Jordanian Universities

Univ.	SW Req.	SW Des-ign	SW Constru-ction	SW Test-ing	SW Mainte-nance	SW Configur-ation Manage-ment	SE Manag-ement	SW Enginee-ring Process	SE tools and met-hods	SW Qua-lity	Total
Philade-lphia						✓				✓	2
JUST			✓			✓		✓			3
Petra			✓		✓			✓			3
Alhus-sien bin Talal					✓	✓		✓			3
Applied Sciences			✓			✓		✓			3
Jadara	✓				✓	✓		✓			4
Alzayton-eh						✓		✓	✓	✓	4
Princess Sumyah					✓	✓		✓	✓		4
Alzarqaa	✓				✓	✓		✓	✓		5
Al-Balqaa		✓	✓			✓				✓	4
Hashimit					✓	✓		✓	✓		4
Amman Alahlia		✓	✓			✓		✓	✓		5
Israa			✓			✓		✓			3
Average											3.6

The following results can be concluded from the analysis in Table 2:
- There are great inconsistencies by the covered SWEBOK knowledge areas among the universities.
- There is no university that provides all the SE knowledge areas recommended by SWEBOK.
- The Software Configuration Management knowledge area is covered only by one university.
- The only knowledge area that is covered by all the universities is Software Project Engineering Management.
- The average of uncovered knowledge areas by all the universities is 3.6; the maximum is 5 knowledge areas and the minimum is 2.

Shortly, SE departments at the Jordanian Universities do not cover many of the knowledge areas recommended by IEEE/ACM through SWEBOK; each of these universities can use the results obtained in Table 2 to add the courses related to the uncovered knowledge areas on the cost of removing some of the non computer related courses that will not benefit the SE graduate when trying to join the software market.

4. USA Universities SE Analysis

In order to conduct a cooperative study; the curriculums of sample of 8 SE departments at different USA Universities were analysed in order to find the percentages of the SE courses to CS and non computers related courses similar to the analysis that were conducted for the Jordanian universities in section 3.1.

It must be noted that the 8 universities were selected randomly amongst the USA Universities that offer the SE degrees, however, the research tried to focus on the top ranked universities in the US.

The result of this analysis is shown in Table 3.

Table 3: Percentages of SE to non SE courses in a sample of the American Universities

University	Percent of SE Courses	Percent of CS Courses	Percent of other Courses
MIT	0.575	0.393	0.121
Auburn	0.406	0.188	0.406
University of California, Berkeley	0.527	0.388	0.138
Miami	0.40	0.175	0.425
Monmouth	0.387	0.258	0.354
Drexel Philadelphia	0.575	0.242	0.181
University of Chicago	0.571	0.351	0.11
RIT	0.564	0.307	0.128
Average	0.50	0.29	0.21

It can be concluded from the results in Table 3 that:
- The USA Universities SE departments have higher percentages of the SE courses than the Jordanian Universities.
- The USA Universities SE departments have almost similar percentages of the CS courses than the Jordanian Universities.
- The USA Universities SE departments have fewer percentages of the non computer related courses than the Jordanian Universities.

For the uncovered SWEBOK knowledge areas by the universities in Table 3, it was found that the average is 5.70 uncovered areas which is more than the average of the uncovered areas by the Jordanian Universities.

5. UK Universities SE Analysis

The same analysis in Section 4 was conducted for SE departments at a sample of 8 UK universities, which is the same number of the US sample, and the results are shown in Table 4. Also same as the US sample the universities were selected randomly amongst the UK Universities that has SE departments.

It must be noted that a better results would have been reached if 13 USA and UK universities were analysed, which is the same number of the SE departments at the Jordanian Universities; however, only 8 were analyzed because of the space limitations.

Table 4: Percentages of SE to non SE courses in a sample of the UK Universities

University	Percent of SE Courses	Percent of CS Courses	Percent of other Courses
University of Brighton	0.39	0.61	0
East London	0.44	0.5	0.06
Nottingham	0.17	0.83	0
De Montfort	0.19	0.52	0.29
Central Lancashire	0.35	0.53	0.12
Solent	0.34	0.55	0.11
Brighton	0.45	0.45	0.1
Cardiff	0.4	0.55	0.05
Average	0.341	0.568	0.091

It can be concluded from the results in Table 4 that:

- The UK Universities SE departments have almost similar percentages of the SE courses to the Jordanian Universities.
- The UK Universities SE departments have much higher percentages of the CS courses than the Jordanian Universities.
- The UK Universities SE departments have much fewer percentages of the non computer related courses than the Jordanian Universities and the USA Universities.

For the uncovered SWEBOK knowledge areas by the universities in Table 3, it was found that the average is 4.33 uncovered areas which is also more than the average of the uncovered areas by the Jordanian Universities.

6. Results

This section will summarize and compare the results obtained in Sections 3, 4 and 5;

For the uncovered SWEBOK knowledge area; the Jordanian universities performed better than the UK and USA Universities, however, this is because the Jordanian Universities SE departments offer more courses (about 44) than the UK and USA Universities and the B.Sc. degree in SE in Jordan is 4 years while it is usually 3 years in UK and USA.

Table 5 and Figure 1 below summarizes the average of the percentages of the SE, Cs and non Computer related courses in Jordan, USA and UK according to the sample universities considered.

Table 5: Average of the Percentages of SE to non SE courses Jordan, USA and UK

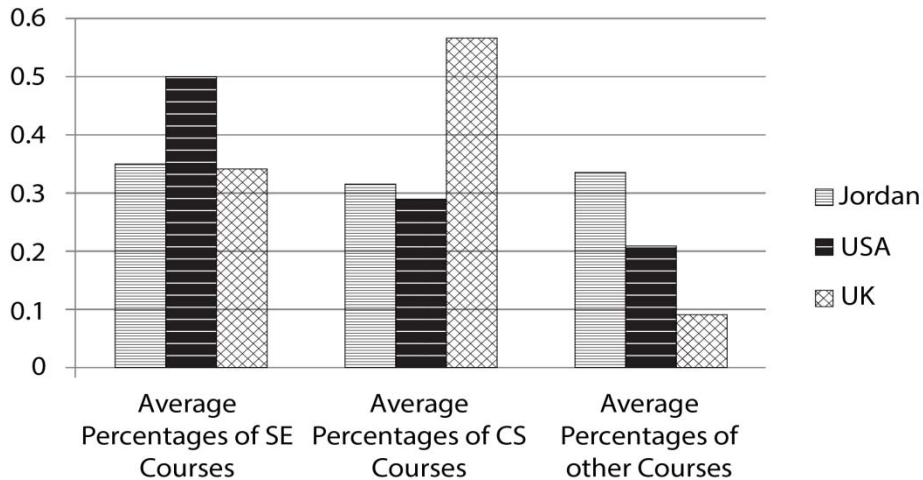| Country	Average Percent of SE Courses	Average Percent of CS Courses	Average Percent of other Courses
Jordan	0.349	0.316	0.335
USA	0.5	0.29	0.21
UK	0.341	0.568	0.091

Figure 1. Comparison of SE courses percentages in Jordan, USA and UK

The following can be concluded from Table 5 and Figure 1:

- The Average percentages of the core SE course in the SE departments are almost similar among Jordanian and UK Universities which is about 34%, however the USA universities has a higher percentages of about 50% of the courses.

- The Average percentages of the CS course in the SE departments are almost similar among Jordanian and USA Universities which is about 30%, however the UK universities has a higher percentages of about 56% of the courses.
- There is over emphasis of the non Computers relates course in the Jordanian Universities; 33.5% of courses comparing to only 21% and 9% in USA and UK Universities respectively.

The following can be concluded from Table 5 and Figure 1:
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- The Average percentages of the CS course in the SE departments are almost similar among Jordanian and USA Universities which is about 30%, however the UK universities has a higher percentages of about 56% of the courses.
- There is over emphasis of the non Computers relates course in the Jordanian Universities; 33.5% of courses comparing to only 21% and 9% in USA and UK Universities respectively.

Shortly; SE departments at the USA universities has the highest percentages of core SE courses while SE departments at the UK Universities has the highest average in the CS courses, and finally the Jordanian Universities has the highest average of the non computer related courses.

7. Suggested Enhancements to the SE Curriculums in Jordan

It was concluded in the last section that the Jordanian University has an over emphasis of the non Computer related courses to the cost of minimizing the core SE and CS courses; to solve this problem and the other problems discussed in Section 2, the following enhancements are suggested:

1- Jordanian Universities can consider replacing some of the non Computer related courses in the SE departments with:
- Core SE courses especially the courses that are related to the uncovered SWEBOK knowledge areas for each university as described in Table 2.
- The courses that can contribute in reducing the chasm between the SE graduates and the software market such as the courses that include a real life projects that are developed by the students.
- The courses suggest by the figures in the field of SE such as the courses suggested by Offutt [2] like: usability, security, design modelling, quality control and embedded applications.
2- Jordan Universities should use a consistent SE study plan that cover all SWEBOK knowledge areas and that have many courses with practical training that demand the implementation of real projects with the cooperation of the software market.
3- Any lecturer who has no educational SE background, namely a Master's or PhD degree in SE, should not be allowed to teach at the SE departments.
4- The Jordanian accreditation committees should use the suggested study plan in step 2 to judge whether to accredit a SE department or not.

Following the previous suggestions can improve the quality of the courses that are taught at the SE departments at the Jordanian Universities and consequently improve the knowledge and the skill of the SE graduates there.

8. Related Work

The most related research found in the literature is:

Offutt [2] mentioned that engineering education must focus on multiple quality attributes—not just efficiency as CS, but reliability, scalability, security, availability, maintainability, and usability, he also mentioned that the following subject should be in the core courses in study plan: usability, testing, security, design modelling, project management, quality control, standards, architecture, embedded applications, evolution, web applications, ethics, and so on.

Pantelis et. al. [3] proposed the use of real free/libre open source software (FLOSS) projects as an educational tool and learning space in software engineering, the results shows that the students appreciated the benefits gained by the method and identified aspects that require further improvement.

Kuang and Han [4] Analysed some outstanding reasons in software engineering curriculum teaching, such as old teaching contents, weak in practice and low quality of teachers etc, and proposed the methods of teaching reform as guided by market demand, update the teaching content, optimize the teaching methods, reform the teaching practice, strengthen the teacher-student exchange and promote teachers and students together.

Lee and Cheng [5] Adopted strategy of identifying dysfunctions of Software Engineering Consortium (SEC) in Taiwan universities at 2003 then designing remedies to address these dysfunctions, the effort to correct the dysfunctions involves design of a module-oriented software engineering curriculum, and organization of people, resource, and activities.

Kitchenham et. al. [6] Adapted a survey instrument developed by Timothy Lethbridge to assess the extent to which the education delivered by four UK universities matches the requirements of the software industry, they showed that mathematical topics were not very important to software engineers and appear to be taught more extensively than is required, and general business topics are quite important, but are not taught in less proportion to their importance, in particular, management, giving presentations, leadership, and negotiating.

Almi et. al. [7] discussed that gaps between the industrial demand and graduates' readiness results due to industry request of high skilled graduates and the graduated student lack the confidence and readiness.

Nguyen et. al. [8] Proposed integrating Project-Based Learning approach where students engaged in real industrial problems by collaborative groups or teams in order to acquire the student's deep knowledge of the subject they are studying.

Gimenes et. al. [9] Suggests involving open educational resources, and distance learning in orders to address the mismatch between the graduate students gap and the market needs.

Mattsson [10] Suggests using Reuse and Progress Driven Software Engineering Educational Method (RaPSEEM) which help organizing SE body of knowledge while designing SE programs.

Chouseinoglou and BilgenIntroducing [11] Proposed and implements an educational approach to software engineering education which combines lecturing, project development and critical thinking with providing the students with the needed theoretical background.

Moreno et. al [12] have examined whether the SE2004 and GSwE2009 cores provide knowledge that is useful for performing each career space task related to each of the three software development-related profiles: Software and Applications Development, Software Architecture and Design and IT Business Consultancy.

They have found that none of the three industry profiles is completely covered by either SE2004 or GSwE2009. The biggest gap found concerns tasks associated with the IT Business Consultancy profile. Knowledge required by such tasks is beyond the classical technical knowledge that we are accustomed to in most undergraduate and graduate SE programmes.

Perez and Alonso [13] Proposed a SE curriculum composed of two levels, the first level provides the students with the basic knowledge of SE that may help students to start developing software, in the second level the students got the knowledge on the development stage such as software architecture, reengineering or components

Lethbridge [14] shows that mathematical and science courses have a negative educational knowledge gap and over taught and it should taught less, and learning should concentrate on software process category, especially in configuration and release management, project management, maintenance.

Gang and Roberts [15] analyzed the curriculum of 31 software schools in the 36 national model schools of software engineering and found there are 10 courses which are the most concentrated offered courses, the Software Process Improvement (CMMI), Java Programming, UNIX/Linux Operating System, ERP, Algorithm Design and Analysis, Network Multimedia, System Analysis and Design, Web Project, User Interface Design, and Database Application.

Sureka et. .al [16] proposed a new approach in teaching software engineering inverted or flipped classroom, studio-based learning, real-client projects and deployment, and large team and peer evaluation.

Richardson et. al. [17] suggests enhancing the level of education in software engineering by participating and sharing the lecturer's researches to develop an interactive study environment and increasing the student knowledge.

Villavicencio and Abran [18] discussed the respective meanings and complementarities of mathematics and measurement in software engineering education, which should increase the innovations of the students.

Hayes [19] shown that a typical industrial project can enhance software engineering research and bring theories to life.

9. Conclusion and Future Work

Current SE curriculums at the Jordanian University have many problems such as: (1) by comparing the SE curriculums at the Jordanian universities with those of a sample of USA and UK Universities it was concluded that Jordan Universities have over emphasis of non computers related courses comparing to the USA and UK universities and (2) SE departments at the Jordanian Universities do not cover all the knowledge areas recommended by ACM/IEEE in the SWEBOK.

SE academic staffs, practitioners, and accreditation committees should all work together to come up with solutions to the previous problems.

The main solution proposed to the Jordanian Universities by this research is to replace the non computer related courses with (a) uncovered SWEBOK knowledge areas related courses and (b) practical courses, borrowed from the software market that can improve student's applications development skills.

Another solution was to design and publish a questionnaire [20] by the authors in order to analyse the opinion of the SE graduate, who already joined the market, of the courses that mostly benefited them in their work and also to take their opinion of the proper means, in their view of point, to enhance the SE curriculums; unfortunately this questionnaire has been publish since 2 weeks only and we still got only 20 responses; after being able to collect more responses, future work will discuss analysis of these responses which will hopefully contribute also to the enhancement of the SE curriculums.

This research has only considered analyzing the SE curricula while future research will consider CS curricula as well.

The main target of our future research is to find means to reduce the gap between SE and CS graduates and the software industry.

Improving the SE curriculums in the SE departments will result in more prepared graduate that can join the software market more easily.

Acknowledgment

References

[1] IEEE Computer Society, Software Engineering Body of Knowledge, http://www.computer.org/web/swebok.

[2] J.Offutt, "Putting the Engineering into Software Engineering Education", IEEE computer society, IEEE, Vol.30 No.1, 2013, pp. 93-95.

[3] M.P. Pantelis, I.G. Stamelos, and A.Meiszner, "Enhancing software engineering education through open source projects: Four years of students' perspectives", Education and Information Technologies Journal, Vol. 18, No. 2, June 2013, pp. 381-397.

[4] L.Q.Kuang, and X. Han, "The Research of Software Engineering Curriculum Reform", International Conference on Medical Physics and Biomedical Engineering, Physics Procedia, Vol.33 No.1, 2012, pp. 1762-1767.

[5] J.Lee, and Y.C.Cheng, "Change the face of software engineering education: A field report from Taiwan", Information and Software Technology, Vol.53 No.1, 2010, pp. 51-57.

[6] B. Kitchenham, D.Budgen, P.Brereton, and P.Woodall, "An investigation of software engineering curricula", The Journal of Systems and Software (JSS), Vol.74 No.3, 2004, pp. 325-335.

[7] N.E. Almi, N.A. Rahman, and E.F. Roberts, "Software engineering education: The gap between industry's requirements and graduates' readiness", IEEE Symposium on Computers & Informatics (ISCI), IEEE, Kuala Lumpur, 2011, pp. 542-547.

[8] D.M. Nguyen, T.V. Truong, and N.B. Le, "Deployment of Capstone Projects in Software Engineering Education at Duy Tan University as Part of a University-Wide Project-Based Learning Effort", Proceedings of the 2013 Learning and Teaching in Computing and Engineering, Vietnam, 2013, pp. 184-191.

[9] I.M.Gimenes, L.Barroca, D. Purusothaman, and S.Sulaiman, "The Future of Human Resources Qualifications in Software Engineering - Meeting Demands from Industry and Benefiting from Educational and Technological Advances", 26th Brazilian Symposium on Software Engineering, SBES, Brazil, 2012, pp. 181-185.

[10] M.K.Mattsson, "A Method for Designing Software Engineering Educational Programs", Proceedings of the IEEE 25th Conference on Software Engineering Education and Training, Nanjing, China, 2012, pp. 139-143.

[11] O.Chouseinoglou, and S.BilgenIntroducing, "Critical Thinking to Software Engineering Education", Springer, Studies in Computational Intelligence, Vol.496 No.1, 2014, pp. 138-195.

[12] A. M. Morenoa, M. S.Segurab, F.M.Dominguezb, and L. Carvajala, "Balancing software engineering education and industrial needs", Journal of Systems and Software, Vol.85 No.7, 2012, pp. 1607-1620.

[13] J.E.Perez, and A.S. Alonso, "A Coordinated Plan for Teaching Software Engineering in the Rey Juan Carlos University", IEEE, 16th Conference on Software Engineering Education and Training (CSEET'03), Location, 2003, pp. 107-118.

[14] T.C.Lethbridge, "What knowledge is important to a software professional?", Computer Volume:33, IEEE, Canada, 2000, pp. 44-50.

[15] Z. Gang, and E.F. Roberts, "Statistical Analysis on Curriculum of the National Model School of Software Engineering", International Journal of Education and Management Engineering (IJEME), Vol.2 No.8, 2012, pp. 72-77.

[16] A.Sureka, M.Gupta, D.Sarkar, and V.Chaudhary, "A Case-Study on Teaching Undergraduate-Level Software Engineering Course Using Inverted-Classroom, Large-Group, Real-Client and Studio-Based Instruction Model", The Computer Research Repository (CoRR) September 2013.

[17] I.Richardson, L. Reid, S.B.Seidman, B.Pattinson, and Y.Delaney, "Educating software engineers of the future: Software quality research through problem-based learning", 24th IEEE Conference on Software Engineering Education and Training (CSEE&T), Honolulu, 2011, pp. 91-100.

[18] M.Villavicencio, and A.Abran, "The necessary software measurement knowledge in software engineering education from the practitioners' point of view", 25th IEEE Canadian Conference on Electrical & Computer Engineering (CCECE), Montreal, 2012, pp. 1-5.

[19] J.H.Hayes, "Energizing software engineering education through real-world projects as experimental studies", Proceeding of the 15th IEEE Conference on Software Engineering Education and Training (CSEE&T), Covington KY, 2002, pp. 192-206.

[20] S. Hanna, H. Jaber, F. Abu Jaber, A. Almasalmeh, T. Slalabi, "Software Engineering Curriculum Questionnaire", available at: https://docs.google.com/forms/d/1i4u9ISWp5-D0GX1KlBmukLFDB-8_5o0P1UOqJIxOkSs/viewform