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Computing education for engineering in Turkey

Abstract. *The study aims to provide a "snapshot" of the current state of computing education in engineering in Turkey by emphasizing on professors, scientific publications, curriculums, and graduate programs in this field. The study can be beneficial in terms of several points: First, it can be used to clarify the weaknesses and strengths of computing education. Second, it can be used to catch new program development opportunities. Third, it can be used to assess the current computing departments and rank them.*

Streszczenie. *Artykuł przedstawia problem nauczania technik komputerowych wśród inżynierów na przykładzie Turcji. (**Nauczanie technik komputerowych w środowiskach technicznych na przykładzie Turcji**)*

Keywords: engineering education, computing, higher education.
Słowa kluczowe: naucznie techniczne, techniki komputerowe.

Introduction

The advent of computer science as a scientific discipline has affected "academic world" in several ways. Today, almost all universities among the world offer degrees in computer science, computer engineering, information systems and technology or in another name closely tied to computing. Moreover, computer and information technology is integrated into other disciplines.

Computer science and engineering is central to computing and it affects the various problem domains, including medicine, science, business, engineering, art, humanities and entertainment [1]. This has lead to integration of computing into interdisciplinary research projects with other disciplines. In [1], the authors argue that "for every field X, it sometimes seems that someone creates a subfield, computational X".

As a result of smaller size, higher performance and lower cost, electronic systems are more pervasive, and accordingly there is a reciprocal interaction between scientific and technological advancements [2].

This essay seeks to give a comprehensive overview of current computing education in engineering at Turkish universities by emphasizing on four important aspects of higher education: curriculum, faculty, scientific works and graduate programs. The rest of the essay first gives a brief history of computing in Turkey and covers four-fold dimensions in detail in the progressive sections.

A Brief history of computing

The roots of computing departments in Turkey go back to electronic computing centers, which are founded in 1960s to teach service courses in computer science, including computer programming, statistics and data analysis, to other departments and faculties of the universities [3]. One of the nation's first departments in computer engineering is founded at faculty of engineering of Middle East Technical University. The department was founded as electronic computing center in 1967 [4]. In early 1970's, the department is organized to offer graduate programs in computer science and is transformed to computer engineering department in 1977 [4]. The nation's other first department in computer engineering is founded at faculty of engineering of Hacettepe University. The root of this department goes back to Informatics Institute of the same university [5]. Several years later, computer engineering departments at İstanbul Technical University, Ege University and Yıldız Technical University are founded [4]. Similarly, computing centers of these departments provided the establishment. There are 102 state and 54 private universities, scattered among all cities in Turkey by 2011. There are recently 73 active computer engineering departments at Turkish Universities, accepting students to undergraduate degree programs by university entrance exam [6]. Software has been an integral part of many systems and applications [7]. It made it necessary to diversify computing programs so that engineers specialized in design, building, testing and maintaining software products can be graduated [8]. As a result of this need, some software engineering departments in the world founded. This has lead to foundation of software engineering departments in Turkey, as well. In 2003, the nation's first department in software engineering is founded at faculty of computer science of Izmir University of Economics [9]. This department took attention of several private universities competing for students' preference. As a result, there are ten software engineering departments in Turkey, nine of them are founded within faculty of engineering at private universities and one of them is founded within a faculty of technology at a state university. Another computing degree in engineering offered by Turkish Universities is information systems engineering (ISE) program. This program is first offered in 2007 at Atılım University [10]. There are also dual diploma programs in ISE which are offered with the collaboration of State University of New York and Turkish universities [11].

Curriculum

Curriculum, by playing an effective role in teaching and learning, enables to graduate productive engineers [12]. In this study, instead of analyzing all the departments' curriculums, we have studied curriculums of universities with both computer and software engineering undergraduate programs. This provided much better comparison and contrast of these departments. We have breakdown the curriculums by adopting Hu's recommended curriculum model's structure [2]. The model of Hu was primarily developed for electrical and computer engineering curriculum, so some adjustments are done to cover courses in both software and computer engineering. As a result, the curriculums are divided into four distinct domains. These are: general education domain, mathematics and science domain, computing domain and electives. The general education domain consists of courses from nonscience area, including communication skills, humanities, behavioral and social sciences, business and economics and art courses. These courses generate a significant ground for an engineer's professional life. Engineers' analytic and problem-solving skills become influential only when they have well-equipped with professional skills [13-16]. In [17] and [18], the writers emphasized also the necessity of understanding of communication skills and humanities for engineers. The second domain includes courses from

mathematics and science. Mathematics is one of the underlying principles of computer science and it provides competency in analysis skills required for a computer professional [19]. The traditional mathematics courses of curriculum are calculus and differential equations and discrete mathematics is included for its importance to the computer engineering community [18]. The other mathematics courses of this domain are linear algebra, probability and statistics and numerical methods and analysis. The science part of this domain consists of courses, such as physics, chemistry, biology and fundamentals of engineering. The heart of computing curricula is generated by courses of computing domain. The detailed representation of courses in computing domain is given in Table 1. In addition, social (free) and technical (departmental) electives are merged into electives domain.

Table 1. Courses included in computing courses domain

Introduction to Computer Engineering	Logic Design and Computer Architecture	Computer Graphics	Modeling
Programming	Operating Systems	Bioinformatics	Operations Research
Data Structures and Algorithms	Computing Theory	Electrical Circuits and Electronics	Compiler Design
Database Systems	Computer networks and communication	Software Engineering	Artificial Intelligence

In Tables 2 and 3, departments and number of courses in each course domain is illustrated. The minimum column in the table represents the department with the least number of courses in a particular domain. Similarly, the maximum column in the table refers to number of courses in department with maximum courses in a particular domain. The total coloum indicates the total number of courses for a particular course domain offered in all computer or software departments and the average column represents the average number of courses for this domain, i.e. total coloum over the number of departments (eleven).

Though there is a slight difference in the number of courses in general education and math and science domains, average number of courses in computing courses and electives are the same for both departments. The differences in curriculums of the departments become more apparent by looking computing courses domain, especially department-specific courses a bit closer. In computer engineering departments, while number of courses offered in electrical circuits and electronics is equal to twenty eight, there are only six courses offered in software engineering curriculums. Similarly, there are sixty eight courses in software engineering specific concepts and applications, such as software architecture, software verification and validation, software management, software measurements, etc. in software engineering curriculums, but there are only twenty one courses dedicated to this area in computer engineering curriculums. Likewise, there are twenty four courses in logic design and computer architecture in computer engineering departments, but there are only ten courses in software engineering departments. The number of courses in some fields are very close to each other in both departments. These courses include programming, data structure and algorithms, database systems and operating systems. Finally, there are some courses in which the differences in numbers are still appearent. These courses include theory of computation, introduction to computing and computer networks and communication.

Table 2. Departments and number of courses in each course domain in Software Engineering

Course Domain	Minimum	Maximum	Average	Total
General Education	7	19	11	122
Math and Science	7	10	8	89
Computing Courses	13	23	18	196
Electives	0	11	7	76

Table 3. Departments and number of courses in each course domain in Computer Engineering

Course Domain	Minimum	Maximum	Average	Total
General Education	8	19	10,5	115
Math and Science	7	11	8,5	94
Computing Courses	13	22	18	194
Electives	1	14	7	80

Faculty

Faculty generates one of the most essential parts of higher education institutions and plays an important role in achieving the missions of them [20]. Computing departments can be seen as interdisciplinary fields and their faculty was formed by people from various disciplines in its early years. These people included mathematicians, electrical engineers and physicist [21].

The power of computer science programs is highly associated with the faculty [22]. In order to give a clearer understanding of current state of computing education in Turkey, all computer engineering (73 departments in total) and all software engineering (11 departments in total) departments and their academic staff have been analyzed in terms of their academic rank, gender, field of first degree (B.Sc., B.A., etc.), and field of doctoral degree (Ph.D.). The two universities with both computer and software engineering departments offer software engineering as an option, rather than being a distinct department. As a result, the faculty of these departments is included into the faculty of computer engineering departments. The faculty is also classified according to where they earned their Ph.D. degrees, i.e, from national institution or abroad. Some details about faculty are listed in Table 4 and 5.

The distribution of faculty members according to academic ranks and gender is divided into two tables to make clearer the distinction of computer and software engineering faculty. In both computer and software engineering departments, the dominance of male over female colleagues in numbers is really apparent. While 81 percent of academic ranks are occupied by male academicians, only the remaining 19 percent is occupied by female colleagues. This ratio holds valid for both computer and software engineering departments. Roughly speaking, the percent of female academicians in computing increases towards the move from upper to lower levels of hierarchical structure of academic ranks. This is not a nationwide case. As reported in [23], women academicians in the USA object to being underrepresented in more prestigious institutions and at the higher faculty ranks.

The vast majority of faculty is occupied by assistant professors in both departments. The second dominant position is lecturers with the numbers of 114 and 10, respectively. While 21 percent of faculty is in the associate professor rank in software engineering departments, only 11 percent of faculty in computer engineering department occupies the same rank. The least number of academicians

are in professor position in software engineering and associate professor position in computer engineering department.

Table 4. The distribution of faculty members according to academic ranks and gender in computer engineering departments

Gender\Rank	Professor	Associate Professor	Assistant Professor	Lecturer
Male	99	60	254	83
Female	12	7	63	31
Total	111	67	317	114

Table 5. The distribution of faculty members according to academic ranks and gender in software engineering departments

Gender\Rank	Professor	Associate Professor	Assistant Professor	Lecturer
Male	5	9	13	7
Female	0	0	5	3
Total	5	9	18	10

Table 6. Academic ranks according to their field of first degree education

Field	Professor	Associate Professor	Assistant Professor	Lecturer
CS or CE	23	30	155	65
EE, EEE or ECE	54	29	25	25
Ced, Eed, or Eced	1	6	18	5
Other Engineering Disciplines	15	2	111	13
Basic Science	20	9	23	14
Management	3	0	3	2
Total	116	76	335	124

In Table 6, the faculty members are classified according to their bachelors' degree. Similar departments or undergraduate programs are grouped together in order to simplify this classification. For example, computer science and computer engineering departments are merged into one unit in the table. Similar simplifications are applied for electrical or electronics related departments, and so on. Here, CS represents computer science, CE represents computer engineering, EE represents electrical engineering, EEE represents electrical-electronics engineering, EEE represents electrical-electronics engineering, ECE represents electronics and communication engineering, Ced represents computer education, Eed represents electrical education, and finally, Eced represents electronic and computer education.

The most dominant field of bachelor's degree for professors is electrical and electronics engineering group (EE, EEE or ECE), with the percentage of 46. The second dominant field for professors is computer science and computer engineering group (CS or CE), with the percentage of 20. The other dominant fields are basic science (mathematics, physics, etc.) and other engineering disciplines (industrial engineering, systems engineering, mechanical engineering, etc.). There is only one professor with bachelor's degree in computer education group (Ced, Eed, or Eced) and there are only three professors with management degree.

The two dominant fields of bachelor's degree for associate professors are computer science or computer engineering (CS or CE) and electrical engineering, electrical and electronics engineering, or electronics and communication engineering (EE, EEE or ECE) groups with the percentages of 39 and 38, respectively. While the dominance of basic science degrees for associate professors is also valid, this is not the case for other engineering disciplines group. The percentage of associate professors with computer education, electrical education, or electronic and computer education bachelor's degree is higher than those of professors with the same degree.

Almost half of the assistant professors earned their first degree in computer science or computer engineering. For assistant professors, the dominance of electrical engineering, electrical and electronics engineering, or electronics and communication engineering disappears. However, the percentage of members with degrees in other engineering disciplines is very high compared to the other academic ranks, with the percentage of 33. The other common fields of bachelor's degree are electrical engineering, electrical and electronics engineering, or electronics and communication engineering (EE, EEE or ECE), basic science, computer education (Ced, Eed, or Eced), and management groups, with the percentages of 8, 7, 5 and 1, respectively.

More than half of faculty members in lecturer rank hold bachelor's degree in computer science or computer engineering. The second dominant field is electrical engineering related group, including electrical engineering, electrical and electronics engineering and electronics and communication engineering, with the percentage of 20. The other common fields are basic science, other engineering disciplines, computer education, and management, respectively.

In Table 7, the faculty members are classified according to their doctoral degrees. The same abbreviations written in Table 6 are used here, but one group is added to represent academicians with Information Systems or Cognitive Science Ph.D. The lecturers without doctoral degree are eliminated from this study, decreasing number of lecturers from 124 to 48.

Table 7. Academic ranks according to their field of doctoral degree education

Field	Professor	Associate Professor	Assistant Professor	Lecturer
CS or CE	58	38	187	27
EE, EEE or ECE	28	23	82	9
Ced, Eed, or Eced	1	5	15	2
Other Engineering Disciplines	15	1	18	1
Basic Science	10	5	12	4
Management	4	0	12	1
IS or COG	0	4	8	3
Other Disciplines	0	0	1	1

Although only 20 percent of professors earned their B.S. degree in computer science or engineering, 50 percent of them earned their Ph.D. degree in this field. This can be explained by the fact that computer science and engineering are relatively new disciplines compared to electrical engineering, other engineering disciplines and basic sciences and many programs were started as master or doctoral degrees, before starting to the bachelor's degree education [4-24]. The second dominant field is electrical engineering related programs, with the percentage of 24. After that, other engineering disciplines, basic science, and management fields come, with the percentage of 13, 9, and 3, respectively. There is only one professor with computer education doctoral degree and there are no any professors with information systems or cognitive science doctoral degree.

The percent of associate professors with computer science or engineering doctoral degree are the same as the

percent for professors with doctoral degree in the same field. The thirty percent of associate professors hold doctoral degree in electrical engineering, electrical and electronics engineering or in electronics and communication engineering. There are five associate professors with doctoral degree in basic science and five associate professors with doctoral degree in computer education. There are four associate professors with information systems or cognitive science degree, and there is only one with other engineering doctorate.

The percent of academicians with doctoral degree in computer science or computer engineering is equal to 56 for both assistant professors and lecturers with doctorate. The 25 percent of assistant professors hold doctoral degree in electrical engineering, electrical and electronics engineering or in electronics and communication engineering. The other common fields are other engineering disciplines, computer education, management, basic science, information systems or cognitive science, respectively. The second dominant field is again electrical engineering related group for lecturers. The others are basic science, information systems or cognitive science, and computer education, respectively.

The last issue to mention is where the academicians receive their Ph.D. degrees. There are 68 professors received doctoral degree from abroad and 48 professors earned from Turkey. The information for other academic ranks is illustrated in Table 8.

Table 8. The place of doctoral study

Place	Professor	Associate Professor	Assistant Professor	Lecturer
Abroad	68	39	137	15
Turkey	48	37	198	33

Scientific Works

In universities, one of the most important criteria for academic promotions is faculty research productivity [25-29]. The importance of scholar activities can be considered with two aspects: collective and individual [30]. In collective level, higher education institutions can be ranked with their research productivity and in individual level, this determines individual faculty member's reputation, visibility and advancement in the academic reward structure [30-31]. In this section, we have analyzed the productivity of Turkish universities in computer science and the rank of Turkey among the world. In order to analyze the national productivity in computer science, the data available in SCImago is used. SCImago (SJR) is a platform which is developed by SCIMAGO Lab. This platform represents the visibility of journals contained in the database from 1996 to 2009 [32]. During the period of 1996 to 2009, the top ranked countries for computer science publications are United States, China, United Kingdom, Japan, Germany, France, Canada, Italy, South Korea and Taiwan, respectively. Turkey is ranked in the twenty seventh places in computer science with 6669 documents, 6565 citable documents, 37353 citations, 10.103 self citations and 5.60 citations per document [33]. On the other hand, India is ranked in the fourteenth places in computer science with 14634 documents, 14396 citable documents, 80489 citations, 13843 self citations and 5.50 citations per document [33].

The data about documents, cites, self cites, cited documents and uncited documents for Turkey is plotted in Fig. 1. As it can be seen from figure, there is a changing pattern in number of documents from 1996 to 2001 and there is continual increase in number of documents since 2001. The least number of cites are seen in 2009 and the highest number of cites are seen in 2004. The other years with higher cites are 2005, 2003, 2006, 2007, and 2002, respectively.

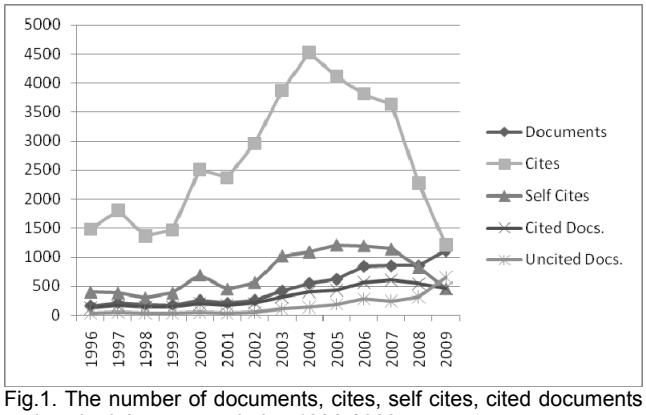

Fig.1. The number of documents, cites, self cites, cited documents and uncited documents during 1996-2009
Source: http://www.scimagojr.com

The highest number of self-cites are seen in 2005, 2006, 2007, 2004, and 2003, respectively. For cited documents, the highest number is seen in 2007 with 609 cited documents. The other years with higher cited documents are 2006, 2008, 2009, 2005, and 2004, respectively. The least number of cited documents is seen in the year 1996 and the other years with smaller number of cited documents are 1999, 1999, 1997 and 2001, respectively. The number of uncited documents reaches its peak in 2009 with the number of 651 documents and the number of uncited documents has been generally increasing since 1996.

In Figure 2, the number of cites per documents and self cites per documents during 1996-2009 period are illustrated.

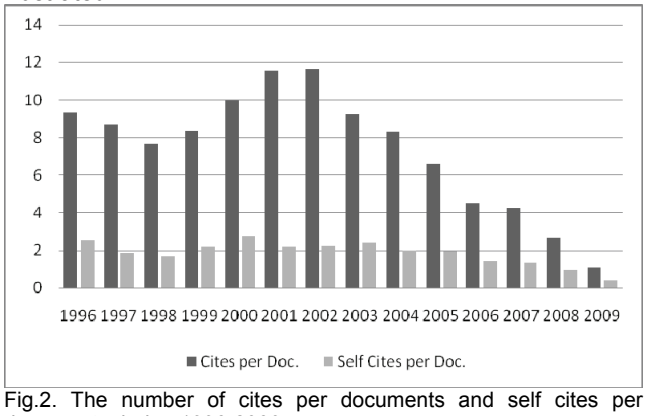

Fig.2. The number of cites per documents and self cites per documents during 1996-2009
Source: http://www.scimagojr.com

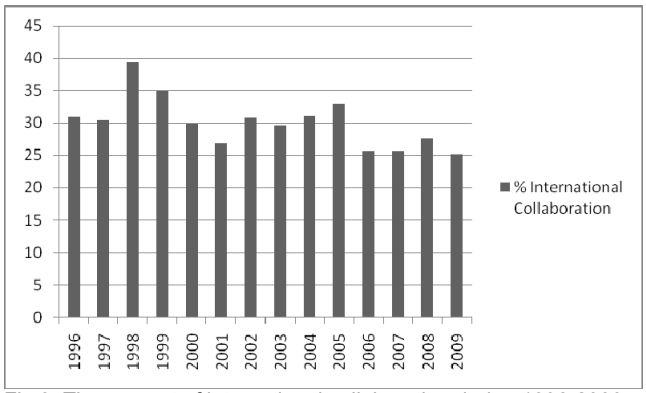

Fig.3. The percent of international collaboration during 1996-2009
Source: http://www.scimagojr.com

The least number of cites per documents and self cites per documents are seen in 2009. Cites per documents reach the peak in 2002 and self-cites per documents reach the peak in 2000. The years with relatively high cites per documents are 2001, 2000, 1996, 2003, 1997, 1999, and 2004, respectively. The years with relatively high self-cites per documents are 1996, 2003, 2002, 2001, 1999, 2004, and 2005, respectively.

In Figure 3, the percent of international collaboration during 1996-2009 is plotted. The international collaboration represents the works conducted by authors from more than one country. The last point of scientific works section is the classification of published work according to computer science fields. Artificial intelligence, computational theory and mathematics, computer graphics and computer-aided design, computer networks and communications, computer science applications, computer science (miscellaneous), computer vision and pattern recognition, hardware and architecture, human-computer interaction, information systems, signal processing and software fields are taken into account.

As it can be seen from figure, for the three years, the most of the publicated documents are from computer science applications, with the numbers of 226, 230 and 368, respectively. While for the years 2007 and 2008, the second dominant field of documents is hardware and architecture, it goes back to fourth place for 2009, with the decrease of number of publicated documents in this field, from 184 to 172. Although the published documents from artificial intelligence field are ranked in fourth place in 2007 and 2008, it is ranked in second place in 2009. The third dominant field of publicated documents is computer science (miscellaneous) for the all three years. Computational theory and mathematics field is ranked in sixth place in 2007, in fifth place in 2008 and in fourth place in 2009. In addition, the small number of publications is written in human and computer interaction area for 2007, 2008 and 2009.

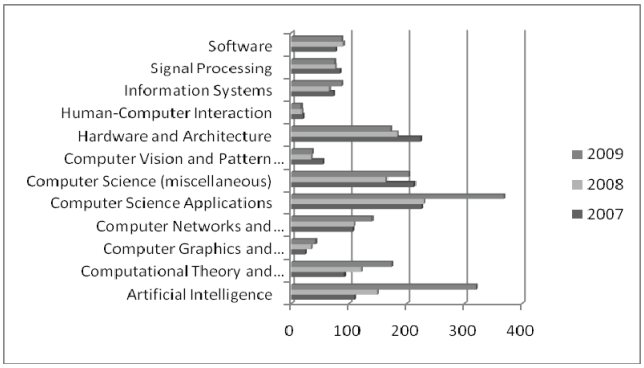

Fig.4. The distribution of publications by fields in the last three years. Source: http://www.scimagojr.com

Another recent study conducted by Aslantas et al. concludes similar remarks. In this study, the scholars ranked computer engineering departments in Turkey according to the number of publications in institutions during 2000-2006 periods. According to this study, the most five productive institutions in Turkey in 2000-2006 period are Bilkent University, Bogazici University, Middle East Technical University, İstanbul University, Istanbul Technical University, respectively [34].

Graduate Programs

The graduate education in Turkey is carried out in forms of Master's degree program (Second cycle) and Doctoral degree program (Third cycle). The Master programs are offered by thesis or without a thesis. The Master's program with thesis consists of at least 21 credit-7 graduate coursework and a thesis, whereas the master's program without thesis consists of at least 30 credit-10 graduate coursework and a final project. A typical Doctoral degree program requires at least 21 credit-7 graduate coursework, passing a proficiency exam and a dissertation [35]. The graduate degrees at Turkish universities are offered at Institutes. Though basic graduate institutes are Institute of Natural Science, Institute of Social Sciences and Institute of Medical Sciences, there are other special graduate schools carrying research projects and offering graduate education in a specific field of research.

In accordance with the decision taken in 1997 by The Turkish Council of Higher Education (YÖK), Institutes of Informatics were established in some universities [36]. Recently, there are five special graduate schools in Computer and Information Science.

The number of master programs with thesis, without thesis and doctoral programs in computing and information science is 140, 65 and 52, respectively. Most of the programs of doctoral degree are in computer engineering, with the number of 23. Then, computer education and instructional technology doctoral programs come. The other Ph.D. programs offered by at least two universities are information systems, computational science and engineering, biomedical engineering, medical informatics, computational design and geographic information systems programs. Among master programs without thesis, the most dominant one is information systems, with the number of 24. The other common non-thesis program is computer engineering. Medical informatics, software engineering, computer science, computer education and instructional technology and geographic information systems non-thesis programs are offered by at least two universities. Information systems engineering, electronics and computer education, computer education, bioinformatics, electrical education, digital communication and computer networks, law informatics, computational design, computational construction management, modeling and simulation, software management and cryptography are non-thesis programs offered by exactly one university. Finally, the most common master program with thesis is computer engineering, with the number of 52. The other common programs include computer education and instructional technology, information systems, medical informatics and electrical and computer education.

Conclusion

This paper demonstrates the current state of computer education in engineering faculty of Turkish universities. To analyze current state, four significant and integral parts of education are taken into account. The curriculums of computer and software engineering departments are compared and contrasted; faculty members are classified based on gender, academic ranks, education fields, where doctoral degree earned, etc. Scientific works of computer science area are compared with other nations' works and classified based on computer science fields. Finally, current graduate programs in Turkey are discussed at the last section.

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