A vision on the evolution of perceptions of professional practice: the case of IT

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Abstract

Human factor is the element that produces more deviations in the costs of information technology (IT) projects. Recently, a gap between the competences required from the IT industry and the competences taught in the computer science university degrees has been proposed as a possible explanation to it. This paper further investigates this issue following several steps. First, through a questionnaire administered to different groups of computer science students, it analyses their performance according to a set of professional competences. Then, it addresses the evolution of the students' competences from the beginning of their studies until the end. Finally, it determines the matching of the students' competences with their personal characteristics at the moment they select their major. The results obtained permit recruiting staff to identify competence stereotypes in students and their evolution as well as comparing them with studies of competence requirements included in recent curricular efforts, so that they can act accordingly.

Keywords: Competences, Computer Science Education, Professional Stereotypes, Students Evolution, Soft Skills

Introduction

Stereotype is one of the most familiar concepts in the fields of Social Psychology, and is applicable to almost every sphere of knowledge. Stereotypes can be defined as a set of shared beliefs about personal attributes, usually personality traits but also the behaviours of a group of people (Yzerbyt & Schadron, 1994). Walter Lippmann (1922) first introduced the concept of stereotype in its socio-psychological sense. To Lippman (1922), stereotypes generally have strong feelings associated; they have their origins in the society and offer a way to justify relationships between groups. Based on Lippmann's (1922) arguments, social psychologists have further studied this issue and offered very different approaches, including the study of professional stereotypes.

The concept of competence, from the Latin verb "competere", is associated with the analysis of professional activities and the inventory of what is necessary in order to accomplish the missions involved in these activities (Levy-Levoyer, 1996). Thus, competences can be defined as an individual's core skills (motives, traits, self-concept, knowledge, and abilities) that are causally related to a specific, effective criterion and/or a superior performance at work (Spencer, & Spencer, 1993). Several authors have established taxonomies in which particular (Levy-Levoyer, 1996) or technical competences are established as those that are necessary to carry out a very specific task of that work position, and include knowledge, abilities, and skills. Whereas, universal (Levy-Levoyer, 1996) or generic competences are those that, though not linked to a specific activity or function, make possible the performance of tasks related to a work position, inasmuch as they refer to characteristics or abilities of the individual general behaviour.

As technology advances and the business environment continues to evolve, organizations and training institutions face a key challenge: to identify critical skill sets for current and future computing practitioners. In an attempt to address this issue, this study carries out a comparative study between stereotypes, descriptions and evaluations of competences, using the above defined two concepts together with several curricular efforts to assess the competences of computer scientists. More specifically, the objectives of this study are twofold. Firstly, it attempts to examine the development of competences in Computer Science students throughout their undergraduate studies and, secondly, it analyses the relationship between stereotypes, students' competences and several curricular initiatives which indicate the generic competences for information technology (IT) professionals. The remainder of this manuscript is structured as follows. Next, the relevant literature in professional stereotypes in computer science is outlined. Then, the characteristics and of the study conducted are described. Following that, the results of the study are presented and, finally, the paper ends with a discussion of research findings and concluding remarks.

Professional stereotypes in Computer Science

Several authors have addressed the stereotype image of the Computer Science profession (Ahuja, 1995; McGrath Cohoon, 1999). Computer science profession is seen as unattractive, hard and "uncool" (García-Crespo et al., 2008). This image is one of the factors leading to career abandonment (Colomo-Palacios et al., 2014a). In addition, this negative image is confirmed by the IT strategic contribution paradox, which recognizes the contribution of IT within enterprises, though at the same time the status of the IT department and IT personnel is low (Avison, Cuthbertson, & Powell, 1999). Moreover, these stereotypes are widely shared by a large part of society and have been reported in several studies. For instance, stereotypes include nerdy/geeky (Beaubouef & McDowell, 2008; Fisher & Margolis, 2002; Gurer & Camp, 2002; Rashid, 2008), anti-social (Martin, 1998), solitary (Beaubouef & McDowell, 2008; Craig, Paradis, & Turner, 2002; Rashid, 2008), unethical (Martin, 1998), snack food and "pizza and coke" eaters (Rashid, 2008; Timms et al., 2008), poorly dressed (Jemielniak, 2007) and men-only (Lavy, 2008; Anderson et al., 2008; Rashid, 2008; Fisher & Margolis, 2002; Durndell & Thomson, 1997), among others. For a summary of the main stereotypes associated with Computer Science students see Joshi & Schmidt (2006). Still other authors have studied the impact of cinema (Colomo-Palacios, Gómez-Berbís, & García-Crespo, 2007) or television (García-Crespo et al., 2008) on the characterization of IT professionals. These studies indicate the proliferation of negative characteristics (personality traits, physical…) of IT professionals, although for the case of cinema, the number of IT professionals working in leading roles is systematically increasing.

The importance of soft skills for computer science roles has encouraged many studies analysing this issue. Several authors (e.g. Beaubouef, 2003; Colomo-Palacios et al., 2013; Colomo-Palacios et al., 2014b; Davis & Berdrow, 2008, Jubas & Butterwick, 2008; Litecky et al., 2004) consider such skills as crucial for IT workers. Not in vain, IT work is seen as a highly-intensive in human capital (Casado-Lumbreras et al., 2009; Casado-Lumbreras et al., 2011; Colomo-Palacios et al., 2010; Colomo-Palacios et al., 2011). In this sense, studies have been conducted on the competencies necessary for different stakeholders such as software project managers (Sukhoo et al., 2005), analysts (Misic & Graf, 2004), chief information officers (Bassellier, Reich, & Benbasat, 2001), entry-level IT professionals (McMurtrey, Downey, Zeltmann, & Friedman, 2008) and IT professionals in general (Bailey & Stefaniak, 2002; Kovacs, Caputo, Turchek, & Davis, 2006; Miller & Duse 2004).

With regard to education, the literature has investigated several issues concerning students' skills and competences, Surendran, Ehie and Somarajan (2005) compared learning outcomes on skill-related objectives to cross-disciplinary student teams with both business and technical backgrounds. García-Crespo et al. (2009) analysed high school students' view of IT professionals, while Biggers Brauer and Yilmaz (2008) compared perceptions from students who graduated in computer science with students who left computer science after their choice. Papastergiou (2008) investigated high school students' perceptions and their career choices.

The white book on Computer Science degrees in Spanish universities

The White Book on Computer Science degrees in Spain is an initiative of the government's accreditation agency (ANECA) which seeks, among other things, to define the competences of Computer Science engineers (Casanovas, Colom, Morlán, Pont & Ribera, 2004). Hence, based on a set of surveys administered to professionals, companies and teachers, the book establishes some generic competences that the professional must possess to succeed in the labour market. The competences are based on lists of competences published by the Tuning project (González & Wagenaar, 2003), sponsored by the European Union for the coordination of the European educational structures. The competences that professionals must have are graded on a scale from 1 to 4, with 4 indicating the highest, 3 very important, 2 important and 1 recommendable (see Table 1).

Table 1. Generic competences of Computer Science students.

Capacity for analysis and synthesis	4
Organization and planning	4
Oral and written communication in mother tongue	3
Knowledge of a second language	3
Computing knowledge related to the field of study	3
Information management	3
Problem solving	3
Decision-making	3
Team work	4
Ability to work within an interdisciplinary team	3
Ability to work in an international context	2
Interpersonal skills	3

Recognition of diversity and multiculturalism	2
Critical reasoning	3
Ethical commitment	3
Independent learning	3
Adaptation/flexibility	3
Creativity	3
Leadership	3
Understanding of other cultures and customs	2
Initiative and enterprise	3
Concern for quality	4
Sensitivity to environmental topics	2

The study

The experiment seeks to define the competences of Computer Science students at different points during their studies so that, firstly, competences acquired by them can be compared with that of IT practitioners and, secondly, with the descriptions of competences offered by the European curricular initiatives. To achieve these objectives, three different questionnaires were designed and administered to different groups. The characteristics of the questionnaires and the targeted stakeholder are as follows:

- The first questionnaire, administered to a group of 5th year students of computer science engineering, requests individuals to assess on a scale from 1 to 4 the proposed set of 27 generic competences, with respect to 3 different scenarios: the computer scientist, the individual himself/herself and, to have a 360-degree feedback, the group of students taking the same courses. Values are 1 (not important), 2 (not so important), 3(quite important) and 4 (very important). This scale was adopted in order to be able to perform comparisons between curricula recommendations and students' views using.
- The second questionnaire, administered to 1st year students of computer science engineering during the first days of the course, is based on the same set of 27 competences. Although, individuals were asked to assess the computer engineer profile and himself/herself only.
- The third questionnaire, administered to pre-university students who were interested in studying a degree in computer science, asked them to assess the 27 generic competences of computer engineers.

Table 1. Generic competences based on the Tuning Project.

Capacity for analysis and synthesis	Organization and planning	Basic general knowledge
Oral and written communication	Ability to retrieve information from different sources	Problem solving
Decision-making	Critical and self-critical ability	Team work
Interpersonal skills	Ability to work within an	Capacity to communicate

	interdisciplinary team	with specialists from other areas
Appreciation of diversity and multiculturalism	Ability to work in an international context	Ethical commitment
Ability to put knowledge into practice	Research skills	Learning capacity
Adaptation/flexibility	Capacity to generate new ideas (creativity)	Leadership
Understanding of the cultures and customs of other countries	Ability to work independently	Project design and management
Initiative and enterprise	Concern for quality	Will to succeed

As shown in Table 2, competences adjusted to the framework described in the European Tuning project (González & Wagenaar, 2003) were to conduct our study.

Methodology

Data Collection

The individuals participating in this study belonged to three well-differentiated groups:

- Thirty 5th year students of Computer Science Engineering from Carlos III and Madrid Polytechnic Universities.
- Thirty one 1st year students of Computer Science Engineering from the Madrid Polytechnic University.
- Twenty nine high school seniors from different places who were interested in studying computer science engineering after finishing high school.

The survey was administered as a voluntary activity. Prior to this task, the instructions for filling in the survey as well as the objectives of the survey were explained to the students. A limited time frame of 20 minutes was given to individuals. The authors assisted the students and were present in the classroom at all times to respond any questions. From the 90 individuals who participated in the experiment 37% of them were women (33) and 63% men (57).

Data Analysis

Three types of studies were carried out:

- The definition of the computer scientist's profile based on the results from the questionnaires
- The analysis of the evolution of the students' competences based on self-evaluations and the 360-degree feedback.
- The Matching of the students' competences with the competence stereotype.

The SPSS statistical software was used to carry out the statistical analysis. The data analysis consisted of the following phases:

- The computer scientist's profile was obtained by a comparison of the descriptions of the three groups' competences, applying the ANOVA analysis.

Then, to identify significant differences between the groups, a t-test was performed.

- The analysis of the evolution of the students' competences was made by the comparison of means (t-test) of self-evaluations from 1st year students and 5th year students. Then, a comparison of self-evaluations with that of 360-degree feedback was performed.
- The analysis of the fit between the individual and the competence profile for the different groups was conducted using the means of dependent variables.

Due to the incomplete inclusion of generic competences in the White Book (Casanovas et al, 2004) and the disparity in existing scales between the two studies, it was decided to compare isolated and comparable values between the investigations.

Content validity

The questionnaire was adapted from another questionnaire used for the determination of competencies for graduates of computer science degrees used by Casanovas et al. (2004), which was based on the white book on computer science degrees. As argued by Emory (1985), content validity is not numerical, but subjective and judgmental. Taking this into account, the authors requested feedback from three academics who were expert in higher education issues. As a result of this process, several items where rewritten based on the experts' opinions.

Results

Table 3 shows the profile descriptions from the different groups which served in this first study. Columns PC, 1P, and 5P present the profile characterization of candidates (high school students), 1st and 5th year students, respectively. Columns 1S and 5S correspond to self-evaluations from 1st and 5th year students and 5O refers to the 360-degree feedback.

Table 3. Means of results obtained per group

	PC	1P	1S	5P	5S	5O
Capacity for analysis and synthesis	2.6	3.4	2.5	3.6	2.8	2.6
Organization and planning	3.1	2.9	2.2	3.5	2.5	2.3
Basic general knowledge	3.1	2.7	2.5	2.8	2.8	2.5
Oral and written communication	2.5	1.9	2.5	2.8	2.9	2.2
Ability to search information from different sources	2.9	2.9	2.9	3.6	2.9	3.0
Problem solving	2.7	3.3	2.6	3.7	2.9	2.9
Decision-making	2.6	2.7	2.5	3.1	2.7	2.6
Critical and self-critical abilities	2.3	2.4	3.1	3.0	2.7	2.0
Team work	2.3	2.9	2.9	3.6	2.8	2.3
Interpersonal skills	2.5	2.2	2.7	2.6	2.7	2.4
Ability to work within an interdisciplinary team	2.3	2.5	2.5	3.1	2.7	2.2
Capacity to communicate with specialists from other areas	2.5	2.8	2.3	2.9	2.3	2.0
Knowledge of diversity and multiculturalism	1.9	1.7	2.4	2.2	2.5	1.9
Ability to work in an international context	2.6	3.2	2.5	3.0	2.1	1.8
Ethical commitment	1.5	1.4	2.2	2.5	2.7	2.0
Ability to put knowledge into practice	3.4	3.5	2.4	3.3	2.8	3.0

Research skills	2.9	2.9	2.1	3.1	2.4	2.6
Learning capacity	2.9	3.3	2.8	3.7	3.4	3.1
Adaptation/flexibility	2.9	2.9	2.7	3.8	3.2	3.0
Capacity to generate new ideas (creativity)	3.1	3.4	2.7	3.3	2.5	2.6
Leadership	1.9	2.2	2.1	2.6	2.7	2.1
Understanding of cultures and customs of other countries	1.5	1.3	2.1	1.5	1.9	1.5
Ability to work independently	2.9	3.0	2.6	2.6	2.6	2.7
Project design and management	3.1	3.3	2.5	3.3	2.5	2.4
Initiative and enterprise	2.9	2.8	2.6	2.8	2.7	2.0
Concern for quality	3.3	3.1	2.8	3.5	3.1	2.4
Will to succeed	3.3	3.3	3.1	3.3	3.2	2.8

Profile of the computer science practitioner

Results from the ANOVA analyses show that statistically significant differences between individuals exist (see Table 4). Table 5 shows the similarities found between candidates, 1st and 5th year students.

Table 4. Competences with significant differences

Capacity for analysis and synthesis	$(F(2)=11.654, p<.05)$
Organization and planning	$(F(2)=3.866, p<.05)$
Oral and written communication in native language	$(F(2)=9.771, p<.05)$
Ability to search information from different sources	$(F(2)=3.904, p<.05)$
Problem solving	$(F(2)=6.991, p<.05)$
Critical and self-critical abilities	$(F(2)=3.753, p<.05)$
Team work	$(F(2)=11.453, p<.05)$
Ability to work within an interdisciplinary team	$(F(2)=4.964, p<.05)$
Ethical commitment	$(F(2)=7.129, p<.05)$
Learning capacity	$(F(2)=3.586, p<.05)$
Adaptation/flexibility	$(F(2)=7.949, p<.05)$

Table 5. Competences showing significant differences between groups

Candidates and 1st year students	1st and 5th year students	Candidates and 5th year students
Capacity for analysis and synthesis	Organization and planning	Capacity for analysis and synthesis
Oral and written communication	Oral and written communication	Problem solving
	Ability to search information from different sources	Decision-making
	Problem solving	Critical and self-critical abilities
	Critical and self-critical abilities	Team work
	Team work	Ability to work within an

		interdisciplinary team
	Ability to work within an interdisciplinary team	Ethical commitment
	Ethical commitment	Learning capacity
	Adaptation/flexibility	Adaptation/flexibility
		Leadership

Competence Comparision

The first analysis performed compared self-evaluations between 1st and 5th year students and between 5th year students and their classmates. Competence for which significant differences existed are presented in Table 6 and 7, respectively.

Table 6. Significant differences in self–evaluations (1st and 5th year students)

Learning capacity	$(t(59)=-2.750, p<.05)$
Adaptation/flexibility	$(t(59)=-2.322, p<.05)$
Leadership	$(t(59)=-2.513, p<.05)$

Table 7. Significant differences in self-evaluations (5th year students and their classmates)

Oral and written communication	$(t(29)= 2.617, p<.05)$
Critical and self-critical abilities	$(t(29)= 2.802, p<.05)$
Team work	$(t(29)= 2.236, p<.05)$
Ability to work in an interdisciplinary team	$(t(29)= 2.804, p<.05)$
Appreciation of diversity and multiculturalism	$(t(29)= 2.942, p<.05)$
Ethical commitment	$(t(29)= 2.843, p<.05)$
Leadership	$(t(29)= 3.247, p<.05)$
Initiative and enterprise	$(t(29)= 2.617, p<.05)$
Concern for quality	$(t(29)= 3.034, p<.05)$

Individual-Professional profile fit

To find out the fit between the individuals and the professional profile defined, an analysis based on the t-test was performed. Competences for which significant differences existed are shown in Table 8.

Table 8. Significant differences between the individuals and the professional profile

5th year students	
Capacity for analysis and synthesis	$(t(29)=5.139, p<.05)$
Organization and planning	$(t(29)=5.058, p<.05)$
Ability to search information from different sources	$(t(29)=3.525, p<.05)$
Problem solving	$(t(29)=3.717, p<.05)$
Decision-making	$(t(29)=2.379, p<.05)$

Team work	$(t(29)=3.979,p<.05)$
Ability to work within an interdisciplinary team	$(t(29)=2.362,p<.05)$
Appreciation of diversity and multiculturalism	$(t(29)=4.877,p<.05)$
Ethical commitment	$(t(29)=2.715,p<.05)$
Ability to put knowledge into practice	$(t(29)=3.340,p<.05)$
Research skills	$(t(29)=2.192,p<.05)$
Learning capacity	$(t(29)=3.764,p<.05)$
Adaptation/flexibility	$(t(29)=5.139,p<.05)$
Leadership	$(t(29)=-2.149,p<.05)$
Ability to work independently	$(t(29)=5.767,p<.05)$
Initiative and enterprise	$(t(29)=2.845,p<.05)$
1st year students	
Capacity for analysis and synthesis	$(t(30)=6.017,p<.05)$
Organization and planning	$(t(30)=4.135,p<.05)$
Oral and written communication	$(t(30)=-3.058,p<.05)$
Problem solving	$(t(30)=3.503,p<.05)$
Critical and self-critical abilities	$(t(30)=-2.867,p<.05)$
Interpersonal skills	$(t(30)=-2.244,p<.05)$
Capacity to communicate with specialists from other areas	$(t(30)=-3.407,p<.05)$
Appreciation of diversity and multiculturalism	$(t(30)=2.559,p<.05)$
Ability to work in an international context	$(t(30)=-3.967,p<.05)$
Ethical commitment	$(t(30)=4.593,p<.05)$
Ability to put knowledge into practice	$(t(30)=3.673,p<.05)$
Research skills	$(t(30)=2.133,p<.05)$
Adaptation/flexibility	$(t(30)=3.992,p<.05)$
Leadership	$(t(30)=-3.230,p<.05)$
Initiative and enterprise	$(t(30)=3.429,p<.05)$

Comparison with the computer scientist stereotype

The computer scientist stereotype described in the literature considers the limited importance of the following competences:

- Oral and written communication
- Team work
- Interpersonal skills
- Ability to work within an interdisciplinary team
- Capacity to communicate with specialists from other areas
- Ethical commitment
- Concern for quality

Results demonstrate that, except for concern for quality, all the other competences are given a medium rating (with around two points, see Table 3).
Ethical commitment is the competence with the lowest rating by all individuals, showing the most stereotyped characteristics.
It is important to note that all the values of column 5O (evaluation of their classmates) are always lower than those of column 5S (self-evaluation) with differences ranging from 0.3 to 0.7 points. This tendency may be explained through the so called “leniency effect”, which consists in assigning higher self-evaluations than those given

by supervisors or equals. Apart from the methodological bias, evaluations in column 5O are the closest to the stereotype, except for the ethical commitment competence, being also the lowest total means in the study.

Comparison with curricular efforts

As mentioned above, the Tuning project is the source form which this study considering the set of competences (González & Wagenaar, 2003). This project did not follow the White Book fully (Casanovas et al, 2004). This work extends that of the Tuning project by improving the scales, which are expanded and include the 0 value.

The findings indicate that the values given by respondents are by far greater than those proposed in the curricular initiatives, especially for two cases: team work (the one with the highest value in the White Book) and ethical commitment. It is also important to note that both competences are part of the stereotype proposed in the literature, respondents corroborated that either with definitions of the computer scientist, their own evaluations or those from their classmates.

Discussion

The results demonstrate that professional descriptions from students tend to be more demanding when they have more information concerning their major. The sums of the means for the set of competences analysed are 71.5 for candidates, 73.9 for 1st year students, and 82.8 for 5th year students. Taking into account this information, it is not surprising to find significant differences between the groups for the competences analysed. A total of 9 significant differences between 5th and 1st year students, and 10 between candidates and 5th year students are found. Whereas, only two competences show significant differences between candidates and 1st year students: capacity for analysis and synthesis, and oral and written communication. These circumstances confirm the wider difference existing between the students' perception of professional capacities, which seem to increase throughout time.

The comparisons between groups provide interesting findings. First, the comparison of self-evaluations from 1st and 5th year students indicate a much lower incidence than the one produced when analysing the professional profile. More specifically, only three competences show significant differences: learning capacity, adaptation/flexibility and leadership. Second, the differences shown between 5th year students and the evaluations made by their classmates are another interesting discrepancy. As mentioned above, the "leniency effect" may explain that. In fact, a total of nine differences appeared. The difference between someone's self-concept and the vision from his/her classmates is a regular tendency in evaluations and has been extensively documented in the literature.

Conclusions

Results demonstrate that several elements of the computer scientist stereotype are presented in students, despite of the different descriptions from the curricular recommendations. Two key competences for computer scientists (team work and ethical commitment) seem to be underestimated by the students, being very much ignored in their evaluations.

Curricular efforts seek to amend the computer scientist profile, adjusting it to the needs of the industry, but students seem to fail to either perceive some professional characteristics as necessary or to include them in their evaluations. This may explain the existing gap between the needs of the labour market and the competences of computer science graduates, which is one of the main causes attributed to the so-called Software Crisis.

Our work and conclusions can help Computer Science University curricula designers to develop programs in which certain competences are developed more effectively and precisely to attend both students' competency gaps and industry needs. In addition, our work can be a warning sign to our professional community. There is a need to communicate our job characteristics, social value and professional recognition.

Future lines of research that can be drawn from this study, apart from this research being applied in other fields of engineering education, are those related to the investigation of educational actions that may inform students of the labour market's competence requirements from the moment they chose their university major. Also, it is important to analyse how they can acquire knowledge regarding the social and work aspects of the computer science profession throughout their schooling as well as how educate them to improve the person-job fit.

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