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Inclusion of gender perspective in Computer Engineering careers

Elaboration of a questionnaire to assess the gender gap in Tertiary Education

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Abstract— **Gender inequality is a global problem present in all facets of life to a greater or lesser degree. In the fields of Sciences, Technology, Engineering and Mathematics, both in career and work contexts, the gender gap continues. The percentage of women who study or work in the technology sector is around 25% according to different international reports. The incorporation of gender studies in the curricula is considered one of the main actions to close the gender gap in tertiary education. Education programs should approach conceptual mismatches between gender or sex and change its foundations to guarantee equal education for any person by limiting the influence of social stereotypes and dominant culture. There are few studies that aim at describing what is the main stream viewpoints among students from research instruments previously validated. This work describes the process to elaborate a questionnaire on gender perspectives and its validation in order to describe what students of Computer Engineering careers think and what changes can be implemented accordingly in future education programs to close the gender gap.**

Keywords—gender gap; gender; inequality; software engineering; questionnaire; tertiary education.

I. INTRODUCTION

Women represent 50% of the population that consume technology, but this percentage is not represented in the gender workforce distribution in the companies that develop it. Worldwide, only 25% of the technological jobs are held by women according to the latest report of the National Center for Women Information Technology (NCWIT) [1]. This percentage is reduced to 18% in Spain, according to Governmental data.

The report "The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution" presented in January 2016 at the World Economic Forum meeting in Davos (Switzerland) confirms these results in its chapter about the gender gap in the industry. Furthermore, the report highlights that only 26% of jobs in the technology sector are carried out by women while the market forces transform industries in favor of technological skills development [2].

In recent years, companies such as Google have implemented measures to reduce the lack of diversity in their hiring policies. Regarding gender and technology, the first report prepared by this company in 2014 revealed that only 17% of its employees in the technology sector were women. Currently that gap has been reduced by 3% as can be checked in the results of its latest report (https://diversity.google/commitments/).

The low participation of women in Science, Technology, Engineering and Mathematics (STEM) studies has been identified as one of the main problems that needs to be resolved in order to reduce the gender gap that exists in the technology sector. Although women have made significant progress in their participation in higher education, they are still under-represented in these fields. This problem is more pronounced at senior levels in both academic and professional contexts.

The social stereotypes in engineering are evident in a misconception of engineering as a male profession that difficult the identification of women with this kind of jobs [3, 4]. Several studies on the subject also agree that there is an absence of female models in technology [5-7].

According to Buquet Corleto [8] the incorporation of gender studies in the curricula is considered a factor that favors the process of institutionalization of the gender perspective in higher education. Additionally, this change has a double impact. On the one hand, academic learning can be more inclusive oriented by providing them with new theoretical and methodological elements for the understanding of social reality. On the other hand, the importance of classroom discussions including the gender perspective contributes to deconstruct the various forms of discrimination prevailing in our societies and to transmit values of equity and respect for differences.

Teacher Education have largely claimed that the gender gap must be overcome in nowadays societies. Research has been pointing out, basically from post-structuralism critical paradigms (i.e., queer theories), that education should approach conceptual mismatches between gender or sex for instance and change its foundations to guarantee equal education for any person by limiting the influence of social stereotypes and dominant culture. In Europe, the number of female tertiary students that choose studies in the field of natural sciences, mathematics, statistics, and information and communication technologies is 38.7% and this percentage is lower in engineering, manufacturing and construction-related studies (26%). By contrast, within health and welfare women accounted for close to three quarters (71.9 %) of the total number of tertiary students and a 77.8% in education studies [9].

In Spain, according to the last report published by the Spanish Ministry of Education, Culture and Sports, Facts and figures of the Spanish Higher Education System - Academic year 2015-2016, the 54,1% of the total university students are women [10]. The proportion of women increases among university graduates to stand at 58% on average. The percentage of women participation in all fields of education is higher than men, with the exception of STEM careers. The highest percentage of women, 69.4%, is in the field of Health Sciences and the lowest, 25.8%, in Engineering and Architecture. These figures have remained stable over the last 10 years if we compare the published results from the academic year 2005/2006.

However, there are few studies that aim at describing what is the main stream viewpoints among students from research instruments previously validated. Therefore, our objective is to have an overview of the gender gap in Computer Engineering degrees with the ultimate purpose of introducing the gender perspective in the syllabus as a cross-curricular skill.

To have a depiction about what undergraduate students think of gender issues in their career we will follow a triple-fold process:

1. Elaboration of a questionnaire (GENCE questionnaire) about the inclusion of the GENder perspective in Computer Engineering. By taking into the account major theories and perspectives on the field of gender education.
2. Application to a pilot sample.
3. Validation of the questionnaire. Assess the psychometric properties of the instrument with the purpose to be consistently applied in wider contexts. Our intention for the validation of the questionnaire followed the methodological rational described in Table 1.

TABLE I. VALIDATION ON THE GENCE QUESTIONNAIRE

Objective	Method	Hypoteses
Test the reliability of the questionnaire	Cronbach's alpha	H0: The items do not correlate with the scale. H1: The items show high internal consistency
Test the experts' degree of agreement	Kendall's W Consistency coeficient	H0: Ranks are independent, there is no concondance. H1: There is significative concordance among ranks.

II. METHDOLOGY

A. Context

In 2007 the Organic Spanish Act 4/2007, of 12 April 2007, modifying the Organic Act on Universities 6/2001, 21 December 2001, established for the effective Equality of Women and Men, that "The universities will have units of equality with the purpose to apply the principle of equality between women and men".

To comply with this Law, the University of Salamanca created in 2008 the Equality Unit (http://igualdad.usal.es/). This initiative has as main aim the promotion of the process to creating consensus on university equality policy, allowing the follow-up of the Equality Plan between women and men of the University of Salamanca, as well as ensuring compliance with current regulations. It was one of the first to be created and also became the first one defined in the Statutes of a Spanish University.

In addition to the Gender Equality Unit regulations, it should be noted that "…the actions of the University are inspired by the principles of democracy, equality, justice and freedom. Any form of sexism or discrimination, direct or indirect, on grounds of sex, goes against both those principles and our sensibilities and convictions" [11, 12].

In this context, during the 2016/2017 academic year, the Gender Equality Unit at the University of Salamanca published a report entitled "Analysis of the subjects on gender taught by the University of Salamanca and the competencies in matters of gender equality" [13]. This study shows that in the Computer Engineering academic guide the only reference on gender was "fundamental rights and equality of opportunities between men and women will be taken into account, the principles of equal opportunities".

The present work incorporates the gender perspective in the syllabus of the Degree in Computer Engineering of the University of Salamanca (Spain) through a first experience in a compulsory course, "Software Engineering: Module 1", as well as the elaboration of the GENCE questionnaire.

B. Participants

The "Software Engineering: Module 1" is a compulsory course for undergraduate students that is taught in the second semester of the 2nd year of the Degree in Computer Engineering at the University of Salamanca, Spain. Due to the number of students the subject is divided into two groups (group A and B). The undergraduates who participated in this study belonged to Group A. This group enrolled 72 students of which 60 are enrolled for the first time (83.33%), 4 is the second time they enroll (5.55%), 3 is the third time (4.17%), others 3 is the fourth time (4.17%) and 2 are in their fifth enrollment (2.78%). 13.89% are women (10 students), all of them with first registration.

There are two course modalities. A traditional approach modality focused on a final exam (designed for those students who have studied the subject before or who were not able to attend the lessons), and a continuous evaluation approach based on active learning [14] where students should attend theory and practice lessons, complete classroom exercises, workshops, oral presentations, and submitting final assignments. Overall, 63 students (87.5%) completed the continuous assessment modality versus 9 (12.5%) who chose the traditional modality.

C. *Instrumentation*

A 33-item questionnaire was elaborated to measure the extent to which the students were aware of the gender issues in their own career to give visibility to this social and professional gap that students usually face after finishing their careers. The GENCE questionnaire is still in an early stage. A first Spanish version of the questionnaire can be viewed on [15].

The questions were divided into 10 demographics items, 12 open items and 12 multiple choice items. The elaboration of the items has combined ad-hoc defined questions and questions based on previous research models found in the research literature in Spanish. More specifically we based our questions in the script of the interviews carried out in the project "Pathways of technological life and gender: psychosocial factors involved in access to computer engineering degrees" [16], and in the questionnaire used in the project "Strengthening the Gender Equality in Higher Education in Colombia " [3].

D. *Study design*

Several activities were carried out to include the gender perspective as part of the course. First, during the development of the course the teachers provided undergraduate students with information about gender studies, emphasizing those topics related to the technological field. Twitter was the mainstream channel to share information under the hashtag *#is1usal17*. Previously this social network had been used to provide extra information about software engineering. During 2016/2017 the focus was gaining visibility on the gender gap (i.e., the tweets were embedded in the course online platform in the Virtual Campus of the University of Salamanca to reach as many students as possible). Fig. 1 shows actual tweets published during the experience.

Secondly the resources used during the theory and practice lessons were updated, as well as those published in the Virtual Campus. The aim of this update process was using a gender-inclusive language avoiding masculine pronouns as generic use (in Spanish). Despite the indications of the Real Academia Española de la Lengua [Spanish Academy of Language] to address this type of action [17]. Consequently, female gender was acknowledged in the classroom materials. For instance, one of the task was to redefine UML (Unified Modeling Language) diagrams about marriage. The traditional version was base in non-inclusive language whereas modified version contemplated that a person can marry people of the same or different sex, and also b2 include polygamy (Fig. 2).

Fig. 1. Tweets with the hashtag defined for the course in 2016/2017 *#is1usal17*

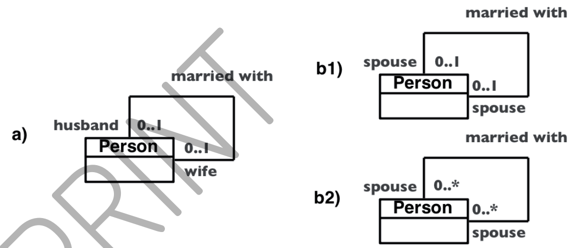

Fig. 2. a) Non-inclusive class diagram b) Inclusive class diagrams

The course had a strong practical component. Throughout the semester, teachers proposed a set of problems to be solved from a software engineering point of view (using UML diagrams). The problems were described through a set of requirements that the software tool had to meet. In our course, the problems related to gender in the technology sector had to be included. Additional information was provided to set the background of the problem. Three problems were handed out to the students:

- Design a web application that provided tools to promote the acquisition of STEM competencies in primary and secondary education with special emphasis on girls, trying to reduce the perception of inequality in the choice of university studies.
- Design a job internet portal for women specialized in computing, telecommunications and technology.
- Design an internet portal for an association whose main goal is to give visibility to women in the technological field through different projects.

Fig. 3 shows an agreed-upon solution given by the students who participated in the workshop related to the first problem described above.

Both the exercises and the final assignment were done in groups of two to three students (defined under the students' criteria). As part of the study, teachers promoted mixed-gender groups, taking into the account the number of women enrolled in the course.

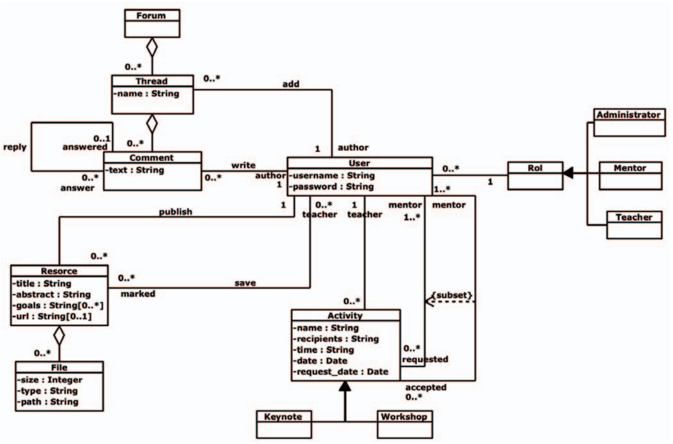

Fig. 3. Class diagram for an application to promote STEM competences in primary schools

Finally, the final assignment consisted in designing a web portal to promote the visibility of women in the STEM context, providing a space to manage and promote brainstorming, projects creation, associations and institutions networks, related to close the gender gap in the technology sector. Previously the main requirements of the software system in the course were defined beforehand, but in 2016/2017 students had freedom to define it and to do research on the topic.

As part of the final assignment, students had to write a brief technical report in which they drafted an introduction to the problem domain, highlighting the most relevant aspects of their work. Some student groups publically presented their technical reports in the classroom.

E. Data collection and analysis

The students of the course "Software engineering: Module 1" voluntarily participated in this study and decided whether to complete the questionnaire. Anonymity was guaranteed.

Initially the questionnaire was answered online by 55 students but these data were invalidated when the link to the questionnaire was made public in an internet forum. It was not possible to restrict access only to users of the university community, in order to ensure the anonymity of the participants. Due to this, the same instrument was applied again during non-school hours, but in printed format to avoid the previous problem. Under this format only 9 responses were collected. A second application (also in print) was conducted during non-school hours and 23 answers were obtained, although one of them was not fully completed.

One data was collected, we proceeded with the validation of the questionnaire. Cronbach's alpha reliability test was calculated to measure the internal consistency of the instrument.

The validity of the GENCE questionnaire was conducted by following these steps [18]: (1) Provide guidelines to the experts; (2) select the experts; (3) Collect each answer –via online- and (4) proceed to calculate the degree of agreement among them.

For calculating the degree of experts' agreement (step 5) we followed a group validity method (in contrast to individual methods such as aggregate methods or Delphi). Five experts were asked to reach consensus on certain decisions affecting the content of the items. The five experts had more than 10 years of working experience in their fields (their age ranged from 40 to 60 years old). Two of them are from Mexico and the other three from different parts of Spain. Three of them belonged to the social sciences domain (one specialist in gender and other two in pedagogy) whereas the other two to engineering and architecture (software and computer engineers).

To determine this consensus, we first calculated the percentage of agreement among experts but we realized that this measure did not correct the agreement reached by chance [19]. Therefore, we finally applied Kendall's W statistic to measure the interrater agreement.

III. Results

A. Reliability analysis

The analysis of reliability was executed by applying the formula (1) below:

$$\alpha = \frac{n \cdot \bar{c}}{\bar{v} + (n-1) \cdot \bar{c}} \qquad (1)$$

Where:

- N = number of items,
- $\bar{c}$ = average covariance between item-pairs,
- $\bar{v}$ = average variance.

The general interpretation of Cronbach's alpha on a Likert scale is $\alpha \geq 0.8$ is excellent; α= 0.6- 0.8, Acceptable; α=0.4-0.6= poor; $\alpha \leq 0.4$, unacceptable.

We obtained a score of α= 0.316 which inform us that the items of the questionnaire are not internally consistent because the items correlations are generally low (see Table 2):

TABLE II. Item correlations of the GENCE questionnaire

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
It1. *Las mujeres que estudian Ingeniería Informática son*	32.09	10.563	.451	.640	.160

poco femeninas / Women who study Computer Engineering are not very feminine					
It2. *Los hombres y las mujeres que estudian Ingeniería Informática son "frikis"* / The men and women who study Computer Engineering are "geeks"	32.91	11.801	.166	.521	.272
It3. *Las mujeres tienen más problemas que los hombres a la hora de programar* / Women have more problems than men when they program	32.23	10.184	.433	.800	.146
It4. *Las mujeres que estudian Ingeniería Informática tienen un comportamiento similar a los hombres* / Women who study Computer Engineering have a similar behavior to men	32.36	12.052	.119	.648	.292
It5. *Los hombres y las mujeres tienen las mismas oportunidades para estudiar carreras de Ingeniería como la Informática* / Men and women have the same opportunities to study engineering careers as Computer Science	34.09	12.563	.035	.780	.326
It6. *Los compañeros(as) en estudios de Ingeniería Informática tratan de igual forma a sus compañeros(as) del sexo opuesto* / The colleagues in computer engineering studies treat their classmates of the opposite sex in the same way	34.59	12.539	.175	.632	.281
It7. *Los profesores(as) de la carrera tratan de igual forma a hombres y a mujeres* / The professors of the career treat men and women in the same way	34.55	11.307	.253	.767	.235
It8. *Los hombres y las mujeres tienen diferentes cualidades a la hora de trabajar en el ámbito informático* / Men and women have different qualities when it comes to working in the computer field	33.50	12.738	-.007	.331	.346
It9. *Las mujeres tienen más problemas que los hombres*	33.91	13.801	-.136	.588	.384

para encontrar trabajo como Ingenieras Informáticas / Women have more problems than men to find work as Computer Engineers					
It10. *En la actualidad, los hombres y las mujeres reciben la misma remuneración por cargos similares* / Currently, men and women receive the same remuneration for similar charges	32.91	12.658	-.036	.656	.369
It11. *Es importante que haya un mayor número de mujeres que ocupen puestos laborales en el ámbito tecnológico* / It is important that there is a greater number of women who occupy jobs in the technological field	34.36	14.433	-.232	.611	.403
It12. *Prefiero ponerme en grupos de prácticas con compañeros(as) de mí mismo sexo* / I prefer to put myself in groups of practices with partners of my same sex	32.50	11.786	.179	.492	.267

A low level for alpha means that the items are poorly correlated. With more numbers of items in the scale it is supposed that alpha might increase its value.

Therefore, the alternative hypothesis must be disregarded. This result might indicate that the instrument designed might also contain more dimensions than the ones intended to measure and thus the test might not be accurately measuring the variable of interest.

A possible solution to increase the coefficient would be to eliminate those items that poorly correlates with the scale. But in this case, we should delete items number 2, 4, 6, 8, 9 and 11 (see column 5 in Table 2) to get a Cronbach's alpha of α= 0.626 but that would mean to practically get rid of half of the questionnaire. The plausible solution would be to rephrase the actual questions and add some more to the questionnaire [20].

B. Expert validation

The 14 items of the scale were independently measured from 1= totally disagree to 7= totally agree by each of the five experts. On the other hand, each item was scored in three predefined dimensions: (1) content adequacy: the extent to which the theme of the item reflects an important content of the domain of study; (2) clear formulation: the use of a language that can be easily understood; (3) and target population addressing: how the items focus on the specific group of people (young students) that are intended to aim at.

The Kendall's W non-parametric statistic was used to calculate the interrater agreement in the ordinal scale used (Table 3). It is basically a normalization of the Friedman's test using the following formula (2):

$$W= \frac{12S}{m2\ (n3-n)} \qquad (2)$$

Where:

- S is the sum of squared deviations,
- m is the number of inter raters,
- n is the total number of items being scored.

TABLE III. KENDALL'S W NON-PARAMETRIC STATISTIC

Dimensions	Kendall's W	Interpretation
Content adequacy	0.25	Moderate agreement
Clear formulation	0.16	Weak agreement
Target population addressing	0.29	Moderate agreement

Kendall's W coefficient range from 0 (complete disagreement) to 1 (complete agreement). The low and medium

Kendall's values in our study might be interpreted as the five experts did not applied the same standards to value the items [21]. For instance, the disagreement in clear formulation ranged from values of 2 to 7 resulting in a very low agreement coefficient (w=0.16). In this sense, we cannot assure that they are using incorrect parameters in their observations but, rather, the items need to be more clearly formulated. We need to take into the account that we are trying to measure a highly complex process that implies not only showing personal views, but surfacing feelings and lining identities. Thus, it is difficult to contemplate all these factors when phrasing the items statements.

On the other hand, and despite the selection of experts guaranteed their independence from each other, we skipped a step suggested by Skjong and Wentworth [18] about the explanation of the rationale of the instrument, purpose and focus our research to the experts. We sent them a short description of the instrument we were elaborating but without entering any debate or personal explanation.

IV. Conclusions

There is a large number of national and international initiatives whose main objective is to reduce the gender gap in the technology sector [22]. On an international level, Women Techmakers (https://www.womentechmakers.com) promoted by Google, intend to achieve greater diversity in the technology sector. Also the IEEE Women in Engineering (http://www.ieee.org/membership_services/membership/women/index.html) and ACM-W (https://women.acm.org) projects, are focused on women visibility in the technology sector from a research perspective. Regarding the initiatives in Spain, The Technological Campus for girls of the University of Granada (http://cs4hs.ugr.es), the Tech&Ladies initiative (http://techandladies.com), the STEM Talent Girl (http://talent-girl.com) or the social startup Adalab (http://adalab.es) is worth to refer to. In all of them their policy is to boost talented women to develop their full potential and give them visibility as digital professionals.

In the educational context, there are a large number of initiatives that work gender issues throughout the early educational stages in order to promote the interest of children, and in particular the girls, for the STEM studies and computational thinking in schools [23-25]. In tertiary education, the problem is not about STEM but about gaining greater visibility of women who study technical careers.

The pilot experience developed in a course of the Computer Engineering career of the University of Salamanca (Spain) has allowed to collect data in order to validate the GENCE questionnaire.

The validation of the questionnaire has been conducted by using two methods: the Cronbach's alpha for measuring the internal consistency of the instrument, and the Kendall's W statistic to measure the experts' degree of agreement.

Regarding the defined hypothesis (Table 1), there are not enough evidences to reject the null hypothesis in both tests. The items of the questionnaire do not correlate with the scale because the Cronbach's alpha is 0.316, so the items of the questionnaire are not internally consistent. On the other hand, there is no concordance among ranks in the experts' evaluation, so there is a very low degree agreement between the experts.

The results of the validation process provide the necessary information to redefine the questionnaire in order to have a more solid and reliable instrument. There are a number of important changes which need to be made. Specially there is a strong need to review previous research published in the English literature (i.e. [26]). Future works will focus on analyze and apply the observations provided by the five experts.

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