“ON THE SHOULDERS OF GIANTS” THE HISTORY OF WOMEN AND MEN IN PHYSICS AS A TEACHING INNOVATION IN ENGINEERING DEGREES

J.M. González-Moreno[1], A. García-Yeguas[2], J. Romero-Cózar[3], M. Gázquez[3], J. Reyes[3], J.J. Muñoz-Pérez[3]

[1]Universidad de Málaga (SPAIN)
[2]Universidad de Granada (SPAIN)
[3]Universidad de Cádiz (SPAIN)

Abstract

This paper describes the results of the teaching innovation project. It was putting into practice at the School of Engineering of the University of Cádiz during the academic year 2016/2017. It was called "*If I have seen further it is because I am sitting on the shoulders of giants. A little history of Women and Men in the history of Science and Engineering in the classrooms of the Higher School of Engineering"*. The main objective of the project was to inform the students of the first year of the Degrees of Electricity, Industrial Electronics, Industrial Technology, Aerospace, about the biographies and the contributions of some of the "giants" of the Physics and Engineering. It supposed a recovery of the History of the Physics in the teaching in the Degrees of Engineering. Moreover, we have tried to make visible some of these researches, especially, the feminine scientists. The realization of this project has increased the motivation of the students for the learning of physics. Knowing the biographies, contributions, successes and failures of great scientists, predisposes students to understand more complex concepts and, at the same time, taking those giants as a source of inspiration.

Keywords: History of Physics, men, women, educational innovation, Engineering.

1 INTRODUCTION

It's not a novelty that the concepts of Physics are difficult to understand and, obviously, this entails a large number of academic failures [1]. Therefore, different alternative methodologies have been tried successfully to increase the number of students that pass this kind of subjects: audio/visual resources, use of GPS and Google Earth, use of “rules of thumb”, tutorials to promote self-directed programming learning, collection of practical exercises already solved, literature search for relevant information and promotion of teamwork, etc. [2-8].

The slogan "On the shoulders of giants" is usually attributed to Newton who, in a letter to Robert Hooke, wrote (1676): "*If I have seen further it is because I am sitting on the shoulders of giants*". But the quote should be attributed to Bernardo Chartres and Juan de Salisbury, philosophers of century XII. On the other hand, the appointment has been used by illustrious thinkers to title their works [9-10]. The idea is that knowledge is collective and has been forged over time on the basis of ideas provided by successive generations of thinkers. However, in the university classrooms, it is not noticed that the knowledge provided by the thinkers of the past is the basis on which our knowledge is based in the present - rather this is given by budget -. Moreover, very little is known about the people who are the architects of this knowledge, as is the case, in the teaching - learning of Physics. And this in spite of the fact that many physical laws have their own name. Even less it is known that the architects of knowledge were both men and women.

This state of affairs, however, is not surprising if we take into account that in the world of knowledge - and the University is part of that world - two exclusions have historically prevailed: the exclusion of History and the exclusion of women. Two exclusions that can be seen as one because they are in agreement. According to Escribano: scientific activity has been characterized by the play of a series of dualisms, among them two dualisms that are quite symptomatic: science versus history and science versus culture [11]. And this dualistic characterization would explain, on the one hand, the proclamation of the neutrality of science, its specificity and its high specialization, and at the same time the exclusion of other branches of knowledge from the field of science. On the other hand, the exclusion of women from the History of Science.

Throughout the History of thought, women have been excluded from Science. According to Duran [12], women have been considered physically and mentally inferior to men. As far as Science was concerned, they were incapable of abstract reasoning, which was the criterion on the basis of which science was - and it is still- defined.

Indeed, History, including the History of Science and, therefore, also that of Physics, has been postponed in the teaching of Science [13-14]. There are also people who insist on the importance of the History of Science (for example, to define the structuring concepts in the moments of transformation of the sciences [15] or to encourage a training that allows the adaptation to changing situations and the acquisition of new knowledge [16]). It is also necessary to incorporate the History of Physics to teaching, to overcome distorted visions [17]. For instance, the curriculum of the Physics career, at the University of Granada, does not include the History of Physics as a subject. Regarding the Degrees of the different Engineering that are taught in the Universities of Málaga and Cádiz, it can be affirmed that the History of Physics is not contemplated as a subject either (www.uca.es and www.uma.es).

In this work we would like to emphasize that attention in the History of Science (and Physics) should also be extrapolated to scientists and not only to the content itself [18]. The university system of teaching - learning is characterized by being impersonal and abstract, centered on the contents. At this point we consider necessary to rescue the researchers because their lives and their experiences are also a source of knowledge.

In addition to rescuing the most relevant characters in the History of Science (and Physics), there is a need to give visibility to female characters. This task has been done since the 70s of last century to alleviate sexism in science [19]. In this sense, it must be said that the interpretation of the relationship between Science and women has been evolving (claiming more in the present). Above all, greater attention has been paid to the diversity of women's experiences in the field of science, and to the construction of a more responsible science that does not adopt the male pattern as a reference [20-22]. The "question of women" in science is not terminated: all the women who have contributed to scientific knowledge have not yet been visualized, nor is significant the presence of women in the sciences. Hence, at the international level, the need to include women in science continues to be insisted on [23].

All these ideas were the ones that inspired the educational innovation project presented in this paper and implemented in the University of Cádiz (hereinafter, UCA) during the academic year 2016/2017. A project whose objective was to complement the teaching-learning of Physics in some Degrees of the Higher School of Engineering -Electrical Engineering (GIE), Industrial Electronic Engineering (GIEI), Engineering in Industrial Technique (GITI) and Aerospace Engineering (GIA)- with the incorporation of History of Physics. In particular, the biographies and the contributions of some people (the giants of that History, also the female giants, who have forged Physics throughout the centuries) have been included.

2 METHODOLOGY

The teaching innovation project that we discussed was reflected in practice in a number of activities. In the first place, during the month of March of 2017, surveys were applied to students in order to inquire about their previous knowledge of facts as well as outstanding men and women in the History of Physics. In total, surveys were carried out to students in the first year of the following degrees in Engineering: 63 surveys in the GIA, 54 surveys in the GIE, 41 surveys in the GIEI, 40 surveys in the GITI, 194 being the total of the respondents. The applied survey contained four basic questions, as reflected in Figure 1.

Figure 1. Survey 1.

1.Do you know any scientific woman and / or engineer ? __Yes __No And men? __Yes _ No Cite two or three people of each gender.	**2**. How have you known them? __Books __In previous courses __Internet __Television __Other: … (cinema, videogames, family)	**3**.Do you know something related to the History of Physics? __Yes __No Cite at least one related fact that you know .	**4**.How have you known it? __Books __In previous courses __Internet __Television __Other: … (cinema, videogames, family)

After confirming that the students did not know many relevant facts in History of Physics or many scientists (especially women), we decided to continue with other activities. Thus, we searched in the UCA library and on the internet bibliographic material about men and women relevant in the world of Science, Physics and Engineering throughout History. Next, we select a series of great scientists or engineers from Ancient Greece to the present day. We delve into the biographies and contributions of the selected scientists or engineers and then expose them to the students in class. In the classes, the biographies and contributions of the selected men and women were explained, in accordance with the course syllabus. In addition, all the teaching material developed was made available to the students in the virtual campus of the subject of Physics II.

Women	Men
Aglaonice de Tesalia	Arquímedes de Siracusa
Teano de Crotona	Pitagoras
Margaret Cavendish	Michael Faraday
Émile du Châtelet	Isaac Newton
Phoebe Sarah Hertha Ayrton	Heinrich Friedrich Emil Lenz
Edith Clarke	André – Marie Ampère
Hedy Lamarr	Nikola Tesla
Tessy Thomas	Albert Einstein
Annie Easley	Thomas Alva Edison
Pilar Careaga Basabe	Juan de la Cierva y Codorniú
Martina Casiano y Mayor	Blas Cabrera
Pilar López Sancho	Peter Higgs

Figure 2. Left. List of men and women scientists and engineers. Right. Image of the posters in the exhibition.

Also, to get these characters and the History of Physics out of the classroom, we decided to make an exhibition at the School of Engineering of the UCA. For this, with the teaching material that we already had, we elaborated 26 posters with the help of collaborating students. Two posters were introductory and of the remaining 24, 12 were dedicated to female scientists or engineers and 12 to male scientists and/or engineers. Each poster contained a short summary of the biography and his/her most important achievements.

Once the posters are made, we present them in panels organized in pairs (scientific woman or engineer / scientific man or engineer) in the centuries that go from Greece to the present day: Aglaonice of Thessaly versus Archimedes, Theano versus Pythagoras; Margaret Cavendish versus Faraday; Émile de Breteuil versus Isaac Newton ... and so on up to a total of 12 pairs, as illustrated in Figure 2. The exhibition, which we call "Women, men and vice versa in the History of Physics", took place in the hall of the Higher School of Engineering of the UCA, from April 24 to 29, 2017.

During the week of the exhibition we also conducted anonymous surveys of 20 people from among the students and professors who came to see it, in order to know what they knew about those exhibited on the posters. And finally, we invite Dr. Francisca Fuentes, professor of Labor Law at the UCA and also General Secretary of the same University, which gave an interesting conference on April 27, 2017 at the School of Engineering about the situation of women in Science and Technology,

3 RESULTS AND DISCUSSION

3.1 The ignorance of people and their facts in the History of Physics

From the initial surveys that we applied to the students of four Degrees that are taught in the Higher School of Engineering of the UCA (GIE, GIEI, GITI, GIA), we were able to know the degree of knowledge/ignorance of the students on the History of Physics, both in regard to the characters of this History and their facts.

In what refers to known facts of the History of Physics, in the four mentioned Degrees, the students stated about 17 to 24 facts. Among them, the invention of the telephone, the wave-corpuscle duality, the discovery of nuclear energy, the discovery of the electron, the heliocentric system, the gravitational force of Newton, the photoelectric effect, alternating current, Einstein's theory of relativity, the discovery of subatomic particles, string theory, the law of Coulomb, the discovery of radioactivity, the invention of the light bulb, the discovery of dark matter, the Big Bang theory. But the most stated facts were: first, Newton's notion of force gravity, cited by more than 12 students in each of the Degrees in which the surveys were conducted, followed by Einstein's theory of relativity, theory that get to cite an average of 7 to 8 students in each of the Degrees.

Specifically, in the GIA, of the 59 students who said they knew something related to the History of Physics, 13 mentioned mostly the force of gravity of Newton, and 6, the theory of relativity while other facts of that History (such as the wave-corpuscle duality, the discovery of electricity, the discovery of nuclear energy ... up to a total of 24 events) are scarcely known (they were mentioned by 2 or 3 students as a maximum). In the GIE, 38 students said they knew something related to the History of Physics, and what they mention above all is Newton's force of gravity (mentioned by 13 students) and Einstein's theory of relativity (cited by 12 students), while other facts (the discovery of subatomic particles, the invention of the light bulb ... up to a total of 21) are less known (each fact is mentioned by 2, 3 or 4 students at most). In the GIEI, in which 44 students said they knew something related to the History of Physics, the same pattern is repeated: 12 students cite Newton's force of gravity, 5 students / as the theory of relativity of Einstein. And the same thing happens in the GITI: 37 students respond that they knew something related to the History of Physics, 16 students mention gravity, for Newton and 7 students, Einstein's theory of relativity, while other facts of the History of Physics are mentioned by 1 or 2 students. The most salient results can be seen in the following illustrative table (Figure 3).

Regarding the question by the History of physics/scientists, the students surveyed stated 9 women, being the most known by far, Marie Curie. Instead, they gave 40 names of men, being the most named Albert Einstein and Newton, followed by Tesla and Hawking.

Figure 3. Knowledge of facts of History of Physics (according to the number of students) in the Degrees of Engineering (UCA)

Knowledge of facts of the History of Physics	**GIA**	**GIE**	**GIEI**	**GITI**
Knowledge of facts, with general character	59	38	44	37
Knowledge of *the notion of the force of gravity* (Newton)	13	13	12	16
Knowledge of the *theory of relativity* (Einstein)	6	12	5	7

Specifically, as far as the knowledge of male scientists of the History of Physics is concerned in the different Degrees, limiting ourselves to the four most cited to compare between Degrees, we have that, in the GIA, 62 students said they knew scientists and / or male engineers, and of these, the most known are: Einstein (44 students indicated their name), followed by Newton (indicated by 37 students). The third place in the degree of knowledge of students and very long distance, Tesla (cited by 8 students) and Stephen Hawking (8 students again). In the GIE, 50 students responded to meet male scientists or engineers, and among those cited, Einstein again occupied the first place (24

students mentioned it), followed by Newton (cited by 22 students), of Tesla (14 students cited it) and Stephen Hawking (mentioned by 11 students). In the GIEI, the results were very similar: 41 students said they knew scientists and / or engineers and the names were Einstein (31), Newton (20), Tesla (19) and Stephen Hawking (4). And in the GITI, 40 students said they knew scientists and / or engineers and the names mostly mentioned were practically the same: Einstein (31), Newton (24), Tesla (10), Stephen Hawking (7). The following table (Figure 4) is illustrative of the most representative results.

Figure 4. Knowledge of scientists (males) of the History of Physics (in number of students) in the different Degrees of Engineering (UCA)

Knowledge of male scientists in the History of Physics	**GIA**	**GIE**	**GIEI**	**GITI**
Knowledge of male scientists and engineers, in general	62	50	41	40
Einstein	44	24	31	31
Newton	37	22	20	24
Tesla	8	14	19	10
Hawking	8	11	4	7

It can be seen in Figure 4 how the most cited scientist is Einstein, while in regard to facts in the History of Physics, as can be seen in Figure 3, Newton's gravitational force is the most named fact. However, in terms of the knowledge of male subjects in the History of Physics by the students, Newton ranks second.

Regarding the knowledge of female subjects of the History of Physics, the respondents cited nine women, but to make a comparison with the results obtained in the surveys on the male subjects, we limited the analysis of the results of the surveys on female subjects to the four most cited authors. Following this criterion, we have that 57 students in the GIA claim to know scientists and engineers, and all of them mention Marie Curie in the first place. The degree of knowledge of other women scientists and engineers is very residual. Thus, 2 students cite Rosalin Franklin, 1 student cites Hypatia of Alexandria, and 1 student mentions Lise Meitner. And in the other Engineering Degrees, the same pattern is repeated, that is, the students who claim to know scientists and engineers cite Marie Curie as the best-known scientist by overwhelming majority. The most representative results can be seen more clearly in Figure 5.

Figure 5. Knowledge of female scientists in the History of Physics (in number of students) in the Engineering Degrees (UCA)

Knowledge of female scientists in the History of Physics	**GIA**	**GIE**	**GIEI**	**GITI**
Knowledge of female scientists and engineers, in general	57	45	40	38
Marie Curie	57	39	39	38
Rosalin Franklin	2	3	6	0
Hipatia de Alejandría	1	3	2	0
Lise Meitner	1	3	2	0

In any case, if we compare the results contained in figure 4 and figure 5 we can affirm that, in the students, the knowledge of male scientists and engineers is distributed, while all the knowledge of women scientists focuses on Marie Curie.

In summary, in a global way, that is, if we take into account both the facts of the History of Physics and the male and female scientists (Figures 3, 4 and 5, respectively), it can be said that the degree of knowledge of the students is rather scarce. Not many facts of the History of Physics are known or many scientists and, of course, very few women scientists are known. This agrees with the trend that

has also followed the research in History of Physics in Spain. As Sánchez-Ron says [13], unlike what happened in previous centuries, we know more from the twentieth century onwards about the physics that was done or taught in Spain and, in particular, what is known most is of the Einsteinian relativity and of Einstein himself [16]. But this does not mean that the terms need to be inverted.

3.2 The need to rescue scientists from the History of Physics, especially the great scientific women

As we have seen in the previous section, the degree of knowledge of scientists in the History of Physics on the part of the students is small, and even more so in the case of women scientists (see Figure 5).

Now, if we take into account that, according to the initial surveys, the main means by which the students have accessed the knowledge of facts of the History of Physics (as well as of the scientists and or relevant engineers) are "from previous courses". That is why our teaching innovation project is justified, to rescue the History of Physics and its researchers.

In the project, the activities chosen to alleviate this situation to a certain extent have been the exhibition in the classes of the biography and contributions of the scientists and relevant engineers throughout history and, above all, the development and subsequent exhibition of posters containing this information, at the School of Engineering of the UCA. This second activity is a visualization of the scientists of Physics that is quite important in itself, and also by the chosen methodological option: the exposure of the scientists in pairs constituted by a relevant male next to an also relevant woman (as shown in Figure 2). Fundamentally because this form of exposure involves presenting women scientists or relevant engineers at the same level (of giants) as their male colleagues, thus revealing "the negative" - the non-visible part - of History (of Physics) always presented as a History in masculine.

In this sense, our project of educational innovation is in line with other works of visibility of women in science [25], but differs from these works, which mostly concentrate on women scientists, presenting them in an isolated way, not together with scientific men and at the same level as we do in our project. We also believe necessary this joint presentation for another reason: students in general [26] must have not only knowledge of the existence of scientist women of the same category of the men, but they also must become aware that it is also necessary to incorporate to textbooks the knowledge contributed by women in different historical epochs.

3.3 The knowledge of the Physics History scientists as motivation for the teaching-learning of Physics

The application of the innovation project has also served to improve the performance of the students in the subject of Physics. Fundamentally, because the exhibition in class to the students of the biographies and the contributions of the most relevant figures of the History of Physics, as well as the exhibition of this information in the posters, has increased their motivation for learning.

The application of the project was carried out in the GIEI in the subject of Physics II during the academic year 2016/2017 (second semester). To evaluate the project, we compared the success and performance rates of the GITI and GIM degrees for the 2015/2016 year. The reason for doing so, is that it was the same teacher who taught the subject, the contents and the practices. Before the 2015/2016 academic year, the GIE, GIEI, GITI and GIM degrees were unified in this course. Let's compare two exam sessions: June and september.

First of all, we are going to define the parameters to be compared (Figure 6): Success rate (SR) = Number of students approved / Number of students presented. Rate of return (RR) = Number of students approved / Number of students enrolled.

Figure 6. Success and Rate of return for academic years 2015/2016 for GITI and GIM and 2016/2017 for GIEI.

	Success rate		Rate of return	
Subject	**Academic year: 2015/16**	**Academic year: 2016/17**	**Academic year: 2015/16**	**Academic year: 2016/17**
Physics II-GIEI		*12/41=0.3 (June) 11/26=0.42 (September)*		*12/64=0.19 (June) 11/49=0.22 (September)*
Physics II - GITI	*24/59=0.4 (June) 8/25=0.32 (September)*		*24/65=0.37 (June) 8/41=0.20 (September)*	
Physics II-GIM	*28/49=0.57 (June) 4/21=0.19 (September)*		*28/69=0.41 (June) 4/40=0.1 (September)*	

The SR and PR were higher in June 2015/2016 in the GIM and GITI grades than in the 2016/2017 course in GIEI. In September 2015/2016 the success and performance rates of GITI and GIM were lower than that of the 2016/2017 course in the GIEI degree.

The students commented that they understood the concepts better and liked the classes more than other years. The classes became more enjoyable and motivated them to try to understand the concepts. What's more, some students have gone from suspending to getting a good grade and pointing out these details. We think that this is a first step for the History of Physics in the classrooms and to rescue the role that scientific women have played in it.

The subject has a high level of difficulty, among other reasons, because students have a hard time understanding the concepts. The students have pointed out that, with the content of this project, the classes had become more enjoyable and had helped them to stop to understand the concepts, rather than to learn the problems by heart (which is not learning Physics).

4 CONCLUSIONS

In the application of this project of educational innovation we have verified the ignorance of the History of Physics in the students of the Engineering Degrees of the Higher School of the UCA. A lack of knowledge both in terms of facts and the scientists of this History, in particular the female scientists. So, as far as facts are concerned, the two mostly known are: Newton's notion of the force of gravity, and Einstein's theory of relativity. And as regards the persons, the most known scientists/engineers are four: Newton, Einstein, Tesla and Hawking. On the other hand, in the case of female scientists, it can be said that Marie Curie is the one who is mostly mentioned by the students.

We believe that this ignorance of the History of Physics highlights the need for rescue and justifies our teaching innovation project. Within the framework of the project and to alleviate this situation that emerges from the results of the surveys, we carried out two activities: first, to show to the students the biographies and contributions of some of the men and women most relevant in the History of Physics and, second, make an exhibition with some of them in the School of Engineering.

For this exhibition we made 24 posters, each containing the biography and main contributions of each scientist or engineer chosen, and we chose to present the posters organized by peers, with the aim not only of visualizing women scientists or engineers but also of present them at the same level as scientific men or engineers. Also, with this joint presentation at the same level (hence the title of the exhibition, "Women, men and viceversa in the History of Physics"). We called attention to another

important issue: the contributions of women to Science, to Physics, to Engineering, are part of the contents of these disciplines that are taught and learned both in the University and in the High School.

Finally, the project presented herein shows how to discover and describe the giants of Science, Physics and Engineering (and explain their biographies, their contributions, their successes and their failures) predisposes the students to understand more complex concepts and, at the same time, to take those giants as a source of inspiration. All of which also demonstrates how innovation in education can refer to our own knowledge of the History of Science, in particular of the people who have forged the knowledge we have today.

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