Attitudes and motivations towards physics and its learning at both high school and university

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Abstract— One of the main objectives of this research is to quantify the attitudes and motivations of students towards physics and its learning at different stages. In addition, it is going to be verified if an instruction in physics during the school year affects in the same way to the attitudes and motivations of students depending on both the stage it is being considered and the gender. The sample is constituted by high school students and students in the first year of engineering that have studied necessarily a physics course during the 2013/2014 school year. The analyses of the results of those 772 students lead to several conclusions: on the one hand, it has been observed that in both stages, instruction affects more positively to men in their image as well as in their interest towards physics. Gender differences are significant at high school where the motivation of female students is especially negative after the instruction. This result makes more sense taking into account that it has been also observed that the sample of this study at university is constituted by one in five female students. On the other hand, the interest of the students is not generally as high as the image they show. Consequently, the influence that the attitudes have on the motivations is not as direct as it was proposed in previous research.

Keywords**—**Attitude, Gender, Instruction, Motivation, Physics Education.

I. Introduction

DURING the last three decades, engineering and technical education in developing countries has witnessed large growth. A majority of the higher education institutes have relatively good infrastructure and qualified teaching staff [1]. On the contrary, it is also known that the number of students who choose scientific degrees has decreased. This is a fact to worry about considering that countries that invest in science and technology can expect a promising future that could disappear if undergraduates do not choose scientific studies [2]. Thereby, Science Education began researching the field of attitudes and motivations with greater intensity, due to the fact that those attitudes and motivations affect the learning process of students [3].

Nowadays a lot of work is being made to change this tendency and to achieve greater rates of university scientific students. There are strategies such as "Eurydice Report" [4] in which the aim is to make general proposals to improve the current situation. These institutionally promoted initiatives mark the way forward whereas other issues may be clarified with this type of works.

Specifically, the main objectives of this research are to measure and analyze the attitudes and motivations of students towards physics and its learning. Apart from that, not only could the gender be relevant, but an instruction in physics has been also considered to learn more about the area of study. Hence, using a pre-post-test methodology we are able to check whether the school year is beneficial to students at different stages of their learning process, as well as to identify if gender makes the difference in any of the groups that has been taken into consideration.

II. Problem formulation

Historically, the term attitude has been defined in many ways and it has often been used interchangeably with terms such as interest, value, motivation or opinion. In its simplest form, attitude is a general and enduring positive or negative feeling about some person, object or issue [5].

To the better understanding of this work, it is important to clarify and to differentiate properly the concepts of attitude and motivation. Therefore, an appropriate definition to motivation could be that it is an internal state that arouses, directs and sustains students´ behavior. As we turn to a discussion of the role of motivation in learning science, it is important to recognize that attitudes influence motivation, which in turn influences learning, and ultimately behavior [6]. That is why in the same work it is also said that authors "strongly encourage new and seasoned researchers to advance what is known about how attitudes influence motivation".

In this paper, all measurements are related to those first two concepts: on the one hand, students' attitudes towards physics are going to be analyzed by measuring their image towards physics. This is because previous researches show that changes in attitudes are strongly influenced by changes in the image toward science [7]. In another work, similarly, alternative teaching that would allow a better image of science was suggested to get higher yields of attitudinal learning [8]. On the other hand, this study will also focus on the motivations of students towards the learning of physics. This is going to be

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measured by the level of interest of students, taking into consideration that their level of interest is a significant indicator of their intrinsic motivation to learn [9].

Some previous works studied the field of both concepts [10] in which it was discovered that in the majority of the countries, students have better attitudes and are more interested in science at the beginning of secondary school than those who finish this stage. In this case, our focus is on the students that are just finishing this stage (16-18 years old) and on the students in the first year of their studies in engineering, where the amount of works is more reduced.

A. Background and research questions

In previous studies of students´ attitudes towards physics, one relevant factor has historically been the gender with more positive attitudes in male students [11]. This could nowadays occur due to multiple reasons such as the current curriculum (where the visibility of female scientist is low) or because of stereotypes towards students [12]. This last factor appears clearly in several research in which gender differences exist because of the prophecies or labeling that ultimately end up happening [13]. It is noteworthy that there are studies in which it is ensured that differences in attitudes depending on the gender have been declining [14], so in this work it is going to be verified whether the differences between men and women in the Basque Country are still significant or not.

It is also known that effective instruction has the potential to improve student attitudes toward science and to increase the motivation to learn [6]. Thus, it is also going to be measured how much attitudes and motivations evolve throughout the school year. However, it is important not to forget what previous works [15] said about external factors: most children between the ages of 5 and 16 only spend 18% of their waking hours in School. Yet contemporary society sees school as almost the sole site of learning, whereas the reality is that much, if not more, learning takes place in the social and cultural contexts that are offered outside school. As a result, despite the fact that the instruction students receive is one of the most relevant factors that affect students´ attitudes and motivations, there may be other factors that must not be forgotten for further research.

According to what it has been exposed, the research questions of this study are these ones:

a) Are the attitudes and motivations of students towards physics and its learning similar in both stages in the initial situation?

b) Do the attitudes and motivations towards physics and its learning evolve similarly at both stages during a school year?

c) Is there any difference on gender in the initial situation or after the instruction in the attitudes and motivations towards physics?

d) As it is recommended in previous works [6], we also focus on researching how attitudes influence the later motivations. Therefore, the last research question´s aim is to discover whether the attitudes have a direct influence in the motivation of students.

B. Methodology

All the measurements have been made by the questionnaire that was designed. Scoring is based on a 4-point Likert scale to compel students to choose between the positive and negative aspect of each statement as in previous works [16]. Answer number 1 indicates a total disagreement to its corresponding statement whereas number 4 indicates complete agreement. Several studies were taken into account to design the statements [17], [18], [19] but none of them could be used directly because they were not suitable for our group of students. The most important one was the Colorado Learning Attitudes about Science Survey (CLASS) [20] because some of their dimensions could be useful for us. Thus, four statements of our questionnaire were taken from CLASS whereas the rest are original to make this study.

The sample is constituted by students that have studied physics in class in the 2013/2014 academic year in the Basque Country (Spain). Data was collected in 8 High Schools (16-18 years) and at the University of the Basque Country, in both the Faculty of Science and Technology and the Polytechnical College with the total amount of 772 students. The university students who took part in the research were basically those in their first year at college. Those students are the most suitable ones taking into consideration that they have no previous ideas about the teaching/learning environment of the university [21] so that it could be possible to measure their motivations just on the point of starting the degree as well as after the experience of the first school year.

Once the data is collected, the next step should be making the factor analysis. This is a statistical method used to describe variability among observed and correlated variables in terms of a potentially lower number of unobserved variables, called factors or dimensions. But first of all, the data must be capable of being factored. To achieve this, Bartlet test of sphericity should be lower than 0.05 (being 0.000 in our case) and the Kaiser-Meyer-Olkin measure of sampling adequacy should be 0.6 or above (which is 0,854 in our sample). The factor analysis provided two dimensions that must overcome the fiability test of Crobach´s alpha in the same way as in previous research [22]. The acceptable values of that coefficient in these cases (0.7 out of 1) confirmed that the dimensions were adequate for the following analyses [23].

The dimensions that are considered in this study are (1) the image that students have towards physics and (2) their interest toward the learning of physics. As it has been mentioned at section 2.1, the students´ image towards physics is an indicator of their attitudes towards physics whereas their interest indicates their level of motivation to learn physics. Bearing in mind those two dimensions, tables I and II show the statements related to each dimension respectively.

Table I: statements that correspond to the dimension of image towards physics.

Number	Statement

1	Physics is useful in everyday life and solving for example problems of the near environment.
2	It is important to make discussions of current issues and to seek solutions through physics.
3	Physics is part of our culture and consequently we all should know about it.
4	I think that physics is an appropriate resource to understand nature.
5	The history of civilization is connected to the knowledge and development of physics.

Table II: statements that correspond to the dimension of interest toward the learning of physics.

Number	Statement
6	Reading about class issues (whether in books, articles...) helps me understand the concepts.
7	I do not feel calm until I understand the fundamental physics of devices that I often use.
8	I like physics problems and especially finding solutions until I achieve a result that convinces me.
9	I like especially the physics problems that require a lot of math.
10	I study physics because I think it will be useful after my studies at school / college.
11	I am aware of scientific informative news (through radio, television, social networks...) that institutions related to physics (ESA, CERN, NASA...) provide.

The concepts of intrinsic motivation and extrinsic motivation could be important in the dimension of students´ interest to learn. Previous studies specified that intrinsic motivation refers to the fact of doing an activity for itself, and the pleasure and the satisfaction derived from participation. On the other hand, extrinsic motivation pertains to a wide variety of behaviors which are engaged in as a means to an end not for their own sake [24]. Although students´ interest is in general more related to intrinsic motivation (which is measured by the statements 7 and 11 of our questionnaire), some statements also have a more extrinsic character (statements 6 and 10) because there are research in which motivation for study comes from courses which are relevant to and provide a good preparation for future careers [25].

Once dimensions are specified, comparisons between different groups are carried out depending on the variables described in the theoretical framework. The Kolmogorov-Smirnov test let us know if the distribution of the sample that is being considered in each case is normal or not. Secondly, we look for statistically significant differences by Student´s t-test (if the distribution of the sample is normal) or the Mann-Whitney U test (if the distribution is not normal). The p-value is the parameter that indicates the probability to achieve significant results when comparing two groups and it is calculated through both statistical tests. In each comparison, it is verified that statistically significant differences occur when the p-value is lower than 0.05 (which means that there is a maximum error of 5%).

The results are shown using bar charts that specify the average score of the students´ interest and image towards physics. Moreover, in each chart bar it is specified the standard error of the mean through error bars. This is the standard deviation of the theoretical distribution of sample means which is a way of measuring the sampling error [23].

III. Results and discussion

This study is focused on high school and 1st year engineering students´ image and interest towards physics and its learning. In addition, the results obtained from each stage will be analyzed taking into account students´ gender and the physics course they attended during the school year in order to answer the research questions.

A. Initial situation

Regarding the initial situation at both stages, the results of the statements related to students´ image towards physics have been grouped in the average of the fig. 1.

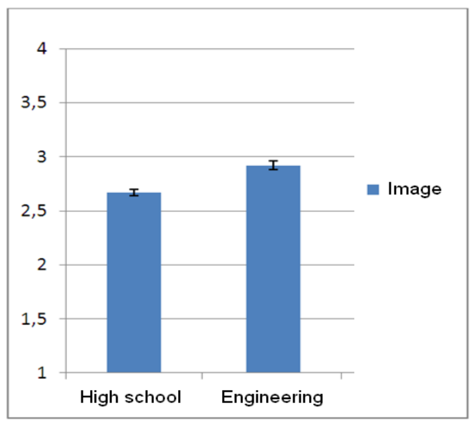

Fig. 1: averages of the image towards physics in the initial situation.

The exact averages related to students´ image are 2.67 at high school and 2.92 at university, being above the central value of 2.5 points at both stages. Hence, it must be clarified that students´ image towards physics is in general positive. Nevertheless, the previous averages show how different that image is depending on the stage, which is even significant ($p < 0.001$) according to the statistical analyses.

Apart from the evident differences between stages, the average of the image towards physics is high especially because of the statement number 4, which is the most rated one in each group. There, it is said that students see physics as an appropriate resource to understand nature.

Concerning the statements related to students´ interest toward the learning of physics, the results are gathered in fig. 2.

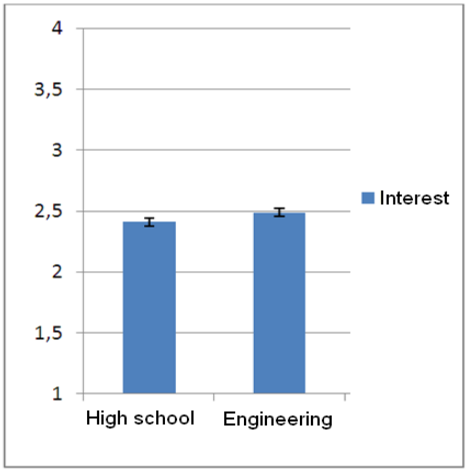

Fig. 2: averages of the interest towards physics in the initial situation.

The averages are near the central value (2.41 at high school and 2.49 at college) so that the interest of students is significantly similar in both stages ($p > 0.05$) in accordance with the statistical tests.

Analyzing every statement, it is observed that engineers´ interest is higher in each statement except in number 9. In this case, students at high school say that they like especially the physics problems that require a lot of math, scoring this statement the most. It has to be said that statements related to the extrinsic motivation have been the most rated ones, being number 10 the most scored statement in both stages. On the other hand, statements related to intrinsic motivation are the least scored ones, where number 11 has been even below the central value at both stages.

B. Situation after the instruction

Regarding the data gathered at the end of the school year, fig. 3 shows the most relevant results.

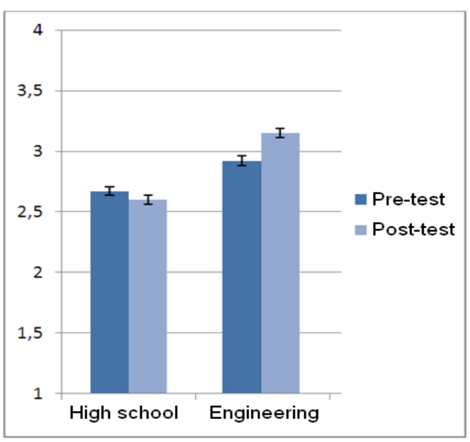

Fig. 3: averages of the image towards physics before and after the instruction.

It is easy to notice the tendency in each stage. The image of high school students towards physics is slightly worse ($p > 0.1$) after the instruction while in the university the image has been improved.

In addition, it has to be said that the previous improvement is statistically significant ($p < 0.001$) because of the increment in the average of 0.23 points. The analyses of the statements add extra information and it seems that the increase proceeds mainly from two statements: statement number 1 (due to the increase in 0.4 points in students´ belief that physics is useful in everyday life and solving for example problems of the near environment) and statement number 4 (due to the increase in 0.3 points in students´ belief that physics is an appropriate resource to understand nature).

The last analyses of the final situation are related to students´ interest towards the learning of physics, whose results are gathered in fig. 4.

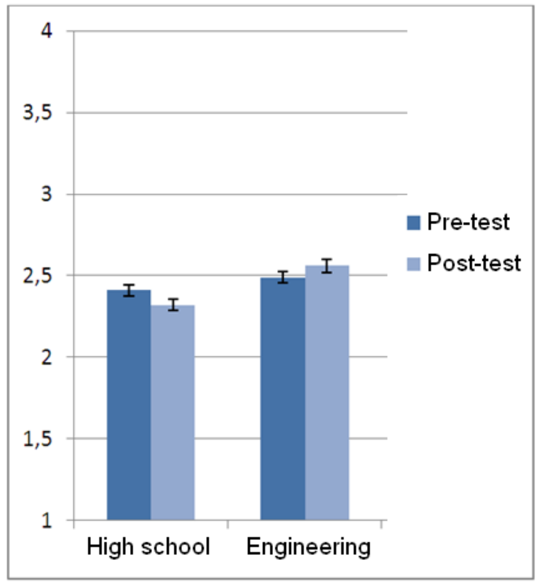

Fig. 4: averages of the interest towards physics before and after the instruction.

At first sight, it seems that the interest of students do not change so easily during the school year as it has occurred with the image previously. In this case, the slight changes (the decrease in 0.09 points at high school and the increase in 0.06 points at college) are not statistically significant in either case. Unlike the case of the image, the interest does not change during the school year in any of the stages that has been analyzed.

The largest difference has been measured at high school because of the decrease in 0.2 points in the tenth statement. This fact indicates that after the instruction students do not think that physics will be as important as they had thought in the initial situation.

C. High School students depending on gender

Regarding high school students, the results of the statements related to students´ image towards physics have been grouped in the average of the fig. 5.

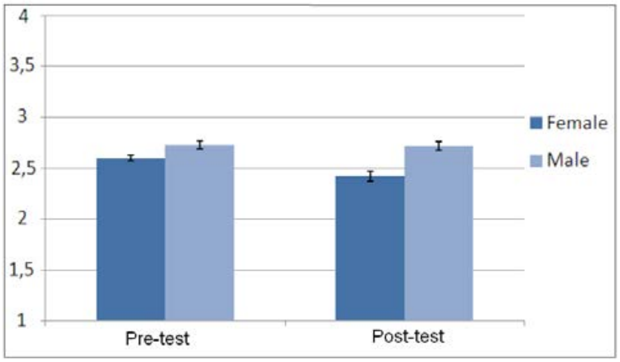

Fig. 5: averages of the image towards physics at high school depending on gender.

The averages obtained at high school are close to the central value of 2.50 points as it is previously mentioned, being men´s averages higher in both the pre-test and the post-test. Only women's image towards physics at the end of the instruction can be considered negative, with an average of 2.43 points on a 1 to 4 Likert scale.

Using the statistical tests that have been previously described, we find that the significant statistical differences between men and women happen in both the initial situation ($p < 0.005$) and after the instruction ($p < 0.001$) at this stage. In the initial situation, the differences in gender comes especially from a greater perception in the case of men (0.20 points higher) who think that physics are part of the culture and therefore everyone should know about it (statement number 3). After the instruction, however, the greatest difference between men and women lies on their perception about the connection between physics and the real world. The clearest example is that the importance they attach to discuss current issues and to seek solutions through physics is especially different (with a difference of 0.39 points in this statement number 2).

The same perception has decreased in 0.24 points from the initial situation in female students and that is why, female students´ image towards physics is significantly worse after the instruction ($p < 0.005$). Consequently, the differences between men and women have increased by the end of the school year as it has been observed with the p-values previously cited.

Regarding the statements related to students´ interest toward the learning of physics, the results obtained at this stage are gathered in fig. 6.

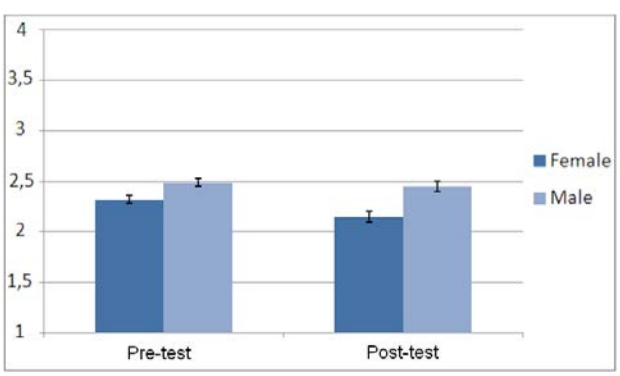

Fig. 6: averages of the interest towards physics at high school depending on gender.

The averages in this case, range from the slightly negative results of men in the pre-test with 2.49 points to the more negative 2.15 points of women in the post-test. Statistically significant differences were also confirmed between men and women in their interest to learn physics ($p < 0.005$ in the pre-test and $p < 0.001$ in the post-test). The gender difference is even greater at the end of the instruction due to the significant decline that has occurred in the case of women during the school year ($p < 0.01$), which comes largely from the decline in 0.28 points in statement number 10, which specifies that students study physics because they believe it will be useful after finishing high school.

Analyzing the results statement by statement, it is noticeable that the gender difference in both the initial situation and the end of the instruction comes mainly from statement number 7. This statement is the one which measures intrinsic motivation, asserts that students do not stay calm until they understand the fundamental physics of devices they normally use. Although men´s perception is higher, it is also far from the central value of 2.50 points, with values between 2.01 and 2.11 points. Moreover, the worst scored statement is in all cases the other one which is also related to intrinsic motivation with values between 1.44 and 1.78 points on a 1 to 4 Likert scale. This statement number 11 asserts that students are aware of scientific informative news (through radio, television, social networks…) that institutions related to physics (ESA, CERN, NASA…) provide, what is denied by students´ answers.

D. Engineering students depending on gender

Concerning to engineering students of the first year, the results related to their image towards physics is shown by the fig. 7.

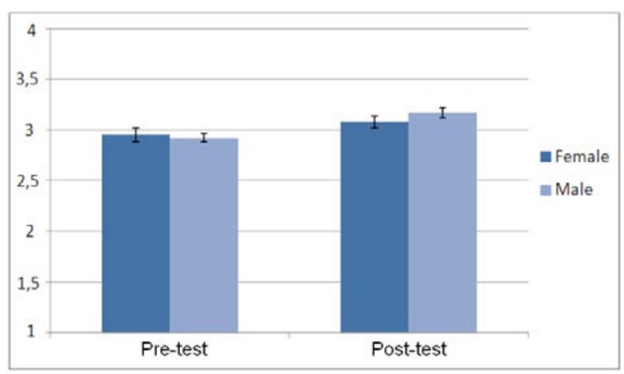

Fig. 7: averages of the image towards physics at college depending on gender.

Student’s image of physics is positive at this stage for men and women in both the initial situation and after the instruction. All averages are between the 2.92 points of male students at the pre-test and the 3.17 points of male students in the post-test. Statistical tests show that differences between genders are not significant in these cases with $p > 0.5$ in the pre-test and $p > 0.1$ in the post-test. For both genders the statement number 4 that points out that physics is an appropriate resource to understand nature, is the most rated statement with punctuations above 3.03 points in both the initial situation and after the instruction.

The unique significant difference that has been measured in this analysis is the increase of men´s image towards physics during the school year with $p < 0.001$. This increase comes especially from students´ perception that physics is useful in everyday life and solving for example problems of the near environment (with an increase in 0.45 points in this statement number 1).

As far as the statements related to the interest of students to learn physics is concerned, the results of this stage are grouped in fig. 8.

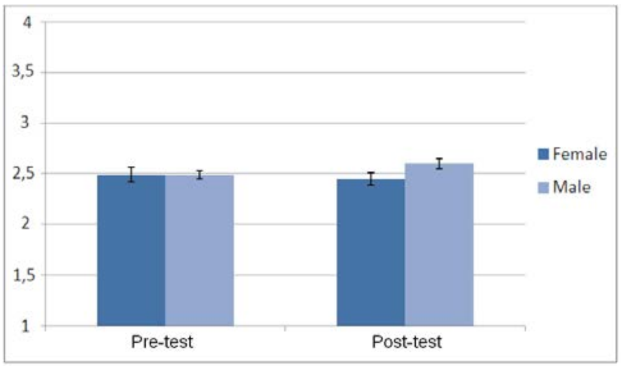

Fig. 8: averages of the interest towards physics at college depending on gender.

The interest of students to learn physics is close to the central value of 2.50 points in all cases. In the initial situation, the values are slightly negative (2.49 points) in both genders in which the statements measuring extrinsic motivation are the most rated with punctuations close to 3.0 points.

After the instruction, female students´ interest toward the learning of physics decrease to 2.45 points whereas men´s interest is increased up to 2.60 points. It has to be mentioned that none of these changes during the school year is statistically significant, but as a consequence of what it has been said the difference between genders after instruction is statistically significant ($p < 0.05$). In this case, the statement number 11 which measures intrinsic motivation is the one that makes the difference with a discrepancy of 0.68 points between genders.

IV. CONCLUSIONS

According to the results related to the first research question, the image of students towards physics is significantly better at college than at high school, being the results of both stages positive in any case. The interest of students toward the learning of physics, on the other hand, is similar in both stages. In this case, nevertheless, the results are worse comparing it to the image of students taking into account that the averages are below the central value of 2.5 points. For that reason, it is observed from the very beginning that students´ attitudes are better than their motivations.

Relating to the second research question, the differences between stages are evident in both the image and the interest towards physics and its learning. The two averages at high school decrease slightly whereas at college those are increased. It is noteworthy that in the case of students at university the increase of their image is actually significant. Nevertheless, there have not been any significant changes in the interest of students at any stage. At the point of answering the first research question, it was found that the image of the students is higher than the interest they show. Because of the last results it has to be said that not only is the interest lower than the image of students towards physics, but it is also more difficult to change. In addition, the clarification of the third research question is going to be useful to the better understanding of the origin of these changes.

With regard to the third research question in which comparisons between genders are made, it has to be said that there are different tendencies at high school and at university in the initial situation. On the one hand, gender differences are significant in high school students, where men´s results are better. Nevertheless, on the other hand, gender differences do not occur in the initial situation at college. Therefore, the way in which the instruction affects to each gender at both stages may be especially important to understand these facts.

At high school male students maintain their image and interest towards physics from the initial situation constant until the end of the instruction. In the case of female students, however, significant decreases occur in both cases during the instruction. Similarly, in the engineering course obvious changes do not occur in female students, whereas male students are more favored again because of instruction. Hence, in all stages the differences depending on gender have been increased in image and interest towards physics from the initial situation, a fact that post-test results reaffirm.

There are previous works [26] in which it was achieved that the main reason to choose STEM (science, technology, engineering and mathematics) studies is the personal interest of students toward science. This fact may explain what happens with high school female students whose results are especially poor. Although these negative conceptions do not necessarily lead to a certain behavior, such as abandonment of scientific studies, it is likely to affect in their decisions and choices. After the instruction female students do not believe that physics is going to be useful after their studies at high school as much as they believed in the initial situation so even their extrinsic motivation to learn has decreased. Taking that into consideration, it has been observed that the sample of this study at university is constituted by one in five female students, strengthening those conclusions.

Before regarding the fourth research question, what it is clear is that high school students´ image of physics is relatively positive [27]. On the contrary, it has been also achieved that the interest that those high school students show is below the central value, which decreases due to instruction in both genders. In addition, the relation of motivation with students´ learning and ultimately with their behavior that is described in the problem formulation, indicates that the lack of interest of high school students would result in few scientific and technological university students.

Finally, engineering students´ results indicate that their image towards physics is positive, whereas their interest is just close to the central value. As a result, the answer of the fourth research question may be clarified: even if students show that they have good attitudes, this is not enough to ensure the later motivation of students in any stage. Consequently and bearing in mind that instruction does not affect in the same way to each gender, the focus of new proposals must be to increase the motivation of students in order to encourage the learning of physics.

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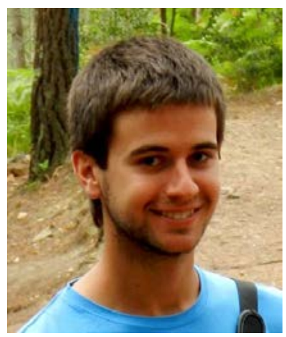

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