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Academic and Professional Relevance of Physics: Comparing Perceptions of Engineering Students from Mexico and Chile*

MONICA QUEZADA-ESPINOZA
Universidad Andres Bello, Facultad de Ingenieria, Antonio Varas 880, Santiago, Chile. E-mail: monica.quezada@unab.cl

ANGELES DOMINGUEZ
Tecnologico de Monterrey, Escuela de Medicina y Ciencias de la Salud, Morones Prieto 3000, Monterrey, Mexico.
Universidad Andres Bello, Facultad de Ingenieria, Antonio Varas 880, Santiago, Chile. E-mail: angeles.dominguez@tec.mx

GENARO ZAVALA
Tecnologico de Monterrey, Escuela de Ingenieria y Ciencias, Eugenio Garza Sada 2501, Monterrey, Mexico.
Universidad Andres Bello, Facultad de Ingenieria, Antonio Varas 880, Santiago, Chile. E-mail: genaro.zavala@tec.mx

Research about the perception of engineering students regarding the relevance of physics could explain the factors that influence their learning and retention in the engineering curricula. In the present study, we investigate students' perceptions of physics' relevance by comparing results by country, student semester, and gender. This is a quantitative comparative study between engineering students from Mexico and Chile. A total of 1,323 engineering students enrolled in physics courses in two private universities from those countries in their first and third semester responded to an eleven-item 5-Likert scale-type statements survey. Results showed that students in their first semester perceive the importance of physics more positively than students in their third semester. In general, students in the Mexican university have higher perceptions of physics' importance in engineering than students in the Chilean institution. Male and female students have similar perceptions about the relevance of physics. However, female students have a slightly higher perception of physics' importance for their ongoing studies in engineering than their male peers in the Mexican institution, opposite to what the results show in the Chilean institution. Reflecting upon the results and discussion of this contribution, some recommendations are: redesign physics courses to include activities in which students are in contact with real-life situations in classes, emphasizing the engineering part of the problem; promote active learning strategies in which students participate in the construction of their learning by interdisciplinary and gender-perspective approaches; and, include the student perspective in the curriculum and teaching materials by involving the higher-year students to demonstrate the relevance of physics to their first-year peers. As students are aware and perceive the relevance of their learning, they will be able to apply their knowledge in different academic careers and professional life situations.

Keywords: student perceptions; relevance of physics to engineering; gender influences on perceptions; educational innovation

1. Introduction

A growing number of researchers have turned their attention to the main factors influencing the learning and retention of engineering students. The relevance of physics in engineering both for academic study and after-graduation professional applications is an essential consideration in the engineering curricula. The inclusion of physics, math, or other Science, Technology, Engineering, and Mathematics (STEM) subjects is a factor that can influence positively or negatively the interest that students have in their professional development as engineers [1]. In this article, we analyse the perceptions of first-and-third-semester engineering students who took common-core courses in introductory physics.

Our literature review reveals that engineering students have little interest in studying subjects such as mathematics, physics, and other sciences and that they consider these courses irrelevant to their future studies. Students have not been able to establish a link between what they see in class and its relevance in a professional working context [1–7].

One crucial aspect affecting the relevance that students attach to the study of physics relates to the teaching strategies and methods used in the classroom. Another is the preconceptions that students have about physics; generally, they consider it a difficult subject to understand and, consequently, hard to pass [8, 10, 11]. Also, several current studies focus on the gender factor as an influence on students' perceptions of STEM curricula; these studies consider the social context and the underrepresentation of women in STEM fields [6, 9].

For instance, the research of Zavala & Dominguez [1] in a private Mexican university with engineering students found that female students have a

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slightly better perception of the importance of physics than male students. On the other hand, male students have a somewhat better perception of the importance of mathematics than female students. In this research, the authors made adaptations to the questionnaire of Flegg et al. [2] about the relevance of mathematics courses in engineering.

Alves, Rodrigues, Rocha & Coutinho [12] carried out a similar investigation, where they applied the questionnaire by Flegg et al. [2] for mathematics to Portuguese students and analysed their perceptions, looking for differences between genders and among programs of study. There were three different programs with different levels of requirements for mathematics courses, namely, Engineering in Natural Sciences (ENS, low level), Engineering and Management (EM, medium level), and Technological Engineering (TE, high level). Alves et al. [12] did not find significant differences between male and female students in their perceptions of the relevance of mathematics courses in their engineering studies. Still, they did find differences among students enrolled in different study programs. The main findings were that the ENS students had more positive perceptions than those from the EM and TE programs, which were the programs with the highest mathematical requirements, according to the syllabi of those programs. Thus, the students who had been assumed to have higher perceptions about the relevance of mathematics to their engineering curricula did not have them. The authors discussed that the perception of the importance of mathematics relates to the students' prior knowledge of mathematics and their perceptions of the utility, value, and application of mathematical concepts in their area of specialty.

We have found in the literature related to this topic that students from different engineering curricula have low perceptions towards the study of science and mathematics. Observing the difficulty that engineering students continue to have to identify and recognize the importance of the study of physics in engineering curricula, we set ourselves the task of analysing the students' perceptions of the relevance of physics to their engineering curriculum and their subsequent professional development. In the present study, the participants are engineering students from Chile and Mexico enrolled in the first and third semesters of their professional engineering program. Our research questions for this study were as follows:

- How do the perceptions of engineering students in Chile and Mexico towards taking physics compare with each other?
- How do the perceptions of the first and third-semester engineering students towards taking physics compare with each other?
- How do the perceptions of male and female engineering students in Chile and Mexico towards taking physics compare with each other?

2. Methodology and Sample

The present research is a quantitative study of the implementation of a survey to analyse students' perceptions of the relevance of taking a physics course to their studies in the engineering curriculum. We analysed quantitative data from a survey that used a Likert scale that scores strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5). The following sections describe the instrument, the sample, and the implementation.

2.1 Survey

This research study reports outcomes obtained from a survey adapted by Zavala et al. [5] modifying the survey by Flegg et al. [2], as previously discussed, to analyse the perception of engineering students about the importance of studying introductory physics in their engineering curriculum. The modified survey was translated into Spanish [5] from Portuguese [12] so that it could be used to measure the perceptions of the students in Chile and Mexico. Table 1 shows the statements contained in the survey and the dimensions to which they belong.

The data analysis began with the scale reliability using Cronbach's alpha and item-total correlation. Items that sound negative in their meaning (see statements 10 and 11 in Table 1) were reversely coded before the analysis. The eleven items present a Cronbach's α of 0.845 (see Table 2), and as in [12], statements 10 and 11 have low item-total correlation (obtaining a Cronbach's α of 0.866). Although this low correlation would usually eliminate them, we decided to use them to continue with the inferential analysis presented in the results section. The reason is that these items encompass the students' perceptions of self-efficacy in the physics course and feelings about the course itself, and we were interested in seeing these outcomes. Besides, the numbers in Table 2 show that keeping these statements in the instrument does not affect the reliability of the scale significantly.

Our method to analyse the survey consisted of looking for approaches to the way the students perceived the relevance of studying physics in engineering. We refer to these approaches as *dimensions*, which are described below. (Table 1, shows the statements that belong to each dimension.)

The *scholar dimension* contains statements that reflect how students perceive the relevance of physics for their ongoing engineering studies. It has

Table 1. The 11 statements and their dimensions included in the survey for the relevance of physics (adapted from [5])

Statements		Dimensions		
		Scholar	Professional	Self-efficacy
1.	I can see how the physics skills that I am currently developing will be useful in an engineering career.		•	
2.	The ways of thinking being taught to me in physics will remain with me long after I graduate.		•	
3.	Physics classes are needed for other courses (mathematics, chemistry, etc.) in my studies.	•		
4.	I feel that the physics course I am currently taking teaches me how to formulate and solve problems that are directly related to engineering.		•	
5.	Physics classes expose me to ideas which I know I will need later on in my engineering degree.	•		
6.	The topics covered in the physics courses will help me later on in my engineering classes.	•		
7.	I see being able to communicate effectively using physics arguments I am taught as an important skill to have.		•	
8.	The formal and rigorous aspects that I have learned in physics classes are important for my future engineering career.		•	
9.	It is important to learn physics to find a better job in engineering.		•	
10.	For me, in physics, I only want to learn what I feel is likely to be assessed.			•
11.	At some stage during my degree, I have been so overwhelmed by physics classes that I have considered withdrawing from my engineering degree.			•

Table 2. Scale reliability: perceptions of the relevance of physics for engineering

Statement	Corrected item-total correlation	Cronbach's α if item deleted
1	0.635	0.824
2	0.537	0.832
3	0.564	0.829
4	0.666	0.823
5	0.705	0.819
6	0.703	0.819
7	0.494	0.835
8	0.534	0.832
9	0.463	0.838
10	0.397	0.844
11	0.292	0.859

Table 3. Scale reliability per dimensions (Cronbach's $\alpha = 0.711$)

Dimension	Statements contained	Cronbach's α	Cronbach's α if dimension deleted
Scholar	3, 5, 6	0.802	0.445
Professional	1, 2, 4, 7, 8, 9	0.781	0.485
Self-Efficacy	10, 11	0.487	0.795

been found that first-year engineering students cannot appreciate the connection between their experiences in physics and their later engineering subjects because the perceived relevance of physics decreases over time [1].

The *professional dimension* classifies how the engineering students perceive the relevance of studying physics to their future professional practices. The study of physics is part of "the science of engineering," which is a set of mathematical and scientific tools acquired in college to solve engineering problems [13].

The *self-efficacy dimension* contains statements 10 and 11; these two statements approach how students feel about themselves studying physics and about the course itself. The concept of self-efficacy is defined as the confidence in one's own ability to perform a particular task [12, 14].

Once the dimensions were defined, Table 3 could be constructed to present the reliability scale per dimension.

Our analysis retained the eleven items from Zavala et al. [1] with a Cronbach's α of 0.845 and 0.711 per the dimensions. In the next section, we present and describe our sample characterization.

2.2 Sample Characterization

In this study, a total of 1,323 students from two countries (Chile and Mexico) were analysed. In Table 4, the numbers in each group are detailed.

As Table 4 shows, in this study, we gathered data reported in previous studies [1, 5] to analyse them in conjunction with other samples. For further discussions, it is important to state that students from the Chilean sample took the survey during the last week of an August-December semester [5]. Students from the Mexican_1 sample took the survey in the last class of an August-December semester [1]. Lastly, students from the Mexican_2 sample took the survey a year later in the first class of the August-December semester. In [1] and [5], the groups reported were 1, 2, 3, and 5 (see Table 4). For this

Table 4. Data by context, course, and gender of participating students

By Context	By Course	By Gender	
	Group	Male (n)	Female (n)
Chilean [5]	1. Physics 1 (P1-Ch)	45	13
	2. Electricity and Magnetism (EM-Ch)	53	14
Mexican 1 [1]	3. Introduction to Physics (IP-M1)	124	55
	4. Physics 1 (P1-M1)	157	82
	5. Electricity and Magnetism (EM-M1)	152	42
Mexican 2	6. Electricity and Magnetism (EM-M2)	446	140

research, we added two more groups, the Introduction to Physics group and the Electricity and Magnetism group. In the former group, the students did not attain the necessary score to sign up directly in the Physics 1 course and, therefore, had to take this subject to be level with their peers. They took the survey in the same semester as the students in Physics I. The students in the Electricity and Magnetism group were standard students from different engineering degrees (group 6 in Table 4).

To understand the gender representativeness in the sample, Fig. 1 illustrates how the genders per group were distributed.

As seen in Fig. 1, male students represent, on average, three-quarters of each sample group, and female students represent one-quarter of the group. For this article, it became necessary to describe the contextual background of each group of students at a scholar level, since these characteristics are essential for further discussions.

2.2.1 Chilean Students' University Context

In this private institution with high undergraduate enrolment, there is a large number of first-year students failing physics courses, some of them withdrawing entirely from the university. Some research argues that these two phenomena (failing a class and dropping out of a university) are caused to some degree by various factors, including the limited preparation that students receive in STEM disciplines before entering the university, traditional teaching strategies, gender, family income, and education of parents, (many of the students in this university are the first to receive a university preparation within their family nucleus [15].) The teaching strategies in the physics courses tend to be teacher-centred; lecturing is a standard methodology, and the classes contain about 60 students per session.

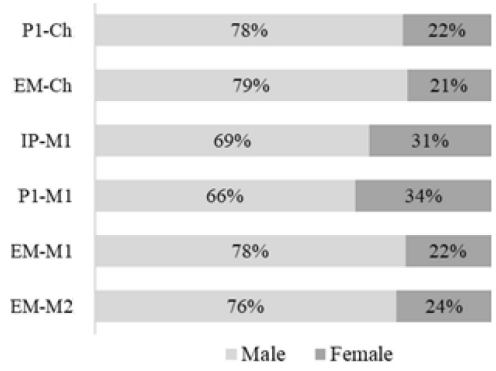

Fig. 1. Gender by group. In the figure, P1-Ch refers to Physics1, Chilean students; EM-Ch refers to Electricity and Magnetism, Chilean students; IP-M1 refers to Introduction to Physics, Mexican 1 students; P1-M1 refers to Physics 1, Mexican 1 students; EM-M1 refers to Electricity and Magnetism, Mexican sample 1 students; and EM-M2 refers to Electricity and Magnetism, Mexican sample 2 students.

2.2.2 Mexican Students' University Context

This large private university in the northern part of Mexico has a large enrolment of engineering students with different majors, all of them requiring three or four introductory physics courses and at least three mathematics courses for engineering. Students come from all parts of Mexico and other Latin American countries. The students who enter this university are admitted carefully; they must demonstrate above-average intellectual capabilities and knowledge. The proportion of students failing a physics course is about 20%, and a similar number fail mathematics courses. Student retention is over 90% for the first year. Most of these students have parents with professional degrees or additional academic preparation. Although failing a course and dropping out of the university is not an issue in this institution, teaching strategies, and retention projects are often implemented to improve learning outcomes. Even though the institution has defined its educational model as a student-centred research university for more than16 years (with some adjustments to the model through the years), there is a sizable percentage of classes that still are taught traditionally.

2.3 Limitations

We believe that the methodology was well designed and implemented and that our results are significant and useful for the engineering education community; however, as in any research, this study has limitations. The main limitation is that we recognize that our samples of the Mexican and Chilean

universities do not represent the universe of Mexican and Chilean engineering students. These are two private institutions in both countries. What is essential in this case is that, to our knowledge, this is the first time (jointly with references 1 and 5) that there are studies about perceptions of students of the relevance of physics to engineering in these two countries or any other Latin American countries. We believe that additional studies are needed to compare to other populations within these two countries and others in Latin American.

3. Results

The results are divided into three sections. First, we present the general perceptions of the engineering students about the relevance of physics in the curriculum. Then, we display a comparison between genders by the group.

3.1 Results by Group

In this section, we present the differences in results in the perception of students by the different groups; that is, the various courses and different institutions. We present the overall results, and the subsequent subsections present a comparison between groups.

Fig. 2 shows boxplots of the score, i.e., the sum of the numerical values for each option chosen by the students of all the items. that represents the perceived relevance of physics by engineering students by group. In general, there were differences among groups in favour of the Mexican samples. We can see that comparing medians among groups within samples, the students who took Physics 1 had more positive perceptions than students from the EM groups in both the Chilean and Mexican samples (groups 1 and 2).

Fig. 2 shows the big picture of the students' perceptions from the two universities and the courses (Introduction to Physics, Physics 1, and Electricity and Magnetism). As reported in previous research, first-semester students from courses in both institutions (P1-Ch, P1-M1) had higher perceptions of the relevance of physics than the third-semester students (EM-Ch and EM-M1) [1, 5]. The same behaviour is observed when bringing the groups, IP-M1 and EM-M2, to the analysis. The EM-M2 group scored similarly to the EM-M1 group. (The particulars are shown in Table 5.) Note that these two groups of students had lower perceptions than the first-semester students in the IP-M1 and P1-M1 courses and higher perceptions than the P1-Ch and EM-Ch groups.

Once overall differences were identified, further analyses were undertaken to find particularities. For this, we conducted Mann-Whitney U tests to evaluate differences between groups in responses to our five-point Likert scale survey, as shown in Table 5.

In Table 5, the grey cells mean that there were no significant differences among groups. The results are shown by comparisons.

3.1.1 Physics 1 vs. Electricity and Magnetism, Chilean Students (P1-Ch vs. EM-Ch [1])

There are three items on the survey (1, 5, and 6) in which the first-semester students agreed more with the sentences than the third-semester students. Analysing items 1, 5, and 6, we found that after one year of studying physics, students' responses decreased significantly; this decrease is significant since one of the sentences is about the perception of the relevance

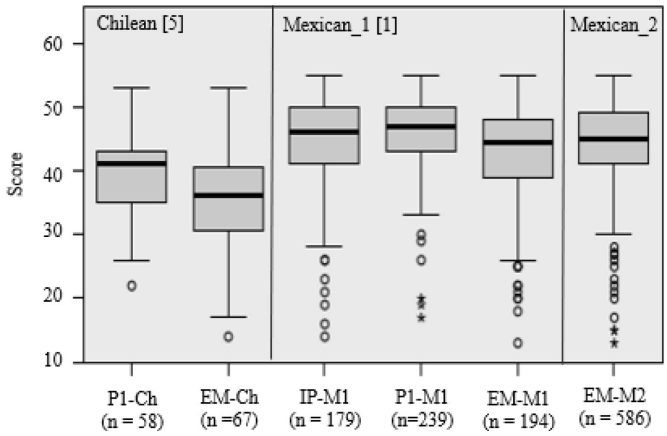

Fig. 2. Box plots of the score, general perceived relevance of physics by engineering students, by group. In the figure, P1-Ch refers to Physics1, Chilean students; EM-Ch refers to Electricity and Magnetism, Chilean students; IP-M1 refers to Introduction to Physics, Mexican 1 students; P1-M1 refers to Physics 1, Mexican 1 students; EM-M1 refers to Electricity and Magnetism, Mexican sample 1 students; and EM-M2 refers to Electricity and Magnetism, Mexican sample 2 students.

Table 5. Statements with significant differences encountered with Mann Whitney's U test ($p < 0.05$)

Groups	P1-Ch vs. EM-Ch	P1-M1 vs. EM-M1	P1-M1 vs. P1-Ch	EM-M1 vs. EM-Ch	IP-M1 vs. P1-M1	EM-M1 vs. EM-M2
Statement						
1	>	>	>	>		<
2		>	>	>	<	
3		>	>	>		>
4			>	>		
5	>	>	>	>	<	
6	>	>	>	>		
7		>	>	>		<
8			>	>		
9			>	<		
10	>	>	>	<		<
11	>	>			<	<
Dimension						
Scholar	>	>	>	>		
Professional	>	>	>	>		
Self-efficacy		>	>	>		

of physics in an engineering career and the other two are related to the importance of physics in their studies of engineering. This effect could be caused by a decrease in the students' perception due to what they experienced in a year of taking physics classes; that is, these students probably believe that their physics courses are not helping them to be successful in other courses. However, another cause could be that students who were not passing the course and ended up withdrawing from the university were those who had more positive perceptions of the importance of physics.

In statements 10 and 11, students from P1-Ch answered these two sentences more positively than those of EM-Ch. It seems that regarding the learning of physics as a pragmatic way to advance into the next semesters prevails after a year of physics. On the other hand, first-semester P1-Ch students are less overwhelmed compared to students in the third-semester EM-Ch course. The interpretation of this is difficult, because if students are becoming more pragmatic (answering as they do in sentence 10), one may think that they would become less stressed about physics. However, the results are opposite to that. Notably, third-semester students are taking Electricity and Magnetism, which is a calculus-based course, and in the first semester, they are taking general physics, which is algebra-based. So, in their third semester, students are studying one of the most challenging courses of their engineering degree.

3.1.2 Physics 1 vs. Electricity and Magnetism, Mexican_1 (P1-M1 vs. EM-M1 [1])

There are six items (1, 2, 3, 5, 6, and 7) in which the first-semester students agreed more with the sentences than third-semester students. In this case, something similar to the previous analysis happened to these groups: after one year of studying physics, the students' responses decreased significantly. This decrease is meaningful, because three of the statements are related to the perception of the relevance of physics in an engineering career and their professional life, and the other three are related to the importance of physics in their engineering studies. The students in the Mexican institution behave the same as students in the Chilean institution; tendencies are similar. The questions in which results are getting less favourable in both institutions are the same. However, there were differences in the Mexican institution between the first and third-semester students in three additional statements. Another vital result to mention is that the tendencies of the results for statements 10 and 11 are the same for all students in their respective universities, i.e., change from the first semester to the third semester is the same, even though they were different students.

3.1.3 Physics 1-Chilean vs. Physics 1-Mexican_1 (P1-Ch vs. P1-M1)

We found differences when comparing first-semester students from the two different institutions in almost all statements, except for statement 11 (Table 5). As Fig. 2 shows, the perceived relevance of physics for engineering students is higher among Mexican students than Chileans. However, they have something in common; namely, they have similarly felt so overwhelmed by physics courses that they have considered withdrawing from their engineering degree.

3.1.4 Electricity and Magnetism-Chilean vs. Electricity and Magnetism-Mexican_1 (EM-Ch vs. EM-M1)

We found differences when comparing students of Electricity and Magnetism (EM) courses from the different institutions in almost all the statements (see Table 5), similar to the results of comparing first-semester students. The perceived relevance of physics by engineering students is higher among Mexican students than Chilean. However, there were opposite results in statements 9 and 10. Students from the EM-Ch group had more positive perceptions through statement 9, "It is important to learn physics to find a better job in engineering." They agreed less with statement 10, "For me, in physics, I only want to learn what I feel is likely to be assessed" than students from group EM-M1. It seems that students from the Chilean institution value more the importance of physics to get a job than students from the Mexican institution. Besides, similarly to first-semester students, students from both institutions felt equally overwhelmed by the physics courses that they had considered withdrawing from their engineering degree.

3.1.5 Introduction to Physics vs. Physics 1-Mexican_1 (IP-M1 vs. P1-M1)

There are two items (2 and 5) in which the group of students from the Physics 1 course agreed more with the sentences than those of the Introduction to Physics group. These are Statement 2, "The ways of thinking being taught to me in physics will remain with me long after I graduate," and Statement 5, "Physics classes expose me to ideas which I know I will need later in my engineering degree." It seems that students who had to take the Introduction to Physics course as remedial level do not see the relevance of physics to their scholarly or professional future as those in the Physics 1 course. It is important to note that these students answered the survey at the end of the semester in which they took that subject. The level of complexity of each topic can cause students of Introduction to Physics to not be able to see the relevance that studying physics has for their future studies and career.

3.1.6 Electricity and Magnetism-Mexican_1 and 2 (EM-M1 vs. EM-M2)

In this part of the analysis, it becomes more relevant to mention the time when the survey was implemented. As we mentioned before, students from the Mexican_1 sample took the survey in the last class of the semester, and students from the Mexican_2 sample took the survey in the first class of the semester. The expected results were that the students of both EM-M1 and EM-M2 would have the same perceptions about the relevance of physics because they belong to the same institution. However, we found that students who took the survey at the beginning of the semester showed a higher level of agreement with statement 1, "I can see how the physics skills that I am currently developing will be useful in an engineering career." Additionally, they disagreed more with statements 10, "For me, in physics, I only want to learn what I feel is likely to be assessed," and 11, "At some stage during my degree, I have been so overwhelmed by physics classes that I have considered withdrawing from my engineering degree." On the other hand, students who took the survey at the end of the semester (EM-M1) agreed more with statement 3, "Physics classes are needed for other courses (mathematics, chemistry, etc.) in my studies." It seems that having finished the course made its importance less relevant for their professional activities but more relevant for the courses they will take later.

3.2 Results by Gender

The perceived relevance of physics was also analysed comparing genders by the groups. We conducted a nonparametric Mann Whitney U test to find significant differences between genders in the perceived importance of physics. The analysis confirmed that there were no significant differences in the perceived importance of physics between male and female students from groups EM-Ch, P1-M1, EM-M1, and EM-M2. However, groups P1-Ch and IP-M1 did have differences in some statements. For example, group P1-Ch had a gap between genders in statement 4, "I feel that the physics course I am currently taking teaches me how to formulate and solve problems that are directly related to engineering," where the male students had higher perceptions than their female peers.

Additionally, group IP-M1 had significant differences between genders in statements 3, "Physics classes are needed for other courses (mathematics, chemistry, etc.) in my studies," and 10, "For me, in physics, I only want to learn what I feel is likely to be assessed," where female students showed more agreement than males with statement 3 and less agreement with statement 10.

It is interesting to note that the differences found were in the first semesters in both universities. In the other more advanced courses, no differences were found. Another interesting finding is that among the differences found, the Chilean male students had more positive perceptions about the relevance of physics than the female students. The opposite happened among the Mexican students. In Mexico, female students had higher perceptions about the relevance of physics.

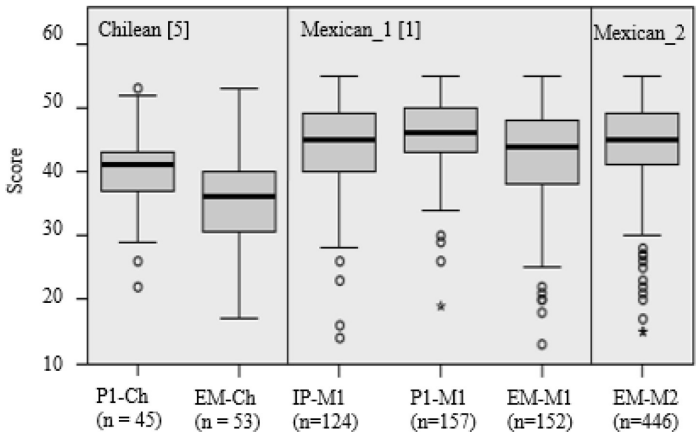

Fig. 3. Box plots of the score, general perceived relevance of physics by male students, by group. In the figure, P1-Ch refers to Physics1, Chilean students; EM-Ch refers to Electricity and Magnetism, Chilean students; IP-M1 refers to Introduction to Physics, Mexican 1 students; P1-M1 refers to Physics 1, Mexican 1 students; EM-M1 refers to Electricity and Magnetism, Mexican sample 1 students; and EM-M2 refers to Electricity and Magnetism, Mexican sample 2 students.

To conduct this analysis, we separated males from female students and ran Mann-Whitney U tests to evaluate the differences in the responses to the five-point Likert scale statements. The results are presented below.

3.2.1 Male Students

First, we present results for the male students. Fig. 3 shows boxplots of the score, i.e., the sum of the numerical values for each option chosen by male students of all the items. The figure shows the existence of variations in the responses of the male students among the groups.

For a more in-depth analysis of the results, Table 6 shows the significant differences for male students between groups.

If we compare Fig. 2 to Fig. 3, we can appreciate that they are very similar. When analysing specific results in Table 5 and Table 6, it becomes evident that the male-student results are very similar to the general ones. We note that this is because most of the participating students were male.

3.2.2 Female Students

Now, we present results for female students. Fig. 4 shows boxplots of the score, i.e., the sum of the numerical values for each option chosen by the female students of all the items.

For a more in-depth analysis of the results of Fig. 4, Table 7 shows the significant differences for female students between groups.

The analysis of the perceived relevance of phy-

Table 6. Statements with significant differences encountered with the Mann Whitney U test ($p < 0.05$) among male students per group

Groups	P1-Ch vs. EM-Ch	P1-M1 vs. EM-M1	P1-M1 vs. P1-Ch	EM-M1 vs. EM-Ch	IP-M1 vs. P1-M1	EM-M1 vs. EM-M2
Statement						
1	>	>	>	>		<
2		>	>	>	<	
3		>	>	>		>
4	>		>	>		<
5	>	>	>	>	<	
6	>	>	>	>		
7		>	>			<
8			>	>		
9		>	>	>		
10		>	>	<		<
11	>	>			<	<
Dimension						
Scholar	>	>	>	>		
Professional	>	>	>	>		
Self-Efficacy		>	>	>		<

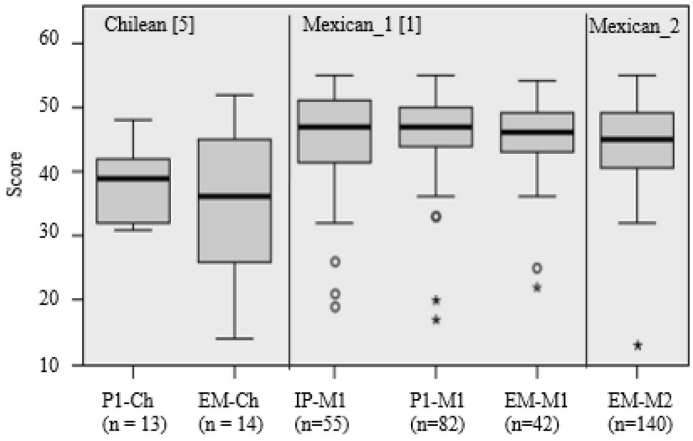

Fig. 4. Box plots of the score, general perceived relevance of physics by female students, by group. In the figure, P1-Ch refers to Physics1, Chilean students; EM-Ch refers to Electricity and Magnetism, Chilean students; IP-M1 refers to Introduction to Physics, Mexican 1 students; P1-M1 refers to Physics 1, Mexican 1 students; EM-M1 refers to Electricity and Magnetism, Mexican sample 1 students; and EM-M2 refers to Electricity and Magnetism, Mexican sample 2 students.

Table 7. Statements with significant differences encountered with Mann Whitney's U tests ($p < 0.05$) among female students per group

Groups	P1-Ch vs. EM-Ch	P1-M1 vs. EM-M1	P1-M1 vs. P1-Ch	EM-M1 vs. EM-Ch	IP-M1 vs. P1-M1	EM-M1 vs. EM-M2
Statement						
1			>	>		
2			>	>		
3			>	>		>
4			>	>		
5			>			
6			>	>		
7			>			
8			>			
9			>	>		
10						
11						
Dimension						
Scholar		>	>	>		
Professional			>	>		
Self-Efficacy			>			

sics by female engineering students yielded fascinating findings. In this case, female students showed similar perceptions of the relevance of physics when they belong to the same institution. Nevertheless, tendencies prevailed between the institutions: Chilean female students scored less positive perceptions than the Mexican female students (see in Table 7, P1-M1 vs. P1-Ch and EM-M1 vs. EM-Ch). This was confirmed when we conducted the Mann Whitney U test and found that students of the groups, P1-Ch and EM-Ch, had lower perceptions about the relevance of physics than the students in groups P1-M1 and EM-M1 in most of the statements. An interesting outcome is that both the Chilean and Mexican female students feel similarly overwhelmed by the physics course, and they only want to study what is going to be assessed. (There were no significant differences between statements 10 and 11.) Another difference found when comparing the groups, EM-M1 and EM-M2, was that these groups had significant differences in statement 3, ''Physics classes are needed for other courses (mathematics, chemistry, etc.) in my studies.'' As in previous analyses, the students who took the survey at the end of the semester seemed to understand the importance of physics and its relation to other subjects. When the female students of EM-M1 answered the survey, they were close to taking their final exam, and we believe that this could be a reason why they attached more importance to the relevance of physics to other subjects.

4. Discussion

There are significant differences among groups. The tendency of the results is the same for both institutions (Table 5). Students present a higher perception in early semesters, and that perception decreases with time (the semester in their curriculum). The same tendency is observed comparing students in the Electricity and Magnetism in the Mexican Universities (EM-M1 and EM-M2). EM-M2 students took the survey at the beginning of the semester, and EM-M1 students took it at the end of the semester. Although the differences between these two groups are less pronounced, there is still some difference that resembles those comparing first and third-semester students.

This study is not longitudinal; students taking the survey are different. However, since the administrations of the survey are at the same time, the difference between students is that those in the third semester enter the university one year before than those of the first semester. We believe that in only one year, the type of students both universities receive is comparable.

The dropout rate of the Chilean university is higher than that of the Mexican university (only about 5%). Many first-year students in the Chilean university do not get into the third semester, and that might change the behaviour of the responses after one year, i.e., students with high perceptions drop out from the university. However, most first-year students in the Mexican university get to the third semester, and the tendency of decreasing perception is the same as the Chilean university. Then there is evidence that dropout is not the main factor for this tendency.

We have mentioned the hypothesis that the way the courses are taught could be the cause of the decrease of perception. In the Chilean university, the instruction is teacher-centred with no emphasis on the application of physics in engineering. In the Mexican university, the instruction has been evolving with time into a more student-centred model (although the instructors are in different phases of that change). Both universities are working toward changing the way students receive their education introducing active learning strategies; however, there is still a way to go. Another characteristic that is similar to both universities and, in fact, most universities in general, is the lack of the application of physics in engineering in these introductory physics courses. There has been some effort [16] and, more recently a new educational model implemented [17] in the Mexican institution that could change the perspective of students in the future. In the Chilean university, at the School of Engineering, there are efforts [18] to promote among faculty members the use of active learning for the engineering classroom, so we expect that the perceptions of students entering the university improve or at least stay the same after taking the physics courses.

Table 5 also shows that in both courses (Physics 1 and Electricity and Magnetism), students in the Mexican University have more positive perceptions than those from the Chilean university. Since the difference between students appears from the first semester, the cause could be due to the difference between students' origin. Both universities are large private institutions. The School of Engineering and Sciences for the Mexican university is very research-oriented similar to the School of Engineering in the Chilean university. Two main factors could cause a difference in results. One is obvious, one is in Mexico, and the other is in Chile. The educational systems previous to college might produce the difference. The other has to do with the type of students each university attracts. While the Chilean university has a broader spectrum of their entering students having those who are the first to receive a university preparation within their family nucleus, the majority of the students in the Mexican institution have parents with professional degrees or even higher academic preparation. These differences in perception could be due to these two factors.

In general, there are no differences by gender when analysing the results by course/semester. However, there were some differences in first-semester courses within each university. An attention-grabbing result was that those differences behave differently in universities. While in the Chilean university, male students had more positive perceptions than female students, in the Mexican university, female students were those with better perceptions.

Female students, different from their male colleagues, do not decrease their perception with time. Table 7 shows that in both universities, there are no significant differences between female students in the first semester and female students in the third semester. The educational strategy or the lack of applications in the introductory courses seem not to affect the perception of the importance of physics in their degrees and their professional life. An improvement of the perception after taking the courses would have been a better result; however, their perception does not decrease as that of male students. It has been proved that any effort of active learning implemented in classes, the impact on female students is a result that is important to take into account. It might be that female students are benefiting from the efforts both universities are doing to change the way classes are implemented, something that has been studied for some time [19].

The current study can be used by instructors and

by administrative officers to devise strategies to motivate engineering students to be more interested in physics and to increase their perceptions about the importance of physics positively. We argue that the differences found could be explained and are related to the need for the students to understand the usefulness of physics in their studies and future engineering practices. We recommend the inclusion of examples of applications as a priority goal to increase the perceived value of physics in engineering.

These connections of professional practice in advanced courses are lost in the practice itself. When unstructured problems arise with new situations, we have to go back to basics. More investigation is needed from upper engineering courses and different engineering programs [12] to focus content and students' competencies in physics courses towards that direction. That is the implementation of interdisciplinary projects that foster interaction among STEM instructors and professors to modify teaching strategies, content, and the focus of their courses.

Similar situation occurs in professional life. Typical solutions in engineering become familiar and the contribution of physics becomes imperceptible. However, solutions to the great challenges of engineering require a focus on the fundamentals, and that is where physics is relevant. Therefore, the recommendations go in the direction of approaching these engineering challenges to the first years of study. As students are aware and perceive the relevance of their learning, they will be able to apply their knowledge in different situations in their academic careers as well as in their professional life.

5. Conclusions

We analysed the perceptions of the importance of physics among engineering students according to our three primary research questions: How do the perceptions of engineering students towards taking physics compare with each other: (a) by country, (b) by semester, (c) by gender. From the study, we found that:

- Students in the Mexican university have, in general, higher perceptions of the importance of physics in engineering than students in the Chilean institution, regardless of gender or college year.
- Students in their first semester perceive more positively the importance of physics than the third-semester students. This behaviour occurs with both the Mexican and the Chilean students. It seems that after taking the physics courses, the students might feel that these subjects are not as vital as they initially thought.
- In general, males and females have similar perceptions about the relevance of physics. However, female students have a slightly higher perception of the importance of physics for their ongoing studies in engineering than their male peers in the Mexican institution. On the other hand, male students are more aware of the importance of physics and its relevance to their future as engineers in the Chilean institution. These differences happened only in the first semester students in the universities.
- Male perceptions of the relevance of physics have a similar tendency to the general findings. Male first-semester students have higher perceptions than third-semester students in the Chilean and Mexican institutions. Mexican male students have higher perceptions than Chilean male students.
- Female perceptions of the relevance of physics are invariable through time. Different from male perceptions' findings, the perceived importance that females attach to physics changes according to context, not by course or semester. Mexican female students have a more positive perception of the relevance of physics than Chilean female students.

The actions we recommend are:

- Redesign physics courses to include activities in which students are in contact with real-life situations in classes, emphasizing the engineering part of the problem.
- Promote active learning in which students participate in the construction of their learning by interdisciplinary and gender-perspective approaches. That is, by bringing together engineering faculty with first-years physics instructors to design interdisciplinary context situations, learning sequences, or challenging activities.
- Include the student perspective in the curriculum and teaching materials by involving the higher-year students to demonstrate the relevance of physics to their first-year peers.

As students are aware and perceive the relevance of their learning throughout their academic journey, they will be able to apply their knowledge in different situations in their academic careers and professional life.

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References

1. G. Zavala and A. Dominguez, Engineering Students' Perception of Relevance of Physics and Mathematics, *ASEE Annual Conference and Exposition*, New Orleans, LA, June 26–29, 2016.
2. J. Flegg, D. Mallet and M. Lupton., Students' Perceptions of the Relevance of Mathematics in Engineering, *International Journal of Mathematical Education in Science and Technology*, **43** (December 2014), pp. 717–732, 2012.
3. C. G. Iñiguez-Monroy, W. Aguilar-Salinas, M. de las Fuentes-Lara and R. Rodríguez-González, El interés en la química general para ingenierías y el bajo rendimiento escolar, *Formación Universitaria*, **10**(4), pp. 33–42, 2017.
4. M. Stuckey and I. Eilks, Increasing Student Motivation and the Perception of Chemistry's Relevance in the Classroom by Learning about Tattooing from a Chemical and Societal View, *Chemistry Education Research and Practice*, **15**, pp. 156–167, 2014.
5. G. Zavala, A. Dominguez, C. Millan and M. Gonzalez, Students' Perception of Relevance of Physics and Mathematics in Engineering Majors, *ASEE Annual Conference and Exposition*, Seattle, WA, June 14–17, 2015.
6. R. L. Kajfez, K. M. Kecskemety E. S. Miller, K. E. Gustafson, K. L. Meyers, G. W. Bucks and K. Tanner, First-Year Engineering Students' Perceptions of Engineering Disciplines: A Qualitative Investigation, *International Journal of Engineering Education*, **34**(1), pp. 88–96, 2018.
7. A. Cruz, A. Rincon, W. Dueñas, N. Luna and D. Torres, The impact of an introductory biomedical engineering course on students' perceptions of the engineering profession, *International Journal of Engineering Education* **32**(1), pp. 136–149, 2016.
8. M. Baran, An Analysis on High School Students' Perceptions of Physics Courses in Terms of Gender (A Sample from Turkey), *Journal of Education and Training Studies*, **4**(3), pp. 150–160, 2016.
9. E. Dare and G. Roehrig, If I Had to Do It, Then I Would': Understanding Early Middle School Students' Perceptions of Physics and Physics-Related Careers by Gender, *Physical Review Physics Education Research*, **12**(2), pp. 1–11, 2016.
10. P. Chou and W. Chen, Female engineering students' perceptions of college learning experiences: A qualitative case study in Taiwan, *Ratio*, 76631, p.18009, 2011.
11. D. Follmer, S. Zappe, E. Gomez, E. Gomez and S. Haydt, Changing the conversation: Impact of a seminar-based classroom innovation on student perceptions of engineering, *International Journal of Engineering Education*, **33**(2), pp. 519–526, 2017.
12. M. Alves, C. S. Rodrigues, A. M. Rocha and C. Coutinho, Self-Efficacy, Mathematics' Anxiety and Perceived Importance: An Empirical Study with Portuguese Engineering Students, *European Journal of Engineering Education*, **41**(1), pp. 105–21, 2016.
13. R. Martin, B. Maytham, J. Case and D. Fraser, Engineering Graduates' Perceptions of How Well They Were Prepared for Work in Industry, *European Journal of Engineering Education*, **30**(2), pp. 167–180, 2005.
14. V. Sawtelle, E. Brewe, R. M. Goertzen and L. H. Kramer, Identifying Events That Impact Self-Efficacy in Physics Learning, *Physical Review Special Topics: Physics Education Research*, **8**(2), pp. 1–18, 2012.
15. K. Soria-Barreto and S. Zúñiga-Jara, Aspectos Determinantes del éxito Académico de Estudiantes Universitarios, *Formación Universitaria*, **7**(5), pp. 41–50, 2014.
16. J. De la Garza and H. Alarcon, Assessing students' attitudes in a college physics course in Mexico, *AIP Conference Proceedings*, **1289**(1), pp. 129–132, 2010.
17. G. Zavala, Integration of physics, mathematics and computer tools using challenge-based learning, *2020 IEEE Global Engineering Education Conference (EDUCON)*, Porto, Portugal, pp. 1387–1391, 2020.
18. A. Dominguez, M.E. Truyol and G. Zavala, Professional development program to promote active learning in an engineering classroom, *International Journal of Engineering Education*, **35**(1), 424–433, 2019.
19. M. Lorenzo, C. H. Crouch and E. Mazur, Reducing the gender gap in the physics classroom, *American Journal of Physics*, **74**, pp. 118–122, 2006.

Monica Quezada-Espinoza is a professor and researcher at the School of Engineering at the Universidad Andres Bello in Santiago, Chile. Monica is currently collaborating with the Educational and Academic Innovation Unit, UNIDA (for its acronym in Spanish) at the School of Engineering of the Universidad Andres Bello, where she works as instructor in active learning methodologies. Her research interest topics involve university education in STEM areas, faculty development, research-based activities, evaluation tools and technology, and gender issues in STEM education. https://orcid.org/0000-0002-0383-0179

Angeles Dominguez is a researcher at the School of Humanities and Education and the Associate Dean of Faculty Development at the School of Medicine and Health Sciences at Tecnologico de Monterrey. She collaborates with the Faculty of Engineering of the Universidad Andres Bello in Santiago, Chile. She is a member of the National System of Researchers of Mexico (SNI-2). Her research interests are faculty development, models and modelling perspective, interdisciplinary education, and gender issues in STEM education. https://orcid.org/0000-0001-6066-355X

Genaro Zavala is a Full Professor and Director of Undergraduate Studies at the School of Engineering and Sciences at Tecnologico de Monterrey, Monterrey, Mexico. He collaborates with the Faculty of Engineering of the Universidad Andres Bello in Santiago, Chile. He is a member of the National System of Researchers of Mexico (SNI-2). His research interests are conceptual understanding, active learning, development of assessment tools, faculty development and studies in STEM. https://orcid.org/0000-0001-5880-1124