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Engineering Students' Perception of Relevance of Physics and Mathematics

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Engineering students' perception of the relevance of physics and mathematics

Abstract

Students' perception of the relevance of science, either in their daily or professional life, is related to their attitudes towards science. Similarly, the self-perception of students towards mathematics is closely connected to their perception of mathematics. We conducted a study in a Chilean university about engineering students' perception of the relevance of physics and math, and found that students in general do not appreciate the importance of mathematics and physics in engineering, neither as a professional career nor as a basis for other courses in their degree. We also found that first-semester students have a better perception of physics and mathematics than third-semester students and that the perception of the importance of mathematics is higher than that of physics. These and other findings have helped us to recommend some actions to the Department of Mathematics and Physics of that university. After this experience, we conducted a similar study with engineering students in a Mexican university. This study's population consisted of 1073 students taking first and third-semester physics and math courses in a large private university in Mexico. A Likert-scale instrument was used, in which students choose from a completely agree-to-completely disagree scale of statements related to the relevance of physics and mathematics to both the applicability in upper division engineering courses and the students' future career. The results of this new study shed light on four aspects: 1) students' perceptions of the relevance of physics and mathematics of scholar engineering and professional engineering practices, 2) the comparison of students' perceptions of the relevance of physics to that of mathematics, 3) semester and gender differences in those perceptions, and 4) the comparison of students' perception of the relevance of physics and mathematics in the Mexican university to that of the Chilean university. As conclusions, we present some recommendations to instructors and course designers.

1. Introduction

A previous, similar study was conducted in a Chilean private university[1]. In many cases, this work will reference that study.

The institution in which this study took place is a large private university in the northern part of Mexico. It has a large enrollment of engineering students with different majors, all of them taking between 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.

Although the Programme for International Student Assessment (PISA) results show that students in Mexican educational institutions show performances in mathematics, science and reading comprehension that are well below the OECD average[2], there is no measure of what kind of students this university receives. The admission test is unique, since in Mexico there is not a standardized test as in other countries. However, it can be assumed that students entering to this university are above average in Mexico in terms of intellectual capabilities and knowledge.

The proportion of students failing a physics course is about 20% and a similar number of students fail mathematics courses. Students' retention is over 90% for the first year. Although failing a course and dropping from the university is not an issue in this institution, teaching strategies and retention projects are often implemented. The institution defines its educational model as student-centered research university. It has been more than 16 years since this educational model was first implemented (with some adjustments over the years); however, there is a sizable percentage of classes that still are taught traditionally.

2. Perception of the relevance of mathematics and physics

2.1 Perception of mathematics

The perception of students regarding their role in mathematics is related to many factors. Among them, is the school experience itself, but also the importance that their families give to education and specifically to mathematics. In families, it is socially justified for a child to do badly in math classes. This acceptance is stronger if no one else in the family has studied a higher degree requiring mathematics. Specially, this factor is more important when the student is female, since society thinks of them as more oriented towards social sciences rather than natural sciences and engineering.

According to Flegg et al.[3], the perception of a student towards mathematics is strongly related to their perception toward the discipline. That is, if the student's vision of mathematics is limited to arithmetic and some knowledge of algebra, then it will be difficult for the student to transfer abstract concepts to different contexts. Therefore, the notion of applications of mathematics and the instrumental nature of this science is reduced. In the case of engineering, it is desirable for students to have a positive attitude towards mathematics and its learning so that their perception of the importance of this exact science allows them to identify their use and relevance in different contexts.

The relevance of the several areas of mathematics in engineering is evident. However, according to Freiman & Sriraman[4], mathematics taught in the classroom might not emphasize this relevance enough for students to appreciate, recognize and value mathematics, not only in engineering, but in everyday activities. That is why it is important to identify the students' perceptions of mathematics in terms of the applicability and relevance to engineering.

In a previous study[1], we studied the perception of the importance of mathematics in relation to engineering (both scholar and professional). The results indicated that students generally have a low perception of mathematics, and that perception only decreases over time in university.

2.2 Perception of physics

Similarly, Stuckey et al.[5] reveal that students' perception of the relevance of science in general, either on everyday basis or more professional basis is related to their attitudes towards that science. However, studies of attitudes or perceptions are rather broad, and rarely underline the relevance of students' career choices.

Some researchers of the area have extensive experience on the evaluation of attitudes towards physics, as well as other variables such as learning, scientific reasoning, communication and collaborative skills by engineering students. However, we did not find many research studies devoted to the perception of the relevance of physics, particularly the relevance of physics on engineering. The only study was a previous one[1] which focused on the perception of the importance of physics in relation to engineering (both scholar and professional). The results indicated that students generally have a low perception and that perception decreases over time in university, similar to what was found in mathematics.

2.3 Perceptions of relevance by gender

When studying the perception of the relevance of mathematics and physics by gender, as with general results mentioned before, several factors like parents, peers, school and society expectations are to be taken into account[6, 7]. Jones & Young[8] worked with pre-college students on their perception of the importance of science and showed that there are significant differences among male students compared to female students, favoring the former. They also found that the difference increases with age. In another study of the perception of the relevance of sciences by gender, Jones, Howe & Rua[9] established that, regarding a professional life, sciences are considered areas of professional development for men. Their results also showed that a larger percentage of women, compared to men, believe that learning science is difficult.

In the aforementioned previous study[1], the results indicated that male students have better perception than female students regarding the importance of physics and that no difference was found in terms of gender in the perception of the importance of mathematics.

3. Method

3.1 Instrument

For the basis for this study we used the survey by Zavala et al.[1], which studied the perception of the relevance of physics and mathematics in engineering in a Chilean university. The survey consisted of eleven Likert-style statements, in which students had to choose from totally disagree, disagree, neutral, agree and totally agree. The statements dealt with students' perception of the relevance of physics and mathematics in engineering, that is, of scholar engineering and professional engineering practices. The survey implemented was based on Flegg et al.[3] which consisted on eight statements, but Zavala et al. added three more statements to complement the original dimensions. Zavala et al. also adapted the 11 item survey to study the perception of the relevance of physics in engineering since the original work by Flegg et al. was only focused on the perception of mathematics. The statements for both surveys (physics and mathematics) are essentially the same; however, instead of asking for the subject of mathematics, the survey asks students for the subject of physics instead. Table I shows the statements.

Table I

This table presents the 11 statements included in the survey for relevance of physics and mathematics in engineering.

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

3.2 Participants

In this study 1073 students of two courses participated, one from first semester, P1 (Physics 1), and the other from third semester, EM (Electricity and magnetism). Table II shows the characteristics of the participants. In this study we will focus on the analysis of the perception of students looking at the differences between the first semester course students and the third semester course students, and those between male and female students. In this paper, we do not study other socioeconomic or ethnic differences.

Table II
Distribution of students by course, gender and survey answered.

Total 1073 students								
Physics 1 (P1) 490				Electricity and magnetism (EM) 583			
Female students 162		Male students 328		Female students 134		Male students 449	
Phys	Math	Phys	Math	Phys	Math	Phys	Math
82	80	157	171	42	92	152	297

3.3 Data collection

The data was collected for several days in the different sections of the courses. The two surveys (perception of the relevance of mathematics and perception of the relevance of physics) were distributed randomly among the students for comparisons between surveys to be valid. The statements were printed on a separate piece of paper of the answer sheet. The survey consisted only of questions on the perceptions of the importance of physics and math in engineering. Once students finished the survey, it was collected and scanned to obtain the results.

3.4 Data analysis

Once the data was collected, we organized it in different ways. To present general results we grouped TD and D responses under *disagree* and TA and A responses under *agree*. In this way the data is presented by points on a graph (agree vs. disagree). However, to compare students' responses, we used the raw data as collected. For that we used non parametric statistics such as the Mann-Whitney's U test.

4. Analysis of results

The results are divided into three sections. The first section shows the results related to the perception of students of the relevance of physics in engineering, analyzing not only the results of the survey but also taking into consideration the differences in course and gender. The second section mirrors the first one, however it focuses on the perception of the relevance of mathematics, rather than physics, in engineering. The third section shows results contrasting students' perception of the relevance of physics and that of mathematics. In all sections, there are discussions comparing these results to those obtained from students from the Chilean university.

4.1 Survey of perception of physics in engineering

In this section we present the general results of the survey answered by all students regarding their perception of the relevance of physics in engineering. Then we analyze the differences in responses students gave depending on whether they belonged to a first or a second year course. The last subsection focuses on the differences in responses of students according to gender.

4.1.1 General results of the physics survey

The general results of the survey are presented in Figure 1, in which there are 11 points (statements according to Table I). The results are sketched as a pair of results, percentage of agreement in the vertical axis vs. percentage of disagreement to the statement in the horizontal axis.

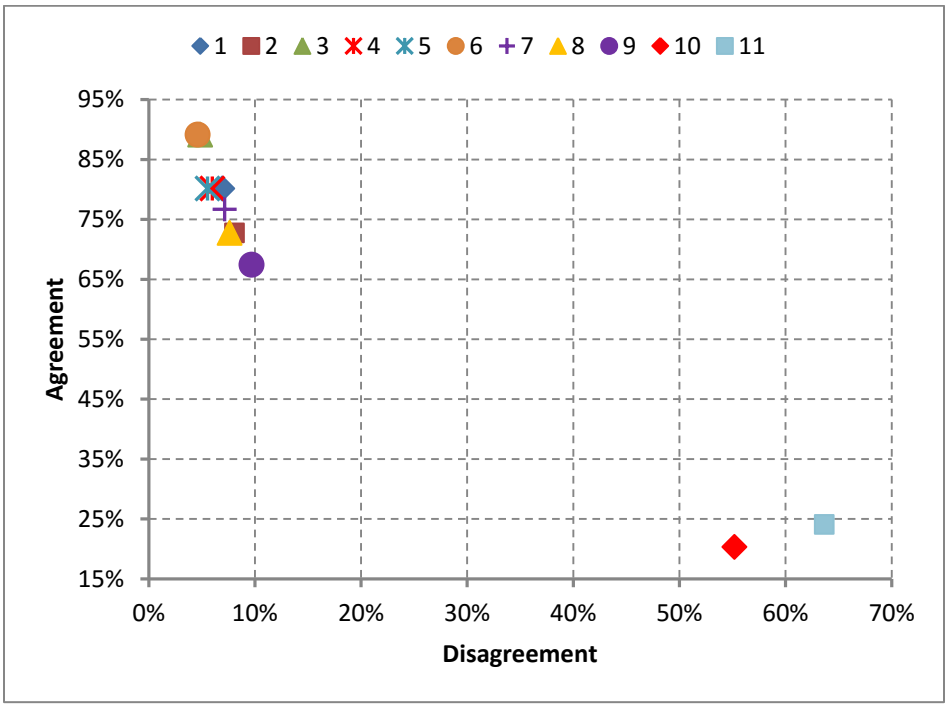

Figure 1. Results by items of the perception of the importance of physics in engineering. The numbers represent the statement according to table I.

In general, engineering students from this university have a strong positive opinion regarding the importance of physics in engineering compared to other studies[1]. Among the positive statements (1 to 9), the statements with the strongest agreements were: item 3 (89%), *Physics classes are needed for other courses (mathematics, chemistry, etc.) in my studies* and item 6 (89%), *The topics covered in the physics courses will help me later on in my engineering classes*. Students understand that physics is important for their engineering degree because they will need physics in other courses throughout their studies.

On the other hand, the statement in which students agree the least with is item 9 (67%): *It is important to learn physics to find a better job in engineering*, that is, physics is important but not as important as to be a factor in finding employment. The second and third statements they agree the least with are item 2 (73%): *The ways of thinking being taught to me in physics will remain with me long after I graduate*, and item 8 (73%): *The formal and rigorous aspects that I have learned in physics classes are important for my future engineering career.* Students do not agree as much in terms of the way physics is taught for them to remember it or the importance of rigor in physics for their engineering career. It seems that students believe physics will help them graduate but not for much else in the long term.

Regarding the negative statements (item 10 and item 11), as expected, students agree the least and disagree the most. For item 10: *For me, in physics I only want to learn what I feel is likely to be assessed,* 20% of students agreed and 55% disagreed. For item 11: *At some stage during my degree I have been so overwhelmed by physics classes that I have considered withdrawing from my engineering degree,* 24% of students agreed and 64% disagreed. An interesting result of item 10 is that it was the item that had the highest proportion of students being neutral (25%), which is, one out of four students does not have a strong opinion about this.
Comparing these results with those of Zavala et al.[1], we can find some strong differences and some similarities. Table III presents a comparison between this work and Zavala et al.[1]

Table III
Results of the survey regarding physics compared to the previous study with Chilean students.

	This Study		Previous study	
Statement	Agreement	Disagreement	Agreement	Disagreement
1	80%	7%	54%	20%
2	73%	8%	44%	17%
3	89%	5%	59%	14%
4	80%	6%	53%	19%
5	80%	6%	49%	15%
6	89%	5%	58%	12%
7	77%	7%	63%	10%
8	73%	8%	51%	16%
9	67%	10%	37%	25%
10	20%	55%	45%	34%
11	24%	64%	22%	64%

Table III shows that students in the Mexican university have, in general, better perceptions of the importance of physics in engineering than students in the Chilean university of the previous study. All results of the positive statements (1 to 9) had a significantly greater agreement percentage and in the negative statement 10 students agreed less with it than Chilean students. The only statement in which there is no difference is 11: *At some stage during my degree I have been so overwhelmed by physics classes that I have considered withdrawing from my engineering degree.* The results are the same.

Even though the results of the students in this study are better, the general tendency is the same, that is, the statements with which they are in most agreement in both universities are the ones that perceive the importance of physics in their scholar engineering. Students from both universities show disagreement with the statements in which the survey asks for the long-term importance of physics in their professional engineering career. The surprising result is statement 11, in which the results from students from both universities are the same. That is, no matter how differently students perceive the importance of physics in engineering and probably how differently physics is evaluated in each university, both samples, in general, they agree regarding their perception of physics as a difficult and stressful subject.

4.1.2 Differences by course (physics)

The physics survey was divided into students who were taking a first semester course (P1) and those who were taking a third semester course (EM). There were some differences in the answers; however, some of them were not statistically significant. As mentioned previously, we conducted a Mann-Whitney's U test to evaluate the differences in responses of our 5-Likert scale questions[10]. Figure 2 presents the summarized results (agreement vs. disagreement) of only the items in which we found a significant effect of Group ($p < 0.05$). The blue symbols are items from P1 and the red symbols are from EM. The numbers in the labels indicate the statements of the survey.

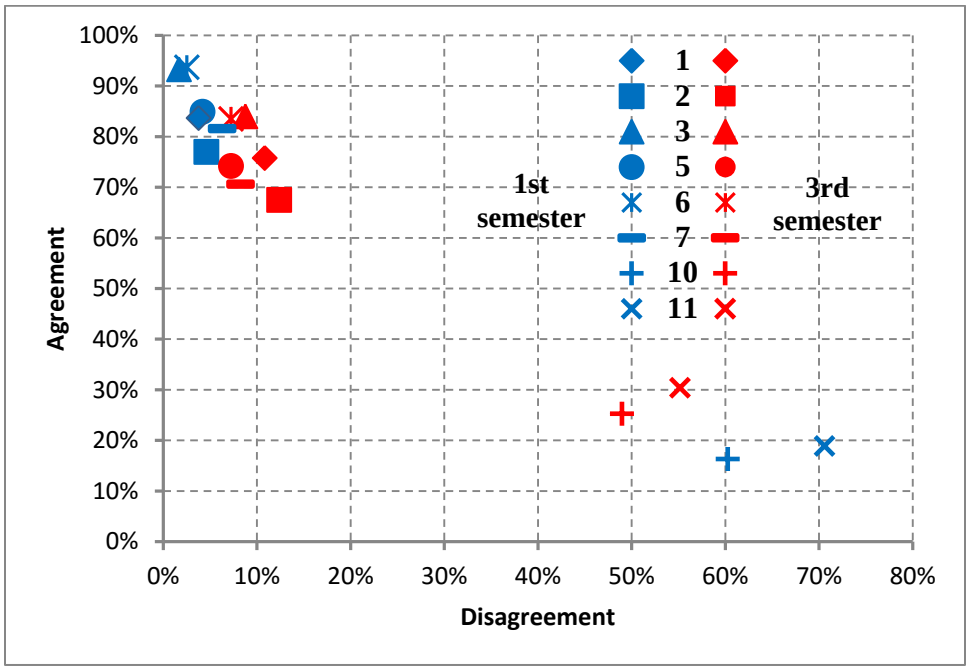

Figure 2. Results of items 1, 2, 3, 5, 6, 7, 10 and 11, in which there was a significant effect ($p < 0.5$) according to the course students were taking, P1 (blue) and EM (red).

There are three items (1, 5 and 6) in which the first semester students agreed more with the sentences than those in the third semester. The statements are:

Statement 1: I can see how the physics skills that I am currently developing will be useful in an engineering career.

Statement 2: The ways of thinking being taught to me in physics will remain with me long after I graduate.

Statement 3: Physics classes are needed for other courses (mathematics, chemistry, etc.) in my studies.

Statement 5: Physics classes expose me to ideas which I know I will need later on in my engineering degree.

Statement 6: The topics covered in the physics courses will help me later on in my engineering classes.

Statement 7: I see being able to communicate effectively using physics arguments I am taught as an important skill to have.

After one year of studying physics, students' responses decrease significantly, from 84% to 76% in statement 1, from 77% to 68% in statement 2, from 93% to 84% in statement 3, from 85% to 74% in statement 5, from 94% to 84% in statement 6, and from 82% to 71% in statement 7. This decrease is meaningful since 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 own studies of engineering. This effect could have been 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 are noticing that their physics courses are not really helping them to be successful in other courses. However, another cause could be that students who failed the course and ended up withdrawing from the university are those who have greater perceptions of the importance of physics. This latter reason is less probable since this university has a high student's retention rate.

The other two sentences are statements 10 and 11, two items for which ideally students would not agree with them:

Statement 10: For me, in physics I only want to learn what I feel is likely to be assessed.
Statement 11: At some stage during my degree I have been so overwhelmed by physics classes that I have considered withdrawing from my engineering degree.

Students in P1 answered these two sentences better than those in EM, that is, with a disagreement of 60% of P1 students vs. 49% of EM students for statement 10, and a disagreement of 71% of the P1 students vs. 55% of EM students for statement 11. Statement 10 is a key sentence to see how the students perceive the value of physics. Are they there to learn physics or are they there to pass a course? It seems that thinking of physics learning as a pragmatic way to get into the next semesters is increasing after a year of physics courses. On the other hand, 71% of the first semester students disagreed that physics is overwhelming compared to 55% of students in the third semester course. The interpretation of this is probably problematic, since if students are getting more practical (to answer as they do in statement 10), it could be concluded that they would become less stressed about physics. However, the results show the opposite. An additional question could be asked, or interviews could enlighten us, regarding why they feel more stressed out regarding physics. One hypothesis, which has to be tested, is that students in the third semester are taking Electricity and Magnetism, which is a more difficult physics course than first semester's Mechanics. Students in the third semester are taking one of the most challenging courses of their engineering degree.

Comparing these results to those in the previous study, as mentioned before, students in this study fare better; however, the tendencies are similar. The questions in which results are getting worst in both studies are the same, although there were differences in this study between the first and third semester students in three additional statements. Another important result to mention is that not only the results for statement 11 are the same for all students in their respective studies, but also, the way in which the result changed from the first semester to the third semester is the same, even though students were different.

4.1.3 Differences by gender (physics)

The physics survey was divided into male and female students. There were some differences in the answers; however, most of them were not statistically significant. We also ran a Mann-Whitney's U test to evaluate the difference in responses to our 5-Likert scale questions. Figure 3 presents the two statements in which we found a significant effect of Group ($p < 0.05$). The blue symbols are items from the male students and the red symbols are from the female students.

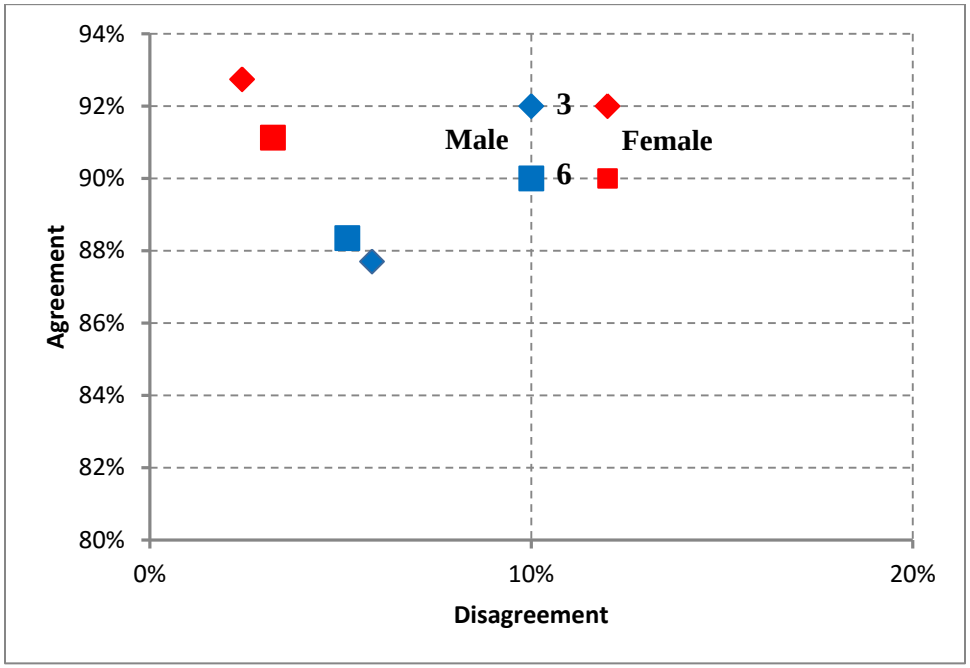

Figure 3. Results of *statements 3* and *6*, in which there was a significant effect ($p < 0.5$) according to the student's gender.

The differences we found, according to gender, were in statements 3 and 6, two items that survey on the importance of physics in relation to their engineering studies:

Statement 3: Physics classes are needed for other courses (mathematics, chemistry, etc.) in my studies.

Statement 6: The topics covered in the physics courses will help me later on in my engineering classes.

Female students agreed more with both statements, in particular with statement 3. This result is different from previous studies in which there was no difference in their perception of the importance of physics in their studies. In the previous study in the Chilean university, the only statement where there was a difference was statement 4, which is related to the importance of physics to formulate and solve problems. Moreover, in that study male students had better results than female students.

4. 2 Perception survey of mathematics in engineering

In this section we present the general results of the perception of relevance of mathematics in engineering by all students who answered the survey. Then, we analyze the difference in responses provided by students depending on the course they were on, a first year course or a second year course. The last subsection shows differences in responses of students according to gender.

4.2.1 General results of the mathematics survey

The general results of the survey are presented in figure 4, in which there are 11 items (statements according to Table I). The results are sketched as a pair of results, percentage of agreement in the vertical axis vs. percentage of disagreement to the statement in the horizontal axis.

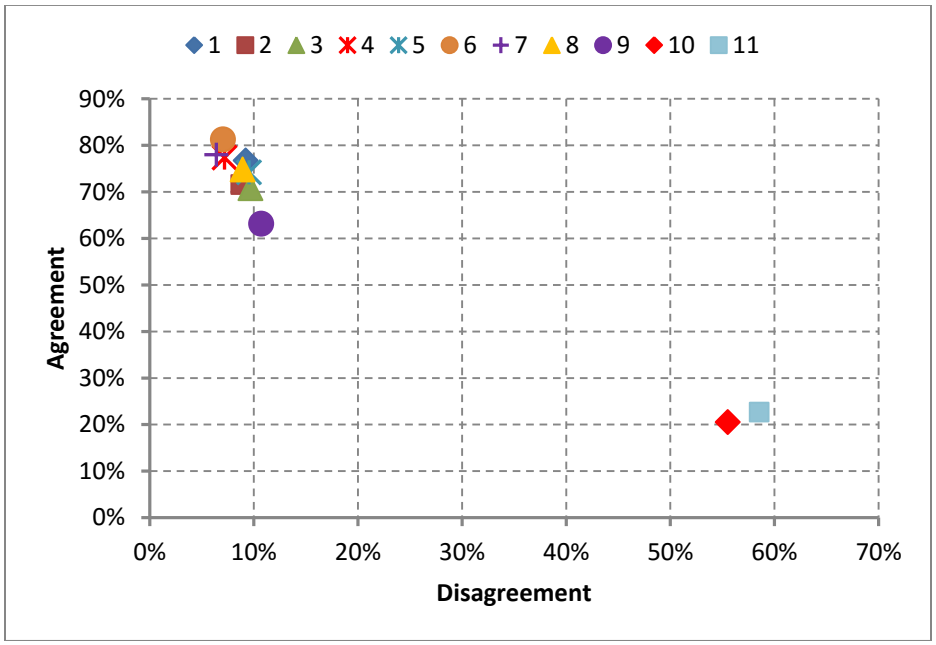

Figure 4. Results by statements of the perception of the importance of mathematics in engineering. The numbers represent the statements according to table I.

In the figure, statement 6 stands out: *The topics covered in the mathematics courses will help me later on in my engineering classes.* 81% of students agreed with this statement. It seems that it is very clear for students that mathematics is used in other courses in their career. Only 7% of students disagreed with the statement.

There are other three items which students strongly agree with:

Statement 7: I see being able to communicate effectively using mathematical arguments I am taught as an important skill to have,

Statement 4: I feel that the mathematics course I am currently taking teaches me how to formulate and solve problems that are directly related to engineering,

Statement 1: I can see how the mathematics skills that I am currently developing will be useful in an engineering career,

A large majority of students, 78%, 77% and 77%, respectively, agreed with these statements. These items are related to the importance of mathematics in their professional lives as engineers.

There is a positive item with the least agreement, *statement 9*: *It is important to learn mathematics to find a better job in engineering*. Even though this item surveys on the importance of mathematics in their professional lives as engineers, the result is different, with 63% of students agreeing with the statement. Moreover, there are 26% of students who were neutral answering this statement. This is an important item on how students perceive what employers look for when hiring engineers. Although the result is not entirely negative, it is important to note that this statement is the one students found less agreeable.

The last two items,

Statement 10: For me, in mathematics I only want to learn what I feel is likely to be assessed,

Statement 11: At some stage during my degree I have been so overwhelmed by mathematics classes that I have considered withdrawing from my engineering degree

are the ones with least agreement. Since the items are negative, it is understandable that students would not agree with them (21% and 23% respectively).

Comparing these results to those of Zavala et al.[1], we built table IV, which shows the results of the students from this study and those from the previous study with students from the Chilean university.

Table IV

Results of the survey regarding mathematics compared to the previous study with Chilean students.

	This Study		Previous study	
Statement	Agreement	Disagreement	Agreement	Disagreement
1	77%	9%	61%	12%
2	72%	9%	52%	19%
3	71%	10%	85%	2%
4	77%	7%	44%	12%
5	74%	10%	53%	14%
6	81%	7%	69%	8%
7	78%	6%	60%	13%
8	75%	9%	53%	10%
9	63%	11%	51%	14%
10	21%	56%	36%	38%
11	23%	59%	31%	47%

Table IV shows that in all statements, with the exception of statement 3, students from the Mexican university have a better perception of the importance of mathematics in engineering than the students from the Chilean university. There are two individual results that are noteworthy. *Statement 3: Mathematics classes are needed for other courses (physics, chemistry, etc.) in my studies* is the only item where the result from Chilean students is better than that from Mexican students. A large portion of students in the Chilean university, 85%, agree with that statement compared to 71% of students in the Mexican university. On the other hand, the greatest difference between the two groups of students resulted with *statement 4: I feel that the mathematics course I am currently taking teaches me how to formulate and solve problems that are directly related to engineering.* In this case, only 44% of students from the Chilean university agreed compared to 77% of students from the Mexican university.

Flegg et al.[3] published their work with some of the statements we implemented regarding the importance of mathematics in engineering. Table V presents their results along with the results of this study.

Table V
Results of the survey regarding mathematics compared to the previous study by Flegg et al.

	This Study		Flegg et al.	
Statement	Agreement	Disagreement	Agreement	Disagreement
1	77%	9%	79%	3%
2	72%	9%	82%	0%
4	77%	7%	59%	12%
5	74%	10%	76%	6%
7	78%	6%	94%	0%

As shown in table V, it seems that there is a difference in statements 2, 4 and 7. It is not possible to be sure whether these differences are significant or not the raw data from Flegg et al.[3] is not available; however, it is probable that they are. The students in Flegg's study had better perceptions on statements 2 and 7, related to the importance of the way of thinking and communications skills. On the other hand, students in this study had a better perception of statement 4, about the use of mathematics to solve engineering problems. These results can be viewed with caution since the number of students surveyed by Flegg et al. is small. What is important about this comparison is that students in different countries (Mexico, Chile, and Australia) have, in general, similar perceptions.

4.2.2 Differences by course (mathematics)

The mathematics survey was divided into students who were taking P1 and those who were taking EM. In all statements, the results indicate that students' perceptions from the P1 course were better than the students' perceptions of students from the EM course. However, some of the differences were not statistically significant. We ran a Mann-Whitney's U test to evaluate the

difference in the responses to our 5-Likert scale questions. Figure 5 presents six items in which we found a significant effect of Group ($p < 0.05$), *statements 1, 2, 3, 4, 5* and *6*.

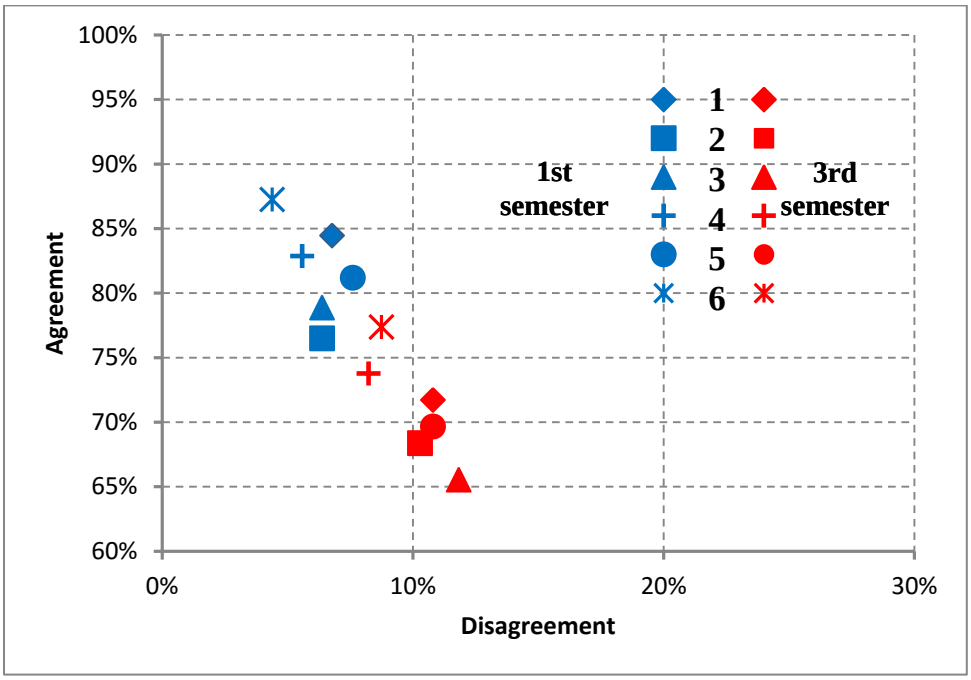

Figure 5. Items 1, 2, 3, 4, 5 and 6 for which there was a significant difference between the results of students taking P1 and those taking EM.

Figure 5 shows that in the first six items, students in P1 agree more with the following statements than students in EM:

Statement 1: I can see how the mathematics skills that I am currently developing will be useful in an engineering career.

Statement 2: The ways of thinking being taught to me in mathematics will remain with me long after I graduate.

Statement 3: Mathematics classes are needed for other courses (physics, chemistry, etc.) in my studies.

Statement 4: I feel that the mathematics course I am currently taking teaches me how to formulate and solve problems that are directly related to engineering.

Statement 5: Mathematics classes expose me to ideas which I know I will need later on in my engineering degree.

Statement 6: The topics covered in the mathematics courses will help me later on in my engineering classes.

The significant differences are found on six out of nine positive statements, which cover both the importance of mathematics in their later classes of engineering and the importance of mathematics in their engineering career. After a year of being exposed to scholar mathematics, students' perceptions decrease. Similarly, in the Chilean university from the previous study the perceptions also decreased after one year; however, significant differences were found only in statement 9.

4.2.3 Differences by gender (mathematics)

We performed the same analysis using the mathematics survey and ran a Mann-Whitney's U test to evaluate the difference in the responses. We found significant differences in five statements, which are presented in *Figure 6*.

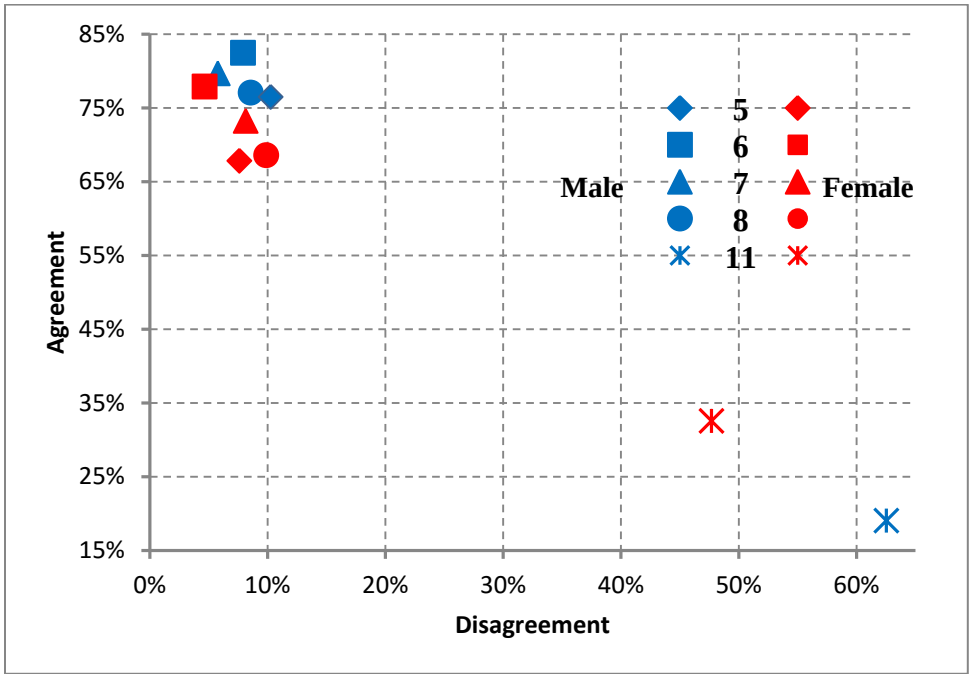

Figure 6. Items 5, 6, 7, 8 and 11 for which there was a significant difference between the results of male and female students.

The differences were found in four positive items (statements 5, 6, 7 and 8) and one negative item (statement 11):

Statement 5: Mathematics classes expose me to ideas which I know I will need later on in my engineering degree.

Statement 6: The topics covered in the mathematics courses will help me later on in my engineering classes.

Statement 7: I see being able to communicate effectively using mathematical arguments I am taught as an important skill to have.

Statement 8: The formal and rigorous aspects that I have learned in mathematics classes are important for my future engineering career.

Statement 11: At some stage during my degree I have been so overwhelmed by mathematics classes that I have considered withdrawing from my engineering degree.

In all of these five statements male students have a better perception of mathematics. The largest difference was found on the negative item (statement 11). Only 19% of male students have felt so overwhelmed by mathematics that they have considered withdrawing from their *engineering* degree. In the case of female students, that proportion increases to 33%, one-third of students.

These results are very different from the results from the Chilean students, in which there was no difference between male and female students in any of the 11 statements.

4.3 Differences in perception of the importance of physics and mathematics in engineering

Since the surveys were identical (except for the change of mathematics for physics in the statements), we are able to compare results. We compared the results on each statement running a Mann-Whitney's U test to evaluate the difference in the responses. The results of the general populations who answered the physics and mathematics surveys are presented in figure 7. The figure presents only the results that are significant differences between the math and physics surveys (*statements 3* and *6*). The difference in results of the other statements is not significant and thus, they are not included.

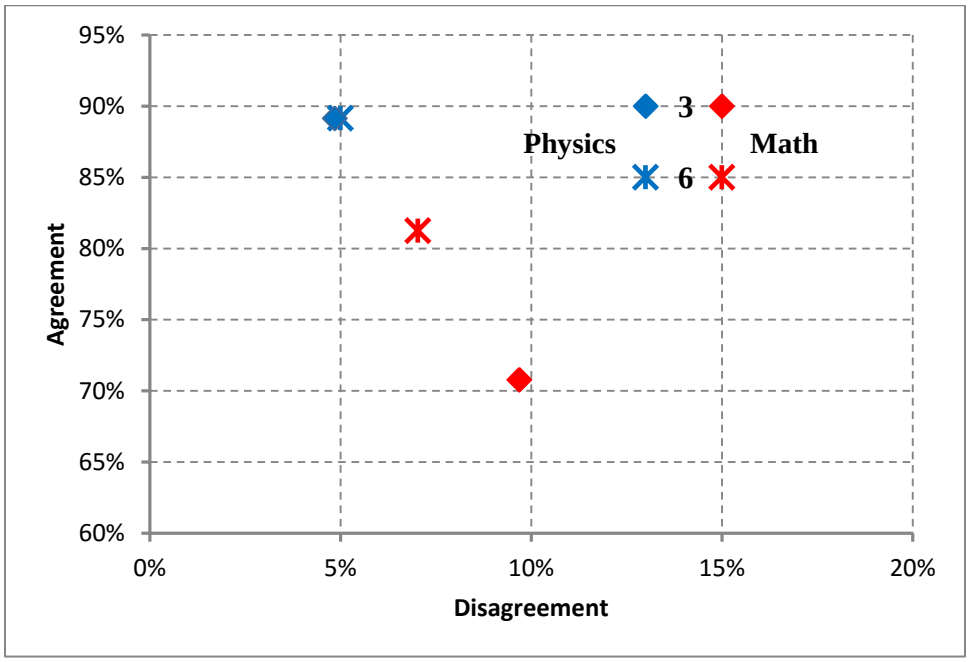

Figure 7. Difference in results from students answering physics and math surveys. There were only two statements where we found significant differences (*statements 3* and *6*). The blue symbols belong to the results of the physics survey and the red symbols to the mathematics survey.

In general, there were differences between the math and physics survey in favor of the latter. However, two statements offered significant differences according to the Mann-Whitney's U test. Both statements are related to the importance of mathematics (or physics) in the academic needs of the degree, *statement 3: Mathematics (Physics) classes are needed for other courses (physics (mathematics), chemistry, etc.) in my studies* and *statement 6: The topics covered in the mathematics (physics) courses will help me later on in my engineering classes.* Students answering math agreed 71% with the statement 3 (10% disagreed) vs. those students answering physics, which agreed 89% with the statement 3 (5% disagreed). In the case of statement 6, students answering math agreed 81% with the statement (7% disagreed) vs. those students answering physics, which agreed 89% with the statement (5% disagreed). The difference is

important: it seems that, in general, the perception of the importance of physics for courses in their degree is greater than the perception of the importance of mathematics.

These results are opposite to those from the Chilean students in the previous study, in which the differences were found favoring the perception of mathematics. In that study, there were three items with significant differences (statements 3, 9 and 11) and in all of them the perception of mathematics was better than that of physics. In particular, statement 3, related to the importance of physics (mathematics) in their scholar engineering degree, 85% of students of the Chilean university agreed with the statement in relation to mathematics and 59% of them agreed with the statement in relation to physics. In the Mexican university, 71% of students agreed with the statement in relation to mathematics and 89% of them agreed with the statement in relation to physics.

5. Conclusions

5.1 Summary

We used a survey of the perception of the importance of physics and mathematics in engineering from Zavala et al.[1] which was adapted from the work by Flegg et al.[3]. Since the survey was implemented randomly with students from two courses (first and third semester), we were able to obtain results not only from each of the surveys, but also to compare these two surveys results with the same population. We analyzed students' perception of physics and the relation to the semester in which students are and the differences by gender. We did the same exercise using the survey of the perception of mathematics. Finally, we compared the results of the two surveys. Whenever possible, we compared the results of this study with the results from a previous study in which students from a Chilean university participated.

5.2 Findings

From the study we can conclude that:

- Students in this Mexican university, in general, have a good perception of the importance of mathematics and physics in engineering. The evidence is found by comparing our results to those published by Zavala et al.[1] and Flegg et al.[3].
- Students in their first semester have a better perception of physics and mathematics than students in their third semester. It seems that after taking physics or mathematics courses, they might realize that these subjects are not as important as they initially thought. These results are similar to those from the Chilean university's study[1].
- In this study, female students have a slightly better perception of the importance of physics than male students. This is opposite to what was found in the Chilean university.
- Male students have a slightly better perception of the importance of mathematics than female students. In the Chilean university no difference was found.
- In general, the perception of the importance of physics in engineering is better than the perception of the importance of mathematics. This is opposite to the results of the Chilean university's study.

5.3 Recommendations

As the last study on perceptions of the importance of physics and mathematics in engineering, this current study can also be used by instructors and by administration officers to devise a strategy to motivate engineering students to pay attention to math and physics. We conducted a study in two very different universities, in two countries with different cultures, and the results show there is a decrease in the students' perception of the importance of math and physics in engineering as they take these courses in university. Moreover, in both studies we found evidence that they are gender-biased in their perceptions. Given these results, we believe that our previous recommendations still are in effect. The actions we recommend are:

- Modification of instruction of math and physics to include more real-life problems in classes emphasizing the engineering part of the problem.
- Modification of instruction of physics and mathematics courses using active-learning strategies in which students participate in their own learning. Although students from the university of this study belong to an institution in which the educational model is student-centered, we believe that the transformation of the courses should be complete.
- Modification of physics courses from being content-related to being model-related, that is, from a knowledge-based view of physics to a model-construction approach of physics.
- Modification from a traditional course of mathematics (drill and practice instruction) to a more context-related, model-building and problem-solving approach.
- Investigation is needed from upper engineering courses to focus content and students' competences of physics and mathematics courses towards that direction; that is, implementation of interdisciplinary projects that foster interaction among physics, math and engineering instructors/professors to modify teaching strategies, content, and course focus.
- Implementation of a longitudinal formative assessment process to monitor students' perception throughout their years at the university, and, in the case of the implementation of measures, an investigation on how students' perception change over time due to the intervention.

These recommendations have not been tested. We have a current project in which one of the objectives is to increase the positive perception of students taking into account gender differences. In the future, we will be reporting the results.

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