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Students' perception of relevance of physics and mathematics in engineering majors

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Abstract

In Chilean universities, a large proportion of engineering students abandon their studies within the first year. There is a variety of reasons for this phenomenon. It is also a fact that a high number of students fail their first year physics and/or math courses. We believe that the high dropout rate is related to failing physics and math courses (sometimes more than once); however, that relation has not been studied in Chile. In general, there is a consensus in the literature that these two phenomena (failing a course and dropping out) are caused in some degree by the limited preparation on these sciences that students receive in precollege education, as well as by the traditional teaching strategies (lecturing being a quite common teaching strategy in physics and math courses). However, this study takes a different approach. We believe that another strong reason for failing courses and dropping out of school might be related to students' perception of the relevance of physics and mathematics to their professional career, which is, in this case, engineering. In this study 232 students taking first and second year physics and math courses at a large private university in Chile participated. We used a Likert-scale instrument in which students chose from a "Totally agree" to "Totally disagree" scale of statements related to relevance of science and mathematics for future career and study. The results of this study discuss four aspects: 1) the 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) gender differences on those perceptions and 4) the relation of those perceptions to their performance in the course. As conclusions, we present the consequences for that practice and some recommendations for instructors and course designers.

1. Introduction

In 2014, the institution in which this research was conducted had high undergraduate enrollment. About 43% of those students enrolled in a mathematics, physics or chemistry course on their first year at the university, and about 80% of all students got a score of less than 600 points out of 850 on the standardized University Selection Test (PSU, after the acronym for Prueba de Selección Universitaria)[1].

Programme for International Student Assessment (PISA) results show that students in Chilean educational institutions show performances in mathematics, science and reading comprehension that are well below the OECD average[2]. For example, the results indicate that over 50% of Chilean students tested in math are at level 1, levels ranging from 1 to 6. Moreover, only 5% of Chilean students are at levels 5 and 6 on that test. Since the educational institution in which this study was conducted has a large number of students with an average PSU of 558 points, it means that the situation identified by PISA results is a reality for this student population.

There are large numbers of first-year students failing physics and/or mathematics courses at this educational institution, with some of them dropping out completely from the university. This problem is very complex. Some research argues that these two phenomena (failing a course and dropping out from university) are caused in some degree by the limited preparation that students receive on these disciplines before entering the university, as well as by the traditional teaching strategies. The PISA results discussed above confirm the former statement. However, in regards to the teaching strategies, lecturing is a quite common methodology in physics and mathematics courses. Even though the courses are not massive (about 60 students per session), teacher-centered strategies are fairly predominant.

2. Perception of the relevance of mathematics and physics

2.1 The case of mathematics

The self-perception of a student regarding mathematics is related to many factors, such as school experience, the importance and support given by the family from childhood regarding the discipline, and the type of intelligence. On one hand, it is socially justified for a child to do poorly in his/her mathematics classes, especially if no one else in the family has pursued studies requiring an advanced level of exact sciences. This situation is accentuated in relation to gender, i.e., in the case of women, where career selection is often more oriented towards social areas than to engineering programs.

The self-perception of a student towards mathematics is closely connected to his or her perception of the discipline. That is, if the student's view of mathematics is limited to arithmetic operations and some notions of algebra, it will be quite difficult for that student to transfer abstract concepts to other contexts. Thus, it reduces the applicability of mathematics and its instrumental character[3]. In the case of engineering, it is desirable for students to have a positive attitude towards learning mathematics, for them to be motivated by the learning of mathematics, and that their perception of mathematics allows them to identify their uses and relevance in different contexts.

The relevance of the various areas of mathematics in engineering is very evident. However, school mathematics (the mathematics taught in the classroom) might not emphasize those connections enough for students to appreciate, recognize and value mathematics, not only in engineering, but in everyday activities[4]. That is why it is important to identify the students' perceptions of mathematics in terms of the applicability and relevance to the engineering topics.

2.2 The case of physics

Students' perception of the relevance of science, either on their daily or professional life is related to his or her attitudes towards science[5]. However, studies of attitudes are rather broad, and seldom emphasize the relevance of the career choices of students. The results of research on students' perception of the relevance of science involving pre-college students show there is a gender bias in favor of male students and, this difference increases with age[6].

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.

2.3 Perceptions of relevance by gender

When studying the perception of the relevance of mathematics and physics by gender, factors like parents, peers, school and society expectations are to be taken into account[7, 8]. In a study of perception of the relevance of sciences by gender, results established that, regarding professional life, sciences are considered areas of professional development for men. Also, results show that a larger percentage of women believe that learning science is difficult[9]. The small ratio of female to male students in the university where this study was conducted is evidence that there is a problem.

3. Method

3.1 Instrument

For the basis for this study we used the survey by Flegg et al.[3,] which studied the perception of the relevance of mathematics in engineering. The survey consisted of eight 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 mathematics in engineering, that is, of scholar engineering and professional engineering practices. We added three more statements to complement these dimensions. We also adapted the 11 item survey to study the perception of the relevance of physics in engineering. The statements were basically 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 physics I am currently taking teaches me how to formulate and solve problems that are directly related to engineering*	*I feel that mathematics 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 seen in physics classes are important for my future engineering career*	*The formal and rigorous aspects that I have seen 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 232 students of two courses participated, one from first semester, FSC (first semester course), and the other from third semester, TSC (third semester course). A small number of female students participated, since the ratio of female to male students in engineering degrees in this university is small. 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.

<table>
<tr><td colspan="8" align="center">Total
232 students</td></tr>
<tr><td colspan="4" align="center">First semester course (FSC)
124</td><td colspan="4" align="center">Third semester course (TSC)
108</td></tr>
<tr><td colspan="2" align="center">Female students
28</td><td colspan="2" align="center">Male students
96</td><td colspan="2" align="center">Female students
20</td><td colspan="2" align="center">Male students
88</td></tr>
<tr><td>Phys
13</td><td>Math
15</td><td>Phys
43</td><td>Math
53</td><td>Phys
14</td><td>Math
6</td><td>Phys
53</td><td>Math
35</td></tr>
</table>

3.3 Data collection

The data was collected in one day for the FSC and in another day for the TSC in the different sections of the same course. We expected to survey more students, but the combination of the lack of mandatory attendance and the teaching style (predominantly lecturing strategies) resulted in a great number of students missing classes. The two surveys (perception of the relevance of mathematics and perception of the relevance of physics) were distributed randomly among the students in order for comparisons between surveys to be valid. The statements were printed on a separate piece of paper of the answer sheet. The survey consisted not only of questions on the perceptions of the importance of physics and math in engineering, but also another survey was included regarding attitudes toward physics and math. Once students finished the survey, it was collected and scanned to obtain the results. The results of the attitude survey are not presented in this study.

The grades of students at the end of the semester were collected from the administrative office of the university. In order to make sure the sample we had was representative of the student population, we filtered students who had 1 or 2 (out of seven) as a final grade, since they were students who had withdrawn from the course at the beginning. Comparing the grades of the students who participated in the survey and students who were missing that day, we concluded that there was no significant difference between the students according to a Mann-Whitney's U test.

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 was presented by points in 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 and the Spearman's Rho correlation coefficient.

4. Analysis of results

The results are divided in 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 looking at the differences in course and gender and the correlation of the results with the final grade in the course. The second section mirrors the first section but looking at 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.

4.1 Survey of perception of physics in engineering

In this section we present the general results of the survey answered by all the students regarding their perception of the relevance of physics in engineering. Then we analyze the differences in responses students had depending on the course they were, a first year course or a second year course. The third subsection focuses on differences in responses of students according to gender. The last subsection of the physics survey is an analysis of contrast between the survey and the final grades of students in their course.

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.

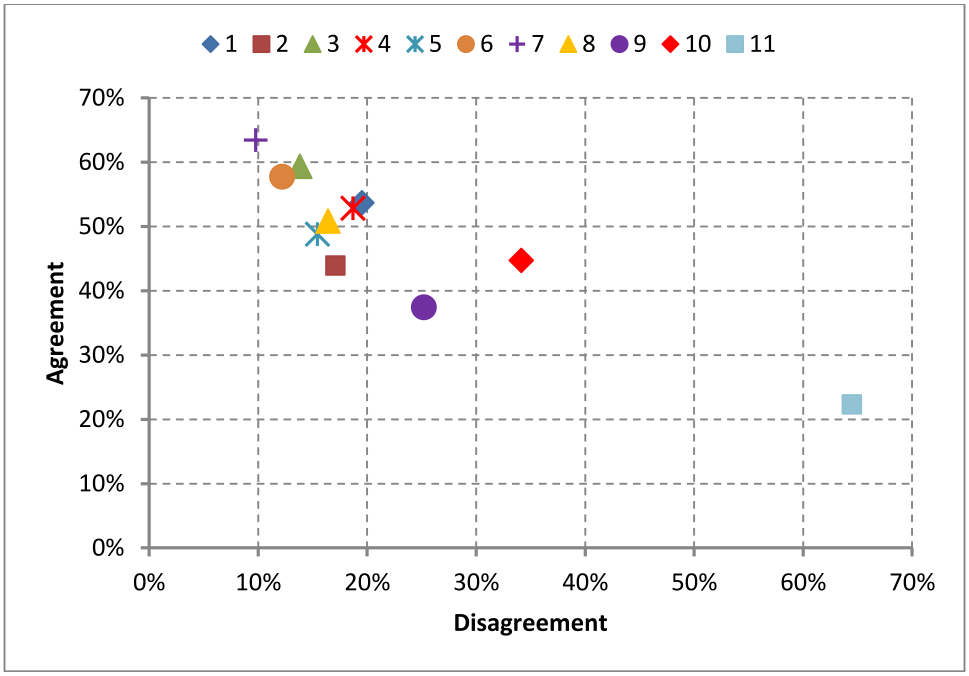

Figure 1. Results by items of the perception of the importance of physics in engineering. The numbers represent the item according to table I.

Among the positive statements (1 to 9), *item 7* is the one in which students agree the most (63%) and disagree the least (10%): *I see being able to communicate effectively using physics arguments I am taught as an important skill to have*. Two more statements have strong agreements: *item 3* (59%), *Physics classes are needed for other courses (physics, chemistry, etc.) in my studies* and *item 6* (58%), *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, not only because the nature of physics benefits their ability to make arguments, but also because they will need physics in other courses throughout their studies.

On the other hand, the statement in which students agree the least is *item 9* (37%): *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 a job. The second statement they agree the least is *item 2* (44%): *The ways of thinking being taught to me in physics will remain with me long after I graduate*. Students do not agree as much in terms of the way physics is taught for them to remember their own learning. If we compare this last statement with the work by Flegg et al.[3,] we can see a large difference in results. While the agreement in mathematics of their study with this phrase was 82%, with students in physics was 44%. Of course, the perception is about a different subject, but the difference is large enough to pay attention to it. Later on this study we analyze the mathematics survey and come back to this point.

It is interesting to note that *item 9* and, more importantly, *item 10*: *For me, in physics I only want to learn what I feel is likely to be assessed* are the ones in which students who agree are in a similar proportion to students who disagree (37% agreement, 25% disagreement for *item 9* and 45% agreement, 34% disagreement for *item 10*). Moreover, *item 9* has a large proportion of students who perceived themselves as neutral to the statement (37%): more than one third of students do not have a strong opinion on whether physics would help them find a job in engineering. *Item 10* is critical, since it refers to their perception (and probably their liking of physics classes). In a later section we compare this statement with characteristics of students and also with final notes on the course.

A statement which is important in terms of how difficult and stressful students perceive physics is *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*. A large proportion of students disagree (64%). Later on this work we discuss the differences on this item in relation to gender and course, and the correlation with their final grade.

4.1.2 Differences by course (physics)

The physics survey was divided into students who were taking a first semester course (FSC) and those who were taking a third semester course (TSC). 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 difference in the 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 the FSC and the red symbols are from the TSC. The numbers in the legend indicate the items of the survey.

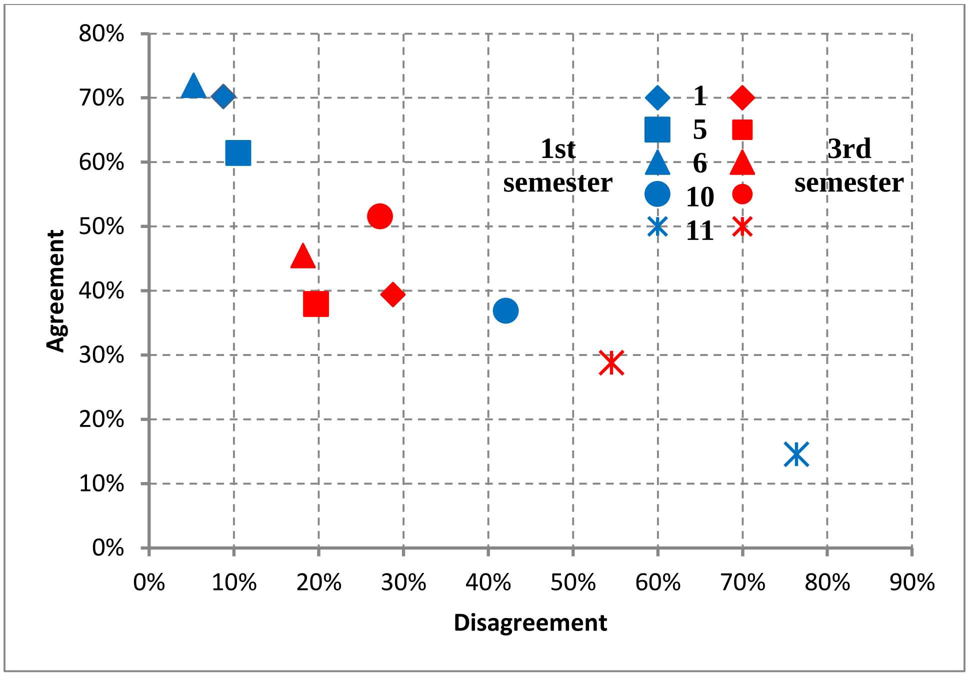

Figure 2. Results of *items 1, 5, 6, 10* and *11*, in which there was a significant effect ($p < 0.5$) according to the course students were taking, FSC (blue) and TSC (red).

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 sentences are:

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

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.

After one year of studying physics, students' responses decrease significantly, from 70% to 39% in *sentence 1*, from 61% to 38% in *sentence 5*, and from 72% to 45% in *sentence 6*. This decrease is important since one of the sentences is the perception of the relevance of physics in an engineering career and the other two are related to the importance of physics in their own 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 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 are not passing the course and ended up withdrawing from the university are those who have greater perceptions of the importance of physics. To test this latter hypothesis we need a longitudinal study, which we are in the process of conducting and of which results will be published in the future.

The other two sentences are items 10 and 11, two items in which the ideal would be that students do 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 the FSC answered these two sentences better than those in the TSC. A disagreement of 42% of the FSC students vs. 27% of the TSC students for *sentence 10*, and a disagreement of 76% of the FSC students vs. 55% of the TSC students for *sentence 11*. *Item 10* is a key sentence to see the value of physics in the perception of students. 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 prevailing after a year of physics. On the other hand, a good 76% of the first semester students disagreed that physics is overwhelming compared to only 55% of students in the third semester course. The interpretation of this is probably troublesome, since if students are getting more practical (to answer they do in *sentence 10*), one may think that they would become less stressed about physics. However, the results are opposite to that. An additional question could be asked to students, or interviews could enlighten us, regarding why they feel more stressed about physics. One hypothesis, which has to be tested, is that students in the third semester 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. Students in the third semester are taking one of the most difficult courses of their engineering degree and, on top of that, they had previously taken in their second semester a calculus-based mechanics course which is also definitely more challenging than the algebra-based general physics course they take on their first semester.

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 the responses to our 5-Likert scale questions. Figure 3 presents the only item 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. The bars represent the percentage of students (male or female) who answered from TD (totally disagree) to TA (totally agree) going through D (disagree), N (neutral) and A (agree).

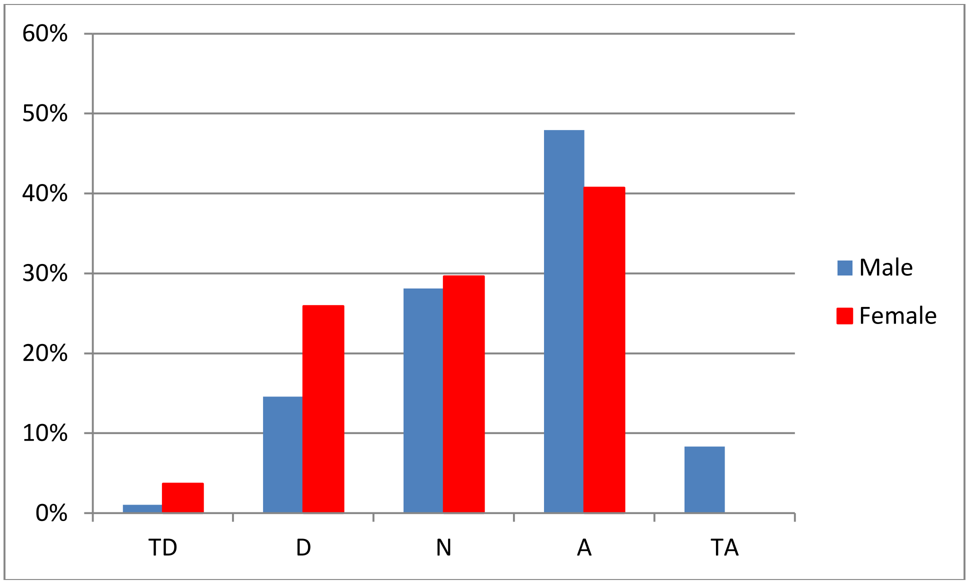

Figure 3. Results of *item 4*, in which there was a significant effect ($p < 0.5$) according to the student's gender.

The only significant difference was in *item 4*: *I feel that physics I am currently taking teaches me how to formulate and solve problems that are directly related to engineering.* Male students answer more strongly in agreement with this item compared to female students (56% agreement of male students vs. 41% agreement of female students). Actually, no female student answered totally agreeing with the sentence. Also, the number of female students disagreeing with this item is greater (30%) than that of male students (16%).

There were three other items in which male students agreed more than female students, although not significantly. However, it is interesting that these three items:

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

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

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

are related to the importance of physics in engineering professionally, the same as *item 4*. That is, these four items belong to what Flegg et al.[3] called: "related to relevance of mathematics to future career". It is possible that male students are more convinced that physics is important to understand if they want to work in engineering.

4.1.4 Relation to final grade (physics)

To obtain the relationship between the 11 items of the survey and the final grades of the student, we used the Spearman's Rho correlation coefficient, since it is a non-parametric test used to measure the strength of association between two variables[10]. Figure 4 shows the Spearman coefficient between the items and the final grade. The figure only shows the ones that are weak and moderate correlated with a significance of $p < 0.05$. Other results are omitted in the figure in order to highlight the important results.

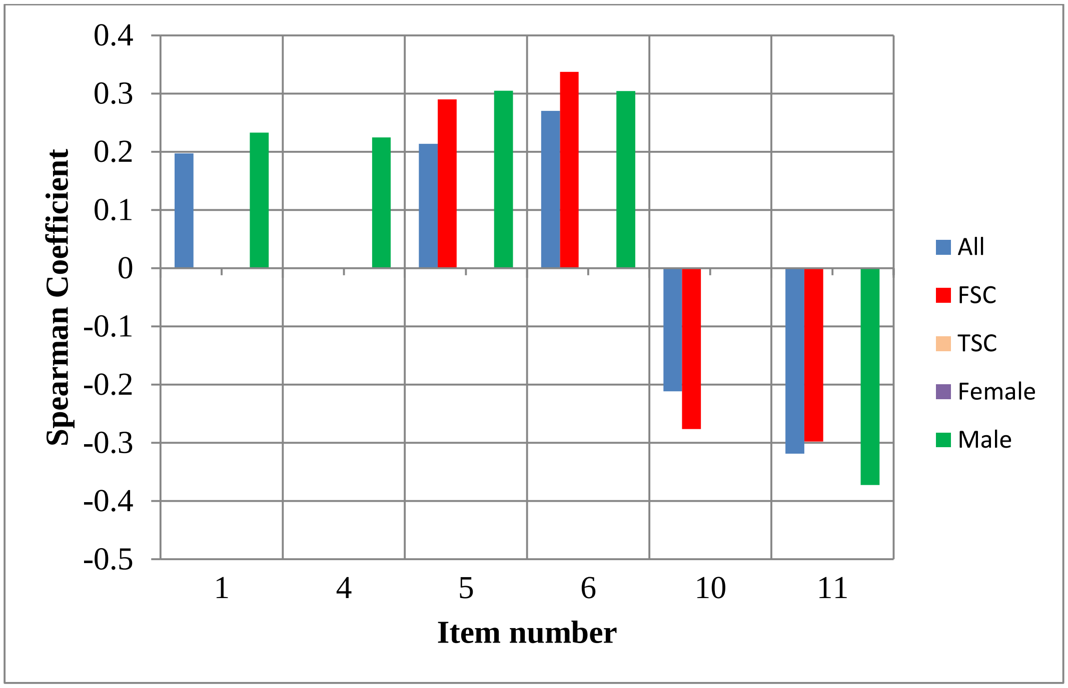

Figure 4. In six items (*1, 4, 5, 6, 10* and *11*) there were weak and moderate correlations with the final grade. The colors of the bars indicate whether the data is from students in the first semester course (FSC), from students who are females, etc.

Taking all students who answered the survey of students' perceptions of the importance of physics in engineering (blue bars), it is observed that there was a positive correlation with *items 1, 5* and *6*:

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

and a negative correlation with *items 10* and *11*:

> *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.*

It is interesting to note that the better grades students get, the better they understand the importance of physics in their professional life (*item 1*) and in their studies for an engineering degree (*items 5* and *6*). On the other hand, the better the grades students get, the more in disagreement they are with *statements 10* and *11*. That is, good students (or at least those who get better grades) do not agree with the idea that they are there to study physics only to pass the course. They neither feel so stressed with physics that they contemplate the idea of withdrawing from school. The results with both the positive and the negative items are consistent with each other. Moreover, the results are in the direction of the ideal situation: students committed to learning instead of wanting to pass the course.

Figure 4 also presents results of students divided into those in FSC and TSC. The FSC students have almost the same results as all students except that there is no correlation to *Statement 1*. The final grade is positively correlated with *items 5* and *6*, and negatively correlated with *items 10* and *11*. In three out of four items the correlation is even stronger compared to all students results. However, final grades of TSC students do not correlate with any item in the survey. In some way, after a year the correlation obtained in the first semester is lost on the third semester. On one hand, if we think that students' final grades on the first semester are strongly correlated to the survey and that the high grades students are the ones who continue with their studies, probably the correlation is lost because the less proficient students withdraw in the process. On the other hand, Electricity and Magnetism could be such a different course compared to General Physics that grades correlation is lost. A longitudinal study we have in progress is expected to provide us with some insights to answer these relations.

The last piece of data figure 4 presents are the differences in correlation with the gender of students. As it is observed, final grades of female students do not correlate with any item. Opposite to that, final grades of male students correlate with the previous five items we have been discussing and also correlate with *item 4*: *I feel that physics I am currently taking teaches me how to formulate and solve problems that are directly related to engineering*. *Item 4* is an additional item which is related to the importance of physics in their professional life as *item 1*. The behavior of the differences in results between female and male students is not understood. However, the small number of the female students participating on the survey (see Table II) makes for a more difficult interpretation.

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 third subsection shows differences in responses of students according to gender. The last subsection of the mathematics survey is a correlation analysis between the survey and the final notes of students in their course.

4.2.1 General results of the mathematics survey

The general results of the survey are presented in figure 5, 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.

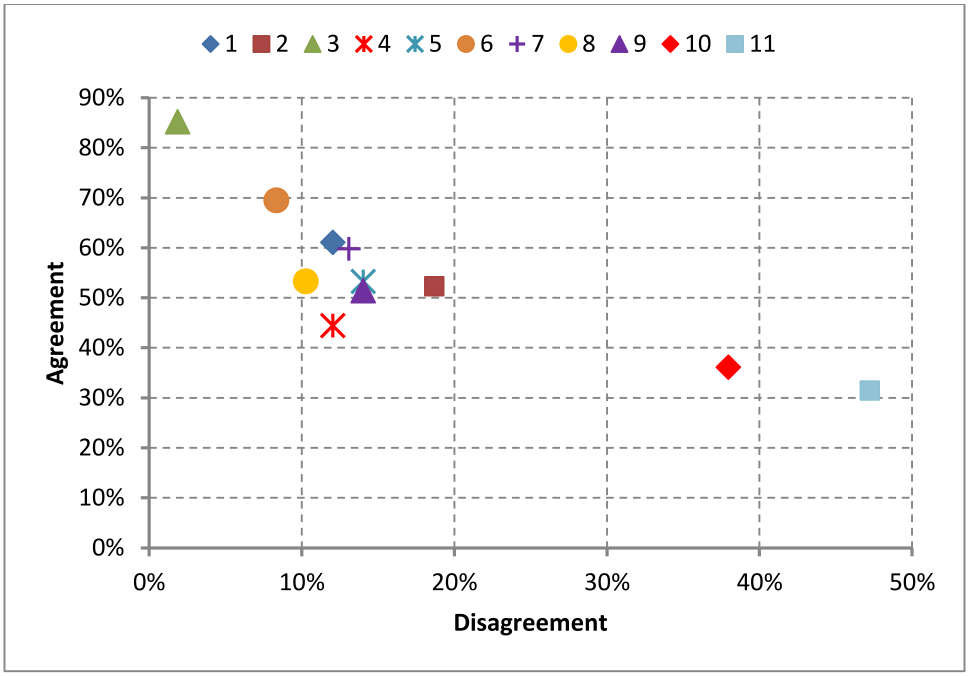

Figure 5. Results by items of the perception of the importance of mathematics in engineering. The numbers represent the items according to table I.

In the figure, item 3 stands out: *Mathematics classes are needed for other courses (physics, chemistry, etc.) in my studies.* 85% 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 2% of students disagreed with the statement, probably those who answered the survey randomly.

There are other three items which students strongly agree:

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

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

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

which were agreed by 69%, 61% and 60% of the students, respectively. These items, together with *item 3*, are a good balance of two items regarding the importance of mathematics in their degree studies and the importance of mathematics in their professional lives as engineers.

There is a positive item with the least agreement, *statement 4*: *I feel that mathematics I am currently taking teaches me how to formulate and solve problems that are directly related to engineering*. Even though this item belongs to the importance of mathematics in their professional lives as engineers, the result is tremendously different, with 44% of students agreeing with the statement. This could be taken as a measure of the way mathematics is taught in that particular university. They understand the importance of mathematics in engineering (both as a professional career and in their academic needs). However, this question goes a little further since the statement refers to the specific mathematics they are taking whether they feel it is helping them to formulate and solve engineering problems. Students might think that this goal is not fulfilled in their math classes.

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 (36% and 31% respectively).

We can observe an interesting behavior in figure 5. There are four items in which neutrals represent a large percentage, *item 4* (44%), *item 8* (36%), *item 9* (35%) and *item 5* (33%). We have discussed *item 4* and *items 8, 9* and *5* are*:*

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

Statement 9: It is important to learn mathematics to find a better job in engineering

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

It is clear that students are having problems answering these statements. We discussed the issues *item 4* could present. *Statement 5* in this list is related to the same issue as *statement 4*. However, *statements 8* and *9* are different. *Statement 8* is an item probably difficult to agree upon by students. As engineering students, they, in general, prefer more pragmatic content, which helps them build concepts and develop problem solving skills, and they probably do not see how formal and rigorous mathematics could help them to reach that goal. On the other hand, *statement 9* is questionable for every person that it is true, that is, difficult to agree upon.

4.2.2 Differences by course (mathematics)

The mathematics survey was divided into students who were taking a first semester course (FSC) and those who were taking a third semester course (TSC). There were some differences in the answers; however, some of them 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 6 presents the only item in which we found a significant effect of Group ($p < 0.05$), *statement 9: It is important to learn mathematics to find a better job in engineering.* The blue bars are items from the FSC and the red bars are from the TSC. The letters in the horizontal axis indicate the answers of the items from totally disagree (TD), disagree (D), neutral (N), agree (A) and totally agree (TA).

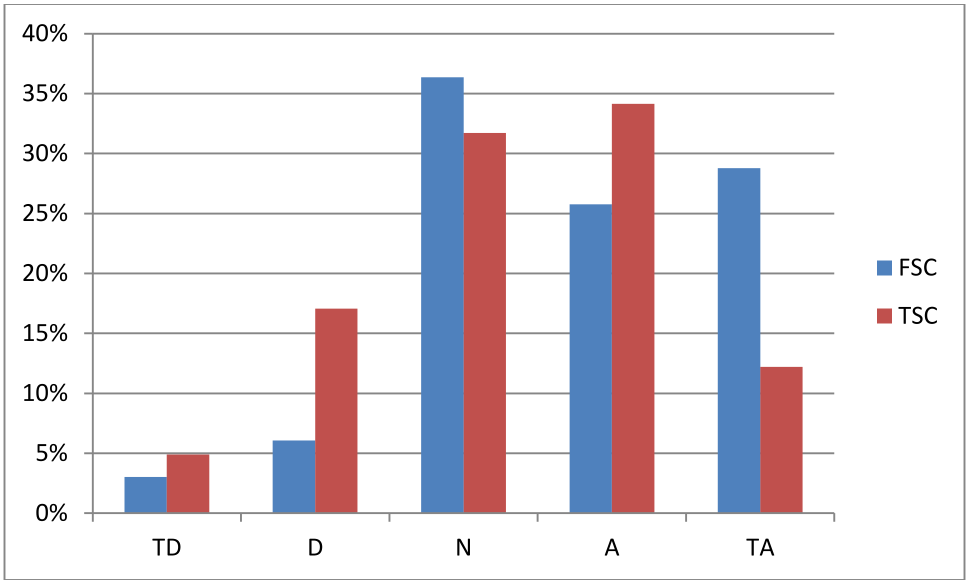

Figure 6. Item 9: It is important to learn mathematics to find a better job in engineering. FSC represents the students in the first semester course and TSC students from the third semester course. TD: totally disagree, D: disagree, N: neutral, A: agree and TA: totally agree.

Figure 6 shows that students in the first semester course agree more with the statement than that of students in the third semester course. This result is consistent to what we found in the physics survey, although in that case there were more items that were different between the courses. Does that mean that students have more ingrained the idea that mathematics is important?

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. However, we did not find any difference. We have evidence to say that female students responded to the mathematics survey in the same way as male students.

4.2.4 Relation to final grade (mathematics)

To obtain the relationship between the 11 items of the survey and the final grades of the student, we used the Spearman's Rho correlation coefficient since it is a non-parametric test used to measure the strength of association between two variables[10]. Figure 7 shows the Spearman coefficient between the items and the final grade. The figure only shows the ones that are weak to strong correlated with a significance of $p < 0.05$. Other results are omitted in the figure in order to highlight the important results.

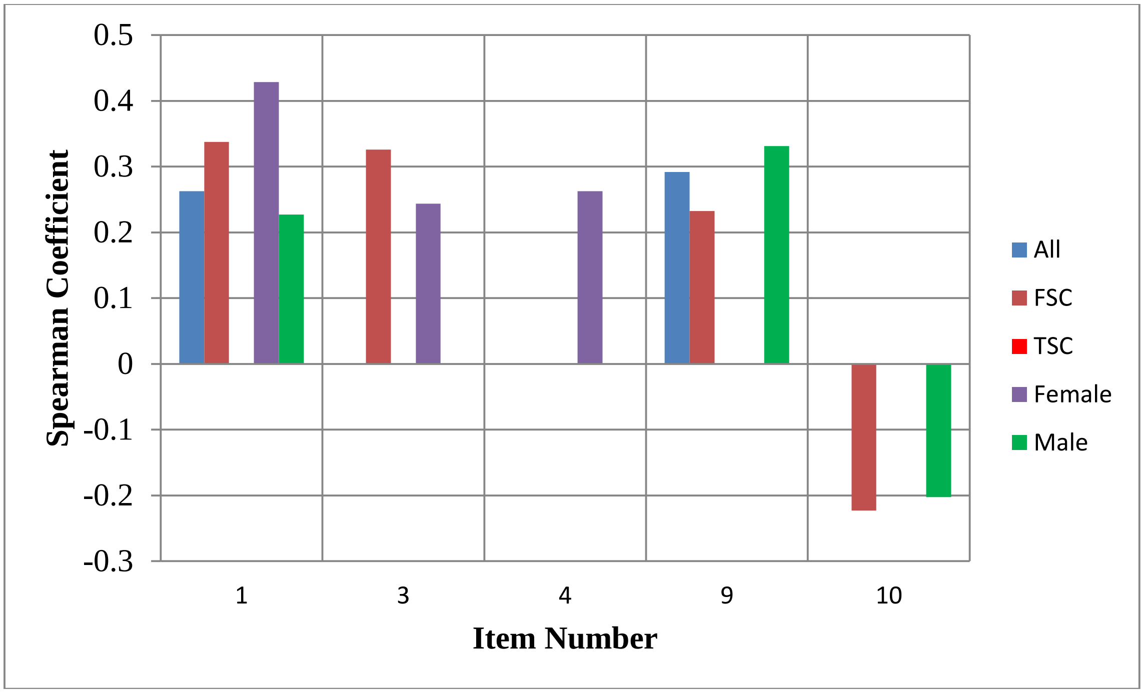

Figure 7. In five items (*1*, *3*, *4*, *9* and *10*) there were weak, moderated and strong correlations to the final grade. The colors of the bars indicate whether the data is from students in the first semester course (FSC), from students who are females or males.

All students who participated in this mathematics survey are included in the group *All*. Final grades of these students correlate with *item 1* and *item 9*,

> *Statement 1: I can see how the mathematics skills that I am currently developing will be useful in an engineering career,*
>
> *Statement 9: It is important to learn mathematics to find a better job in engineering.*

As with the physics survey, it is interesting to note that, in general, the better the grades of the students (a measure of capacity of the student), the more they agree with the importance of mathematics in engineering careers and see the importance of mathematics to find a better job. There are other items that are related to this aspect of the importance of mathematics, but the correlations were not significant.

As it happened in the physics survey, there is a great difference between the results of the correlation of final grades to the items when we compare the students in the first semester to those in the third semester. In the case of the latter, no item was correlated with the grades. With students in the first semester, *statements 1* and *9* correlate as with the group *All* but also *statements 3* and *10*, *item 3* positively and *item 10* negatively:

> *Statement 3: Mathematics classes are needed for other courses (physics, chemistry, etc.) in my studies,*
>
> *Statement 10: For me, in mathematics I only want to learn what I feel is likely to be assessed.*

The first statement is related to the importance of mathematics in the academics of an engineering degree. The second statement is a pragmatic view of learning mathematics where the motivation lied on passing the course rather than learning from it. As it happened in physics, the FSC students are well behaved and the TSC students are not. For the TSC students there were not any item that was correlated with the final grade.

Comparing the results for female students and male students we can see that in both of them the final grade correlates with *statement 1*. However, female students' final grades correlate with *statements 3* and *4* and male students' final grades correlate with *statements 9* and *10*. The correlation of the final grades of female students with *statement 1* is much greater than that of the final grades of male students, something surprising, since in the physics survey that was not the case. Another interesting result is that female students' grades correlate with *statement 4: I feel that mathematics I am currently taking teaches me how to formulate and solve problems that are directly related to engineering*, and was the only group of students who had that behavior. This statement is more related to the way mathematics is taught instead of the idea of mathematics by itself.

As we can observe, male students' final grades correlate almost in the same way as the group *All*. This is due to the fact that female students are a small number and the majority of the group *All* is male students. However, final grades of male students correlate with *statement 10* and final grades of *All* students do not. This is due to the small but important contribution of female students whose final grades do not correlate with that item.

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 8. The figure presents only the results that are significant differences between the math and physics surveys (*statements 3, 9* and *11*). The difference in results of the other statements is not significant so they are not included.

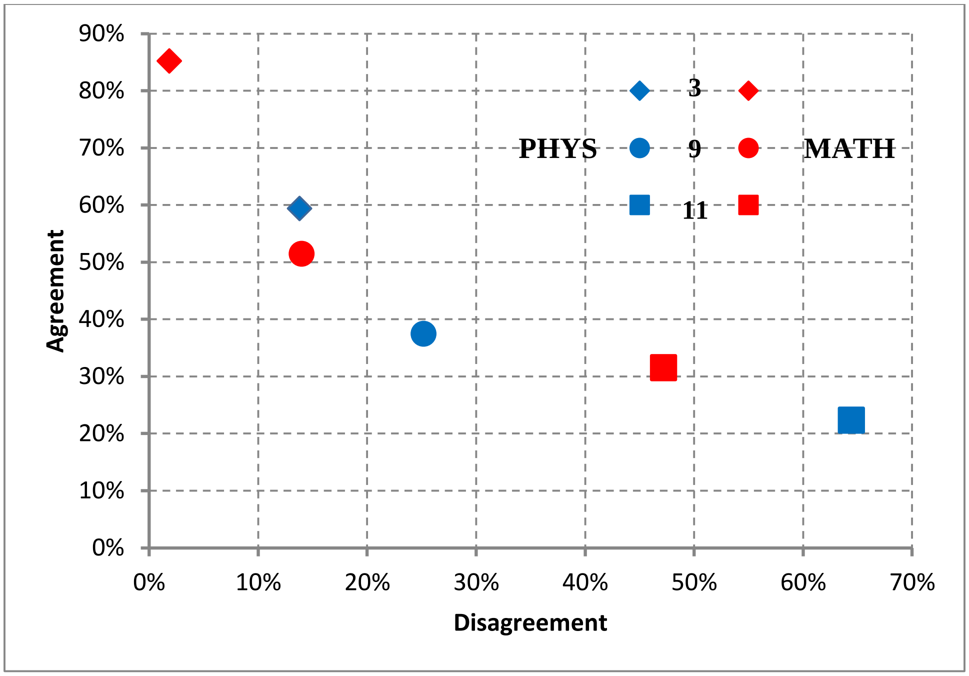

Figure 8. Difference in results from students answering physics and math surveys. There were only three statements where we found significant differences (*statements 3, 9* and *11*). The blue symbols belong to the results of the physics survey and the red symbols to the mathematics survey.

In general there were differences between the math and physics survey in favor of the former. However, three statements offered significant differences according to the Mann-Whitney's U test. *Statement 3: Mathematics (Physics) classes are needed for other courses (physics (mathematics), chemistry, etc.) in my studies* is the main representative of the statements which were related to the importance of mathematics (or physics) in the academic needs of the degree. Students answering math agreed 85% with the statement (2% disagreed) vs. those students answering physics, which agreed 59% with the statement (14% disagreed). The difference is important. It seems that, in general, the perception of the importance of mathematics for courses in their degree is greater than the perception of the importance of physics.

Statement 9: It is important to learn mathematics (physics) to find a better job in engineering is one of the terms related to the importance of mathematics (or physics) in terms of the professional life after graduating. Although the agreement of this statement decreases importantly with respect to *statement 3*, still the difference between the mathematics result (51% agree, 14% disagree) and the physics result (37% agree, 25% disagree) is large.

The last item which we found a significant difference was *statement 11: At some stage during my degree I have been so overwhelmed by mathematics (physics) classes that I have considered withdrawing from my engineering degree*. In this case the mathematics result (31% agree, 47% disagree) is not as good as the physics result (22% agree, 64% disagree). It seems that even though students regard mathematics higher in terms of the importance for their degree, they also have more difficulties with it. Of course, this result has to be modulated by the way math and physics are taught in the University where this study was conducted, but the result is interesting, and there is a need to continue our investigation to fully understand these results.

5. Conclusions

5.1 Summary

We adapted from the work by Flegg et al.[3] a survey of the perception of the importance of mathematics in engineering to be used for the study of the perception of mathematics as it was originally intended, but also to analyze the perception of the importance of physics in engineering. Since the survey was implemented randomly with students from two courses (first semester 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. Moreover, we obtained the final grades of the students who participated in the survey and we were able to see the relationship of students' perceptions and their achievement in the course.

5.2 Findings

From the study we can conclude that:

- Students in general do not have a good perception of the importance of mathematics and physics in engineering, neither as a professional career nor as a basis for other courses in their degree. The evidence is that comparing our results to those published by Flegg et al.[3], our students fell short in their perceptions.
- Students in their first semester have a better perception of physics and mathematics than students in their third semester. It seems that after taking courses, they might realize that physics and math are not as important as they initially thought.
- Male students have a slightly better perception of the importance of physics than female students. We did not find any difference in relation to math.
- The better the students are, the better their perception of the importance of physics and mathematics in engineering is. This tendency is greater in the first semester than that in the third semester. After one year of taking courses at the University, the correlation between grades and perception is almost lost.
- There is no evidence that in the case of female students the tendency of having a good perception of physics comes from the students with higher grades.
- There is evidence, however, that in the case of female students, the tendency of having a good perception of math comes from the students with higher grades.
- In general, the perception of the importance of mathematics in engineering is better than the perception of the importance of physics.
- Even though students have a better perception of the importance of mathematics than that of physics, they also have more trouble with mathematics courses, since they feel more stressed out by mathematics courses than they do with physics courses.

5.3 Recommendations

This study can be used by physics and mathematics instructors and by university administrative officers to make a plan to motivate engineering students to study math and physics. Since students show a decrease in their perception of the importance of these subjects in engineering when actually taking physics and math courses, we recommend to:

- modify instruction of these subjects to include more real-life problems in their classes, implicitly emphasizing the engineering part of the problem,
- modify instruction of physics and mathematics courses using active learning strategies in which students participate in their own learning,
- modify physics courses from a content-related to a model-related, that is, from a knowledge-based view of physics to a model-construction approach of physics,
- modify math courses from a traditional formal mathematics or from a drill and practice instruction to a more context-related, model-building and problem-solving approach,
- investigate what engineering professors need in their upper courses to focus students' learning of physics and mathematics courses in that direction,
- implement interdisciplinary projects that foster interaction among physics, math and engineering instructors/professors to modify teaching strategies, content, and course focus for both disciplines,
- implement a longitudinal formative assessment process to monitor students' perception throughout their years at the university, and
- conduct a study on how the students' perception changes over time due to the implemented measures.

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