# Self-efficacy, mathematics' anxiety and perceived importance: an empirical study with Portuguese engineering students

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The accomplishment in mathematics has gained attention from educators and arises as an emerging field of study, including in engineering education. However, in Portugal there is still incipient research in the area so it is high time to explore factors that might enlighten the gap in the study of the relationship between Portuguese engineering students and the learning of mathematics. The main purpose of this study is to explore three factors identified in the literature as influencing the learning of mathematical concepts - self-efficacy, anxiety towards mathematics and perceived importance of mathematics - and search for differences by gender and by type of engineering course, a dimension not much reported in the literature but which revealed important in team´s previous research. Based on a sample of 140 undergraduate students of different engineering courses from University of Minho, results only identify differences in the type of course and not in gender. These results constitute a contribution and open new paths for future research in the engineering education.

**Keywords**: learning factors; mathematical achievement, self-efficacy; anxiety; mathematical concepts, University of Minho, Portugal

## 1. Introduction

Mathematics is a discipline that appears on the syllabus of engineering courses and reveals itself to be essential to the training of all future engineers, whatever their field of study and work. Many aspects of engineering activity comprehend the correct problem formulation and analysis, and the choice of the adequate method to solve it. During the course, students learn and consolidate basic mathematical principles in order to solve practical problems (Mustoe, 2002; Fuller, 2002). As part of their formal undergraduate training, engineering students should enhance knowledge in several mathematical areas such as statistics, numerical methods, optimization and simulation, among many others. In this sense, we consider appropriate to make an objective and accurate study of the factors that might affect the learning of mathematics.

Portuguese studies on the learning of mathematics focus mainly on elementary education or high school levels and on demographic factors (Fonseca, Valente, and Conboy, 2011). The literature does not identify Portuguese studies at the higher education level that include psychographic factors. Even so, the concerns about school failure have played a leading role in education research in Portugal (see for instance Alarcão, 2000; Buescu, 2012; Domingos, 2003; Ponte, 2003; Tavares et al, 2000). In this context, it is important to identify what factors affect the learning of mathematics concepts in Portugal, particularly in the specific context of engineering education, an area with an important mathematical component and recognized impact on the application of mathematical developments.

A preliminary study conducted at University of Minho, Portugal, with the aim of studying the mathematics achievements in engineering showed that the students faced difficulties and motivational issues that go far beyond the required mathematical knowledge (Alves, Rodrigues, and Rocha, 2012a, 2012b). An interesting result is the fact that it was possible to identify significant differences in the curricular unit grades between female students and their male counterpart: the female students presented higher scores than their male colleagues. Acknowledging that this is not a biological and/or cultural issue, the team considered necessary to identify the psychographic factors than can help to explain gender differences.

Further focus group sessions, carried out with students from different courses (Alves, Rodrigues, Rocha and Coutinho, 2012), suggested different mathematical demands among engineering courses.

The main purpose of this study is to explore three factors identified in the literature as influencing the learning of mathematical concepts: self-efficacy, perceived importance of mathematics and the anxiety towards mathematics. Thereafter, an exploration of these psychographic factors is conducted by gender – a consensual demographic factor reported in literature – and, more specifically, by type of engineering course, a dimension rather understudied in the literature that revealed to be important in authors' previous research. Based on the literature, the team identified scales already developed and validated mainly in the context of the learning of mathematics concepts with engineering students. From this research three authors were highlighted: Flegg et al. (2012), Bai et al. (2009) and Korea et al. (2009). The work of Flegg et al. (2012) focused on scales to measure the perceived importance of mathematics and the one from Korea et al. (2009) on self-efficacy. On the other hand, the study of Bai et al. (2009) developed a measurement scale for the anxiety towards mathematics. The research questionnaire developed for this study used validated scales from these three authors and collected data from 140 students of engineering courses of the University of Minho. The outcomes expect to contribute to a deeper comprehension of the explanatory factors associated with the learning of mathematical concepts of the engineering students.

The remainder of the paper is as follows: Section 2 includes a literature review summarizing the factors that could influence the learning of mathematics. Section 3 presents the methodology and sample characterization. Section 4 focuses in the main results and their discussion and the paper concludes in Section 5.

## 2. Mathematics learning factors

The importance of performance and achievement in mathematics gained educators' attention and became an increasing field of study. The literature identifies several studies that suggest that the learning of mathematical concepts may be constrained by several factors that fall into two distinct groups: the demographic and psychographic factors. In the demographic factors, the gender is the factor that could better explain differences in academic performance. In the psychographic factors, the literature points out personality, socio-cognitive aspects and the anxiety towards mathematics as the more relevant to explain academic performance in mathematics. In the following paragraphs, we summarize the most important ideas related to the above factors.

Since the 1970s, gender has been investigated as a factor to identify differences for student’s performance and attitude towards mathematics. It is a general perception that boys are better at maths than girls (Patterson et al, 2003). The gender difference in aptitude for mathematics can be explained by various factors, namely the preconceived idea that is imbued in the students early on: boys have more aptitude for maths than girls (Meelissen and Luyten, 2008). However, the traditional stereotype favouring boys in mathematics might have changed over the past few years. There are studies on gender and mathematics achievement that show that the advantage held by boys over girls has diminished remarkably over the last 40 years. Plante, Théorêt, and Favreau, (2009) consider that gender differences in mathematics achievement are no longer a relevant issue while Brandell, and Staberg (2008) show that low participation of women at higher studies in mathematics and their performance in mathematics are more complex than the stereotype assigned to women. They also refer that in some countries, like Australia and the UK, girls outperform boys in many subjects, among them mathematics, which has led to intense debates in these countries. Many researchers are taking part in the debate referring that neither all boys are successful and nor all girls fail. Other factors such as class and ethnicity have influence. Research on gender and mathematics is often limited to the relationship between gender differences in attitudes toward mathematics and gender differences in mathematics achievement. Gender alone may not explain significant differences in performance when viewed in the context of multiple types of mathematical knowledge. There is therefore a need to explore other factors that can explain the differences between the genders (Patterson et al, 2003).

Students' motivation for learning mathematical concepts is a major concern of educators and educational researchers. Motivation is the driving force behind the actions and behaviour that leads students to achieve a goal. Hence, there must be an effort by educators to stimulate the students' attitudes and motivation towards learning. This will lead them to achieve the best results (Bakar et al., 2010).

Educators and psychologists have given special attention to the relationship between personality characteristics, learning and academic performance. As stated in several studies, the learning of mathematics is related to personality traits and these are considered as predictors of students' mathematical ability (Homayouni, 2011; Clearly, Breen and O'Shea, 2010; Tariq et al., 2013; Zimmerman, Bandura, and Martinez-Pons, 1992). The socio-cognitive aspects are considered the most important in the process of teaching and learning (Homayouni, 2011). Students' attitudes towards mathematics can generate positive or negative emotional responses in certain situations and are an indicator of success in this discipline. Studies have shown that teaching methods and teachers' personality influence students' positive or negative attitude towards mathematics (Sirmaci, 2010).

Mathematical beliefs and the results obtained by university students show several evidences of students' beliefs about mathematics being crucial in the development of careers related to this discipline (Suthar, Tarmizi, Midi and Adam., 2010; Gordon and Kim, 2012). In higher education, a factor that influences students' motivation for learning mathematics is the perception that students have about the role of mathematics in their courses and in their future career (Flegg, Mallet, and Lupton, 2012).

In the case of engineering students (the object of this study), literature reports that many engineering students struggle with the mathematics in their courses because they have "no idea" what role mathematics will play in their future careers (Goold, and Devitt, 2012). Winkelman (2009) in his study on perceptions of mathematics in engineering verifies that, although most students see mathematics as "(…) a gateway to engineering" (p. 1) for many students it is a difficult subject only get-a-able for talented students, becoming a sort of "(…) gatekeeper, denying entry to otherwise talented would-be engineers" (Winkelman, 2009, p. 19).

Self-efficacy is another factor that influences the students' mathematical performance and is closely link to motivation (Korea et al., 2009; Bandura et al., 2008). Bandura (1997) defined self-efficacy as "not a measure of the skills one has, but a belief about what one can do under different sets of conditions with whatever skills one possesses" (Bandura, 1997, p37). According to Bandura et al. (2008), individuals can influence the course of events according to their interests and are active participants in the direction that their lives take, since it sets targets to be reached through paths chosen by them. Stronger self-efficacy beliefs of the individual, lead to a major motivation for performing tasks (Walter, and Hart, 2009; Bandura, 2000; Bandura et al., 2008; Zimmerman, Bandura and Martinez-Pons, 1992).

Cleary, Breen and O'Shea (2010) refer that there are several studies showing that self-efficacy is related to engagement in learning and there is a correlation between self-efficacy and performance on task (Pajares, and Miller, 1994; Pajares, and Graham, 1999). Also, confidence in one's ability to learn mathematics and mathematical achievement has a strong positive correlation (Fennema, and Sherman, 1978).

Self-efficacy is strongly linked with attitude towards mathematics. Hodges and Kim (2013) define attitude towards mathematics as a construct that determines the way of reacting to mathematics in certain contexts. The authors argue that motivational factors like interest, task value, self-efficacy, constitute attitudes. Attitude towards mathematics can interfere with future self-esteem, identity formation and relationship with the utility of this discipline in the profession (Hodges, and Kim, 2013). The beliefs have an influence on the action, motivation and cognitive processes, the latter being related to the anticipation of consequences of actions and results. In the school context, these beliefs can affect students' motivation to perform tasks or avoid them, their reactions to their achievements, and even career choices (Bandura et al., 2008).

Anxiety appears referenced as a determining factor in students' academic performance in mathematics (Bai, Wang, Pan, and Frey, 2009; Miller, and Bichsel, 2003). Maths anxiety is defined by Richard and Suinn (1972) as a tension that interferes with the manipulation of numbers and solving everyday problems. In academic context, mathematics anxiety is also described as number anxiety and its negative effects on students' performance have been a subject of study of several investigations (Ashcraft and Moore, 2009; Kargar, Tarmizi, and Bayat, 2010; Núñez-Peña, Suárez-Pellicioni and Bono, 2012; Miller, and Bichsel, 2003). There are consequences to the fact that students are anxious about mathematics, and this interferes with their academic achievement. Students who suffer from math anxiety typically refuse to enrol in mathematical courses or attending courses with important mathematical component that will condition their future career options. The mathematical anxiety is the result of low self-esteem and fear of failure (Kargar, Tarmizi, and Bayat, 2010; Meelissen, and Luyten, 2008). Students with a high degree of anxiety had less satisfactory academic results and when this anxiety was reduced, there was an improvement in their performance. Research shows that math anxiety can be reduced through the adoption of special methods of teaching and psychological intervention in the areas applicable to improving the educational curriculum practices (Kargar, Tarmizi, and Bayat, 2010). Mathematics anxiety among engineering students is manifested in five dimensions, namely: i) Feel mathematics is a difficult subject; ii) Always fail in mathematics; iii) Always writing down in a mathematics class; iv) Anxious if one does not understand and, v) Lost of interest in the subjects of mathematics (Vitasari et al., 2010).

Mathematics anxiety has also been associated to gender. Studies on gender differences and mathematics anxiety have several results. Some authors defend that male students suffered less anxiety dealing with mathematics tasks than female students and they are also more confident and motivated at learning mathematics. This statement is supporting that women have a higher incidence of depression, post-traumatic stress disorder, and other anxiety disorders (Vitasari et al, 2010; Karimi, and Venkatesan, 2009). However there are studies that show there are no significant differences in mathematics anxiety among gender (Vahedi, Farrokh, and Brevani, 2011; Baloglu, and Kocak, 2006). This is a controversial topic and according to Jansen et al. (2009), gender differences in mathematics anxiety may differ between cultures and between age groups.

## 3. Methodology and Sample

The research uses a questionnaire with the goal of exploring demographic and psychographic factors that could influence the learning of mathematical concepts and the students' attitudes towards mathematics. The development of the questionnaire was motivated by previous results obtained from *focus groups* performed with students from different engineering courses that showed differences in the perceptions on the learning of mathematical concepts (Alves, Rodrigues, Rocha and Coutinho, 2012). This fact inspired us to consider in our analysis the differences between courses.

Since the sample was derived from different engineering courses that have different application areas, the mathematical demands of each engineering course became necessary to be investigated. Thus, two complementary procedures were implemented. First, the course syllabi of each engineering course was analysed in order to identify the curricular units that involve the learning of mathematical concepts. Then, the syllabus of each curricular unit was analysed and the level of mathematics knowledge was recognized. The first two academic years of engineering courses of University of Minho have highly demanding curricular units in mathematical components, which are essential for the engineer's training and learning of fundamental methods and concepts. These units address students with a set of mathematical theories and provide basic essential calculation tools for more specific courses for each engineering course. Following those preparation years, engineering courses diverge in their mathematics needs and field of application. Besides, from the authors' experience as teachers in this university, it was possible to identify different mathematical demands among the different engineering courses. Considering these facts as well as findings from the studies conducted by Alpers (2010), SEFI (2013), Kent and Noss (2003) and

Cardella (2008), the engineering courses were classified according to the incidence of mathematics components in three categories:

- Engineering in Natural Sciences (ENSC): engineering courses with a focus in natural sciences, for which the main components are chemistry and biology, so with low mathematical demands;
- Engineering and Management (EM): high specialized engineering courses with a management component, applying engineering principles to business practice, with a medium demand on mathematical concepts;
- Technological Engineering (TE): engineering courses that emphasize the application of mathematics, science and engineering, demanding high level of mathematical concepts.

In conclusion, the above classification assumes that the engineering courses in natural sciences have low mathematical requirements, whereas in engineering courses related to management can be considered an average mathematical requirement, and finally, the engineering courses distinguished as technological have high focus on mathematical knowledge.

### 3.1. Questionnaire

The final questionnaire had two parts. The first part collected respondents' characterization information, such as gender, age, course and year of course. The second part contained the questions related to respondents' perspective of the perceived importance of mathematics, anxiety towards mathematics and self-efficacy. The scales were adapted from prior research studies (see Table 1) and a 5-points Likert type scale, anchored by 1-"Strongly disagree" and 5-"Strongly agree" was used. To refine the scale adaptation process to Portuguese, a back translation and back translation review were implemented (the scales were translated into Portuguese and then translated back into the original English and the versions were compared with the original).

Table 1: Measurements

| Scale | Original Number of items | Author |
|---|---|---|
| Perceived importance of mathematics | 8 | Flegg et al. (2012) |
| Anxiety towards mathematics | 5 | Bai et al. (2009) |
| Self-efficacy | 12 | Korea et al. (2009) |

Previous to the questionnaire administration, a pre-test was driven with a pilot group of five engineering students who did not participate in the final study. The pre-test registered the students' opinions about the comprehension of the sentences and verified the suitability of each item to the interpretation of subjects with characteristics similar to the sample to be surveyed (Coutinho, 2011). After minor changes, the final questionnaire was made available for implementation.

The data were collected at the end of the second semester of 2012/13 academic year from students enrolled in an undergraduate level of engineering in the University of Minho, located in the northern region of Portugal. Students from Integrated Master Engineering Courses, namely from areas of Industrial and Management, Biological, Polymer, Materials, Mechanical and Textile were invited to participate in the study during classes of Numerical Methods or Applied Statistics.

### 3.2. Sample characterization

A total of 141 questionnaires were returned and 140 were considered usable for data analysis (one was eliminated due to incomplete filling). Among the respondents, 50.0% were male, 42.9% enrolled in a technological engineering course, 90.0% in the second year of course, and 72.9% aged 19 or 20 years. **Erro! A origem da referência não foi encontrada.** summarizes sample profile.

Table 2: Respondents' profile

| Respondents' Profile | Response Count | Response Frequency (%) |
|---|---|---|
| Gender | | |
| Male | 70 | 50.0 |
| Female | 70 | 50.0 |
| | | |
| Course | | |
| Engineering in Natural Sciences | 48 | 34.3 |
| Engineering and Management | 32 | 22.9 |
| Technological Engineering | 60 | 42.9 |
| | | |
| Year of course | | |
| First | 3 | 2.1 |
| Second | 126 | 90.0 |
| Third | 5 | 3.6 |
| Fourth | 3 | 2.1 |
| Fifth | 1 | 0.7 |
| Do not know/ Do not respond | 2 | 1.4 |
| | | |
| Age | | |
| 19 years old | 55 | 39.3 |
| 20 years old | 47 | 33.6 |
| Age greater than or equal to 21 years | 37 | 26.4 |
| Do not know/ Do not respond | 1 | 0.7 |

In order to understand the gender representativeness on the sample, the analysis explored the distribution by course. Results reveal that the unusual high percentage of female students is explained by the nature of the courses (see **Erro! A origem da referência não foi encontrada.**). Engineering in natural sciences presents a common high percentage of female students and technological engineering has a high percentage of male students. As Powell (2004) explained, the less emphasis on heavy engineering and machinery, and more focus on computers, mathematical models and electronics combined with adequate guidance counselling prior to entering university contribute to attract women to engineering degree courses.

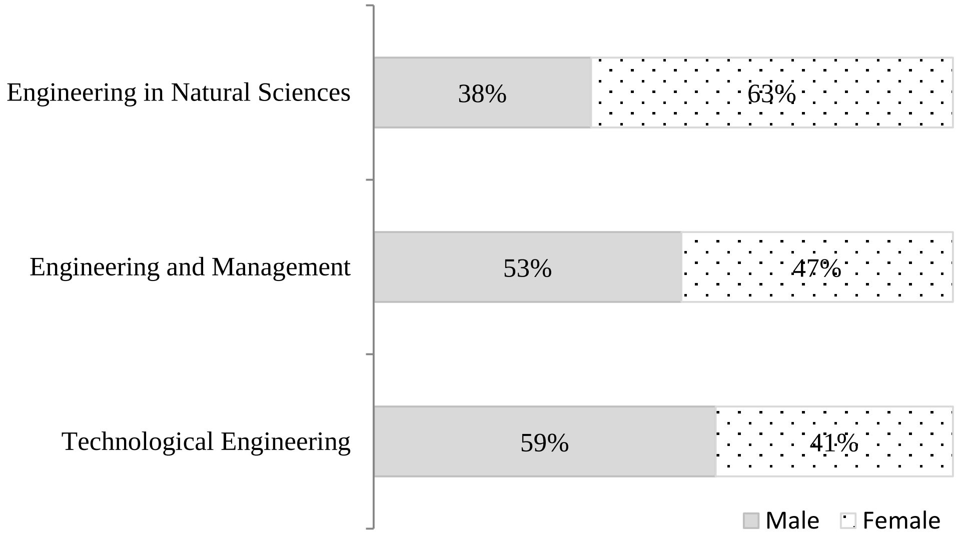


Figure 1: Gender by course

## 3.3. Scale reliability

In the data examination process, the analysis initiate with scales reliability and unidimensionality using Cronbach's alpha, item-to-total correlation and exploratory factor analysis (before analysis, items that sounded discordant with the majority of the statements of the scale were reversed coded). Reliability results are summarized in **Erro! A origem da referência não foi encontrada.**, **Erro! A origem da referência não foi encontrada.** and **Erro! A origem da referência não foi encontrada.**. Statements of each scale are presented in full length and were translated from Portuguese into English.

The scale of perceived importance of mathematics required the elimination of two items of the original eight items from Flegg, Mallet and Lupton (2012). The six selected items present a Cronbach's alpha of 0.770 with 49.97% of variance explained by a single factor (see **Erro! A origem da referência não foi encontrada.**).

Table 3: Scale Reliability: perceived importance of mathematics

| *Items of Perceived importance of mathematics* | Corrected Item-Total Correlation | Cronbach's alpha | Factor Loading | Variance explained (#1 factor) |
|---|---|---|---|---|
| 1. I can understand how mathematical skills that I am acquiring will be useful in developing my career as engineer | 0.547 | 0.770 | 0.725 | 49.97% |
| 2. The way of thinking that is being taught in this curricular unit remain after I graduate | 0.497 | | 0.692 | |
| 3. I feel that in this unit I learn how to formulate and solve problems directly related to engineering | 0.610 | | 0.789 | |
| 4. This unit puts me challenges that will be useful to achieve the engineer graduation | 0.717 | | 0.857 | |
| 5. The ability to communicate effectively by using mathematical arguments is an important skill to develop | 0.402 | | 0.529 | |
| 6. The formal and rigorous aspects of mathematics are important in my future career as engineer | 0.348 | | 0.487 | |
| 7. For me, I just want to learn what I think will come out on the test or exam (-) | - | | - | |
| 8. During course the math component is too much present which makes me consider quitting engineering course (-) | - | | - | |

The anxiety towards mathematics retained the five selected items from Bai et al. (2009) and presents a Cronbach's alpha of 0.803 with 56.33% of variance explained by a single factor (see **Erro! A origem da referência não foi encontrada.**).

The self-efficacy also retained all items selected from Korea et al. (2009), with a Cronbach's alpha of 0.803. Although the variance explained by a single factor is only 32.43%, we decided to keep all items due the value of Cronbach's alpha (see **Erro! A origem da referência não foi encontrada.**).

Table 4: Scale Reliability: anxiety towards mathematics

| *Items of Anxiety towards mathematics* | Corrected Item-Total Correlation | Cronbach's alpha | Factor Loading | Variance explained (#1 factor) |
|---|---|---|---|---|
| 1. My mind goes blank when I do the math exams | 0.626 | 0.803 | 0.784 | 56.33% |
| 2. My ability to solve mathematical problems worries me | 0.685 | | 0.825 | |
| 3. I feel anxious when I try to revolve mathematical problems | 0.585 | | 0.746 | |
| 4. I feel nervous when I have math courses | 0.661 | | 0.803 | |
| 5. I am confident in my ability to learn advanced mathematical concepts (+) | 0.395 | | 0.565 | |

Table 5: Scale Reliability: self-efficacy

| *Items of Self-efficacy* | Corrected Item-Total Correlation | Cronbach's alpha | Factor Loading | Variance explained (#1 factor) |
|---|---|---|---|---|
| 1. I see myself as an engineer in the future | 0.503 | 0.803 | 0.611 | 32.43% |
| 2. I can succeed in math courses | 0.459 | | 0.583 | |
| 3. I like to solve problems in innovative ways, even if it takes longer | 0.465 | | 0.594 | |
| 4. I can deal with problems when they arise unexpectedly | 0.528 | | 0.646 | |
| 5. I can help my teammates when they are struggling | 0.478 | | 0.607 | |
| 6. I can find different solutions to different problems | 0.475 | | 0.585 | |
| 7. I am able to acquire skills for most engineering courses | 0.322 | | 0.422 | |
| 8. I can have original ideas that others did not think | 0.415 | | 0.518 | |
| 9. I can understand and define the problems in the area of engineering | 0.463 | | 0.562 | |
| 10. I try to know the current trends in engineering (technology) | 0.334 | | 0.424 | |
| 11. I can succeed in engineering course where many students failed | 0.490 | | 0.607 | |
| 12. I can give my best in solving problems in engineering | 0.501 | | 0.622 | |

In the next section, we present and discuss the results obtained with the exploratory study of these three factors identified as determinants in the learning of mathematical concepts.

## 4. Results and discussion

### 4.1. Results

After reliability analysis, every measure was calculated as a mean indicator of the retained items (see **Erro! A origem da referência não foi encontrada.**). Results indicate that students acknowledge the importance of mathematics (values range from a minimum of 2.5 to a maximum of 5.00), and suggest an interesting self-efficacy (range from 2.25 minimum to 4.58 maximum). Anxiety towards mathematics reveals some variability, since students' responses vary from a minimum of 1 and a maximum of 4.60.

Table 6: Indicators and statistics

| Measures | Indicator | N | Min | Máx | Mean |
|---|---|---|---|---|---|
| Perceived importance of mathematics | mean of 6 items | 140 | 2.50 | 5.00 | 3.97 |
| Anxiety towards mathematics | mean of 5 items | 139 | 1.00 | 4.60 | 2.31 |
| Self-efficacy | mean of 12 items | 139 | 2.25 | 4.58 | 3.70 |

In order to explore the existence of significant differences, students' responses were analysed considering respondents' gender and type of course. More specifically, the analysis intends to test the following two hypothesis:

H1: There are significant differences between gender concerning perceived importance of mathematics, anxiety towards mathematics and self-efficacy.

H2: There are significant differences between type of course concerning perceived importance of mathematics, anxiety towards mathematics and self-efficacy.

#### 4.1.1. Perceived importance of mathematics

**Erro! A origem da referência não foi encontrada.** allows visualizing the perceived importance of mathematics by gender. It is possible to note that the distributions are similar for men and women, with the exception of some female respondents identified as outliers, *i.e.*, respondents who recorded lower values on the perceived importance of mathematics.

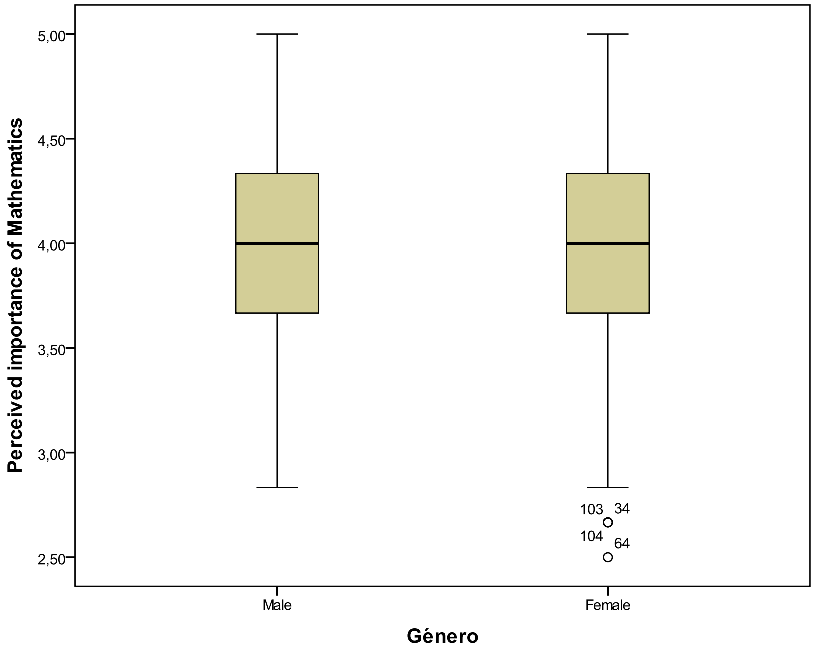


Figure 2: Students' level of perceived importance of mathematics by gender.

Thereafter a nonparametric Mann-Whitney test was used to test significant differences between genders in perceived importance of mathematics. The test confirmed that there was no significant difference in perceived importance of mathematics between male and female students (U=2456.5, p=0.978) (no validation of hypothesis 1).

The perceived importance of mathematics was also analysed by type of course. **Erro! A origem da referência não foi encontrada.** allows to visualize the existence of variations in the responses of students among the courses. ENSC students recognize the importance of mathematics when compared with EM and TE courses, since ENSC responses suggest a higher median value and small dispersion in the data.

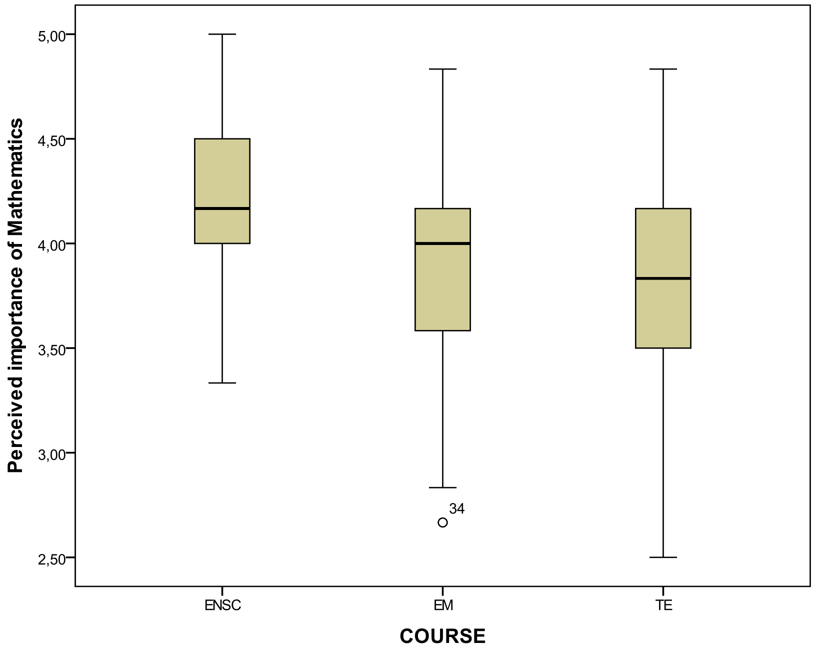


Figure 3: Students' level of perceived importance of mathematics by type of engineering course.

A Kruskal-Wallis test was conducted to evaluate differences among the three types of engineering courses on perceived importance of mathematics. The test was significant (chi-square=12.781, p=0.002) (validation of hypothesis 2). *Post hoc* pairwise comparisons using Mann-Whitney demonstrated a significant difference between ENSC and both EM and TE courses. There was no significant differences between EM and TE courses.

#### 4.1.2. Anxiety towards mathematics

The anxiety towards mathematics was also analyzed by gender and type of course. When analyzing male and female results, the chart presents differences with male respondents to have higher dispersion in anxiety (see **Erro! A origem da referência não foi encontrada.**).

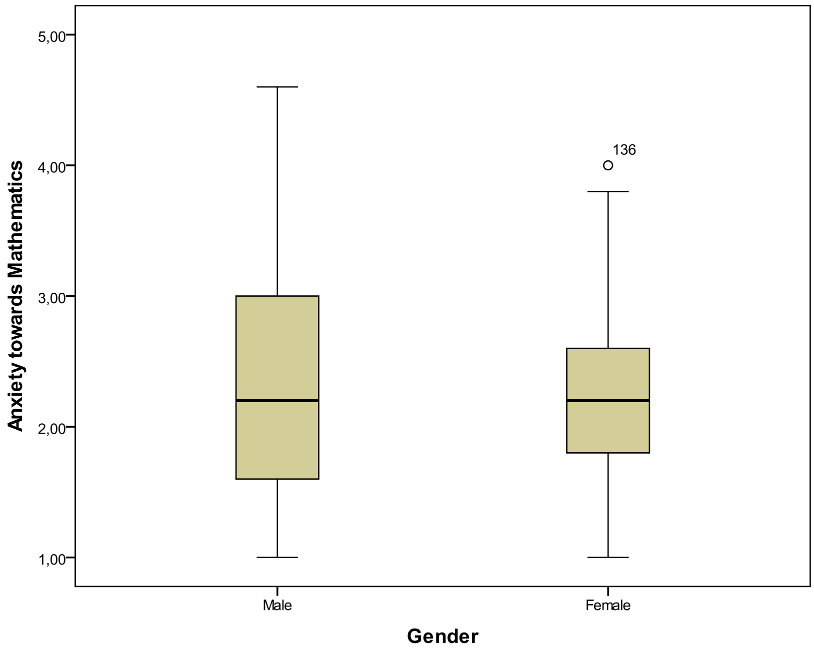


Figure 4: Students’ level of Anxiety towards mathematics by gender.

The Mann-Whitney tests showed no significant differences in anxiety towards mathematics between male and female students (U=2270.5, p=0.541) (no validation of hypothesis 1).

The analysis by type of course indicated the TE courses as having higher data dispersion. EM courses presented lower anxiety values (see **Erro! A origem da referência não foi encontrada.**). The Kruskal-Wallis was significant (chi-square=9.948, p=0.007) (validation of hypothesis 2). *Post hoc* pairwise comparisons using Mann-Whitney demonstrated a significant difference between TE and both ENSC and EM. There was no significant differences between ENSC and EM courses.

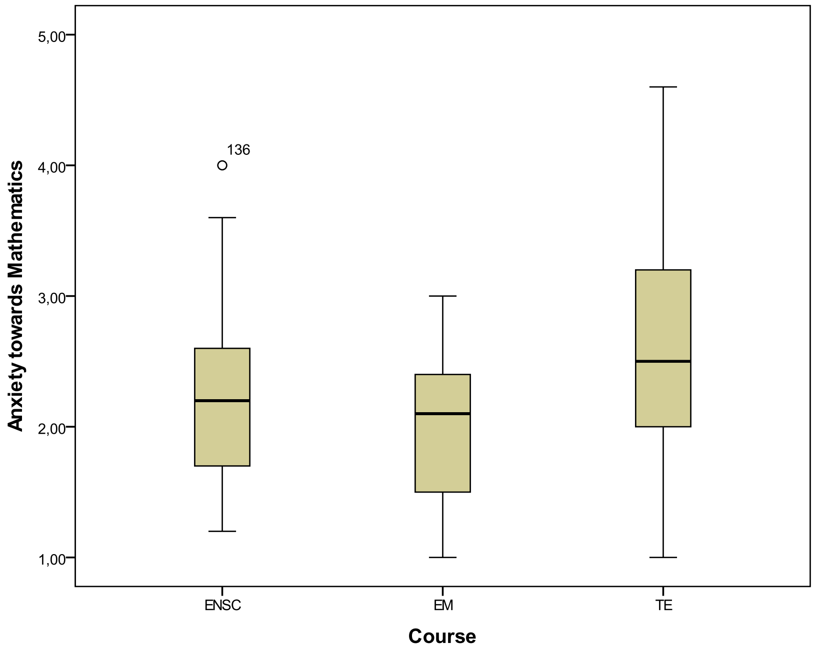


Figure 5: Students' level of Anxiety towards Mathematics by type of engineering course.

4.1.3. Self-Efficacy

When analysing the self-efficacy by gender, no visual differences are displayed (**Erro! A origem da referência não foi encontrada.**), with the exception of some male outliers. In general, the majority of students feel confident about their skills to solve problems and about their future careers as engineers. As expected, the Mann-Whitney tests disclosed no significant differences in self-efficacy between male and female students (U=2110.5, p=0.198) (no validation of hypothesis 1).

The analysis of self-efficacy by type of course revealed similar distributions of data. Nevertheless, when compared with other courses, EM students have a large dispersion, recording the lowest minimum value of self-efficacy and an outlier respondent (see Figure 7). The Kruskal-Wallis was not significant (chi-square=1.031, p=0.597) (no validation of hypothesis 2).

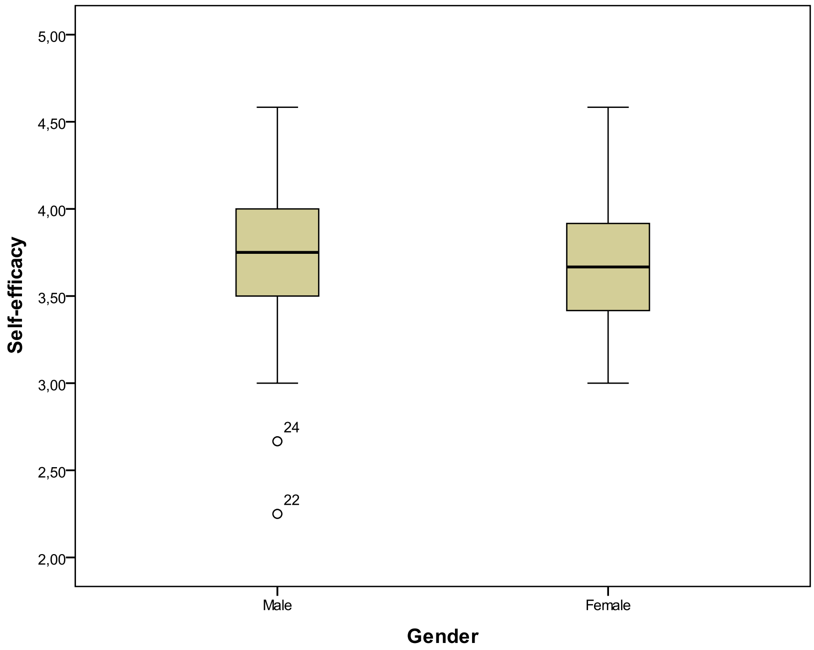


Figure 6: Students’ level Self-efficacy by gender

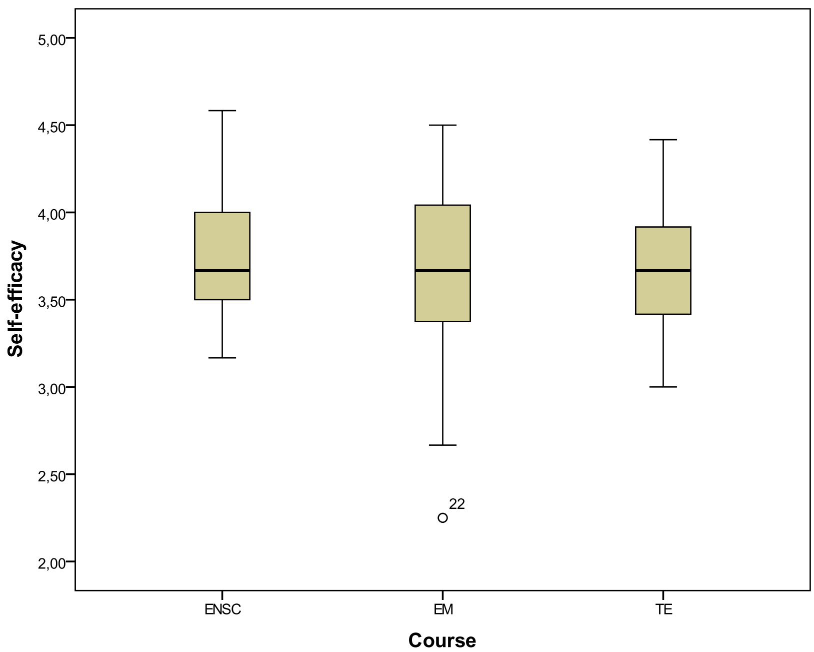


Figure 7: Students’ level Self-efficacy by type of engineering course

## 4.2. Discussion

This research was carried out in an effort to explore the importance of psychographic factors in the learning of mathematical concepts, namely the perceived importance of mathematics, mathematics' anxiety and self-efficacy. Our study aims to contribute to the state of the art of engineering education, presenting a case study developed with engineering students from University of Minho, Portugal.

Considering the validated scales in the literature we assessed the levels of the psychographic factors in a sample of 140 engineering students and explored the existence of differences according to two variables: gender and type of engineering course.

Gender has been a variable widely studied in engineering education and there is still no consensus regarding its influence on mathematics learning. However, our previous research showed significant differences between male and female students concerning grades/academic performance (Alves, Rodrigues, and Rocha, 2012a, 2012b). Assuming that gender is not a strong variable to explain the learning of mathematical concepts we decided, as suggested by the literature, to direct our research for more consistent explanations such as the exploration of the psychographic factors here discussed. For instance, Jansen et al. (2009), report that gender differences in mathematics anxiety may differ between cultures and between age groups.

Regarding the type of engineering course, we assumed, in our study, based on the analysis of the course syllabus and our previous experience as teachers, that there are three types of courses with different levels of mathematical requirements: Engineering in Natural Sciences (low), Engineering and Management (medium) and Technological Engineering (high).

The descriptive analysis of the indicators reveal that the engineering students recognize the importance of mathematics (mean value of 3.97); the engineering students rate of anxiety towards mathematics with a mean value of 2.31; and the analysis of the self-efficacy suggest positive levels in the belief of the engineering students individual performance (mean value of 3.70). It would be interesting, in addition, to study the impact of these measures in students' grades, which is not the scope of this paper. Regarding the perceived importance of mathematics, our results are similar to those obtained by Flegg, Mallet and Lupton (2012), Suthar, Tarmizi, Midi and Adam (2010) and Gordon and Nicholas (2012) who concluded that the majority of students tend to agree or strongly agree that mathematics is relevant to their study or future career.

**Erro! A origem da referência não foi encontrada.** summarizes hypothesis' test results, considering gender and type of engineering course:

H1: There are significant differences between genders concerning perceived importance of mathematics, anxiety towards mathematics and self-efficacy.

H2: There are significant differences between courses concerning perceived importance of mathematics, anxiety towards mathematics and self-efficacy.

Table 7: Hypothesis results

| Measures | Gender | Type of Course |
|---|---|---|
| Perceived importance of mathematics | H1 Not validated | **H2 Validated** |
| Anxiety towards mathematics | H1 Not validated | **H2 Validated** |
| Self-efficacy | H1 Not validated | H2 Not validated |

The data reveal some interesting results. The research concluded that male and female students show no significant differences in all three measures investigated meaning that gender does not influence the perceptions of perceived importance of mathematics, mathematics' anxiety and self-efficacy (H1 not validated). These findings are supported by others studies such as Vahedi, Farrokh and Brevani (2011) and Baloglu and Kocak (2006) but contradict some other studies in the literature on the topic (Vitasari et al, 2010; Karimi, and Venkatesan, 2009).

When searching for differences by the type of engineering course, the results identified significant differences in two of the measures: the perceived importance of mathematics and anxiety towards mathematics (H2 validated).

In fact, students from ENSC courses reveal higher levels in the perception of the relevance of mathematics than the others, suggesting that engineering students from different course syllabi perceive the importance of mathematics differently. This result comes to support and validate the insights obtained in the focus group, where the students stated that the math difficulties have to do with the abstraction level of the learning of mathematics and with the lack of connection with practical examples/application of the learned concepts (Alves, Rodrigues, Rocha and Coutinho, 2012). Perhaps the higher levels in the perception of the relevance of mathematics associated with the ENSC students can somehow have to do with their prior knowledge of the area of study (biology and chemistry) and a more clear perception of the utility/value/application of the mathematical concepts in their area of specialty. These findings are in line with Harris, Black, Hernandez-Martinez, Pepin, Williams, and the TransMaths Team (2015): to foster the perception of the utility of mathematics, engineering courses should include appropriate examples of use-value of mathematical concepts in the engineering context.

Concerning the anxiety towards mathematics, our findings suggest that TE students have higher levels of anxiety towards mathematics. These results may be due to the fact that the TE courses require a deeper understanding of mathematical concepts. When combining the higher level of anxiety with the lower level of perception towards mathematics regarding TE students, we may infer that there is a gap between the mathematics and its application in the engineering context. Since they are students from second year, findings suggest that the teaching of mathematics isolated from its use in engineering can be a danger as reported by Harris et al. (2015).

## 5. Conclusions and Recommendations

Studies on learning mathematical concepts in engineering courses are still scarce in Portugal. Most studies identified in the literature on the failure in mathematics are focused on elementary and high school education. In the higher education context it is identified a research gap of studies on this topic that includes psychographic variables.

The University of Minho, Braga, Portugal is a university with a major role in engineering education at the European level appearing on the ranking as one of the best universities of the World. The exploratory research presented in this paper is important because it aims to contribute to the worldwide discussion in the learning of mathematical concepts in engineering courses. Considering this objective, a study was carried out with 140 students of different engineering courses at the University of Minho. The purpose of this study was to explore three factors identified in the literature as influencing the learning of mathematical concepts in engineering courses: perceived importance of mathematics, the anxiety towards mathematics and self-efficacy. It was also a purpose to test the existence of significant differences by gender and by type of engineering course, this latter based on the weight of mathematics in its curricula.

Results show the emergence of some important and triggering findings, although we were unable to make the bridge between the psychographic variables and academic performance. However, we believe our findings contribute to the comprehension of the explanatory factors associated with the learning of mathematical concepts of the engineering students, supporting the research that connects the utility and value of mathematics as a relevant issue to be taken into account.

In this study, we concluded that gender shows no differences in perceived importance of mathematics, the anxiety towards mathematics and self-efficacy, but differences emerge when considering the type of course. This variable was assumed as new framework to study the learning of mathematical concepts in engineering courses and presents differences among the students from different type of course in perceived importance of mathematics and the anxiety towards mathematics. We argue that these differences could be explained and are related to the need of the students to understand the utility of mathematics in their engineering course. These are very important results for the engineering teachers, since it highlights the risk of isolating mathematics from its use in engineering courses. We recommend the inclusion of application examples as a priority goal to increase the perceived value of mathematics in engineering.

Although not generalizable, these findings provide interesting clues for further studies to be carried out. As typical in this type of research, a number of questions remain unanswered. For instance, it would be interesting to determine the sources of students' mathematics anxiety and how they are related with the type of engineering course attended by students. Therefore, studies on mathematics anxiety will be more comprehensive.

An interesting study from Vitasari et al (2010) showed that there is a cause/effect relationship between mathematics anxiety and mathematics performance. This would be a good topic to be explored.

In the future research it would be also interesting to compare the grades of students and analyse the link between mathematical performance and the psychographic factors already studied as well as other such as personality or motivation.

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