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ENGINEERING STUDENTS AND THE APPLICATION OF MATHEMATICAL KNOWLEDGE: HOW TO EXPLAIN THE DIFFICULTIES EXPERIENCED?

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Abstract

The article presents the results of two focus groups and a questionnaire implemented with engineering students from the University of Minho, in order to assess opinions and perspectives concerning the main learning difficulties in mathematics-based disciplines. The results obtained show that students generally see the relevance of mathematics to engineering courses. Mathematics is considered as an essential discipline in course selection and a vital part of their career as engineers. The importance of the instructor is recognized when learning mathematical concepts. Students would like their courses to address mathematical concepts that are more in line with their future professions. The 73 undergraduate students who completed the questionnaire manifested a high self-efficacy and a high perception that the learning of mathematical concepts and the development of mathematical skills are essential for progression in their future career.

Keywords: *Learning factors, Mathematical concepts, Engineering students, University of Minho, Portugal.*

1. Introduction

Engineering plays a significant role in the modern world since it is always present in day to day activities concerning construction, computers, technology, energy, electronic devices, and manufacturing process. Regardless of the area of study, the mathematical concepts are essential in the training of engineers, both for understanding the different concepts as well as the specific knowledge of their applicability. Nevertheless, and despite Mathematics constitute an essential discipline on admission to engineering courses, engineering students reveal difficulties in Mathematics based disciplines. Students' grades reveal difficulties and motivational issues that go far beyond the required mathematical knowledge. The study involved collecting data from two complementary data sources: two focus groups and a questionnaire.

The purpose of this study is to measure and analyze tree factors identified in the literature as influencing the learning of mathematical concepts: engineering self-efficacy; perceived importance of mathematics and the anxiety towards mathematics. The remainder of this paper is as follows: in Section 2 a literature review is presented, summarizing some of the factors that could influence the learning of mathematics. Section 3 presents the methodology and afterwards we present the results of a focus group and a questionnaire. Section 5, summarizes the most relevant conclusions.

2. Mathematics learning factors

The literature review identified several studies that suggest that learning of mathematical concepts may be constrained by several factors ranked as

psychographic or demographic factors. The most reported psychographic factors include concepts such as the personality of student attitudes, socio-cognitive aspects, motivation and anxiety about mathematics. The demographic factors focus more specifically on gender differences (see for instances Bakar et al., 2010; Homayouni, 2011; Kargar et al., 2010; Sirmaci, 2010). Most Portuguese studies on the learning of mathematics focuses only on demographic factors or on the level of elementary education or high school. The literature does not identify Portuguese studies that include psychographic factors. Even so, the concerns about school failure have played a leading role in research in education in Portugal (Buesco, 2012). The PISA 2006 showed that the performance of Portuguese students in science, although improving, is still lower than most OECD countries. In 2000, Portuguese students occupied one of the last places, but in 2009 it was the first time they achieved scores that fall in the average performances of the OECD (Conboy, 2011). In this context, it is opportune to explore the learning of mathematical concepts in Portugal, particularly in the specific context of university education and of engineering education, an area with strong math component and recognized impact on the application of mathematical developments.

3. Objectives and methodology

This study was conducted in three stages. In a first stage, two focus groups were carried out with undergraduate students of Master in Industrial Engineering and Management (MIEGI) and Master in Mechanical Engineering (MIEMAC) of University of Minho. The first focus group was involved students from 3rd, 4th and 5th years of the MIEGI course with a total of 10 students, 5 female and 5 male, aged between 21 and 24 years old who participated in the study. Due to the specificity of the MIEGI course, (with a strong management component), it was of the utmost interest to reproduce the focus group and broadening the investigation to engineering courses with a stronger technical foundations and stronger needs concerning the application of mathematical concepts. We therefore conducted a second focus group with undergraduate students in the 2nd year of MIEMAC with a total of 28 students, 24 male and 4 female, aged between 19 and 32 years old participated in the study. The objective of the focus groups was to know the opinions of the students about mathematics in general and ascertain the factors that they identified as influencing their performance in UC's with mathematics background. The focus groups, with 30 minutes each, were carried out in two stages: a discussion oriented by six questions script; 2) a comment to three sentences presented to the students.

In a second phase, we examined the literature related to the factors that influence the learning of mathematical concepts and engineering education.

In order to complement our studies, we developed a questionnaire using existing scales that included items related to engineering self-efficacy (Korea et al, 2009), items evaluating students perceptions of the relevance of mathematics in engineering (Flegg, Mallet & Lupton, 2011) and anxiety towards mathematics (Bai, Wang, Pan, & Frey,2009).

The final questionnaire consists of 8 initial questions with the purpose to characterize the sample followed by 3 sections, in the format of a five point Likert scale, with 25 items whose purpose is to measure and analyze the perspectives of engineering students about learning mathematical concepts, as well as difficulties perceived related to the importance of mathematics in their future career. The first section, with 8 items aims to assess the perceived importance of mathematics; the second section with 5 itens aims to assess anxiety towards mathematics and finally in third section, with 12 items, we intended to assess self-efficacy.

In order to validate the questionnaire a pretest was driven with a pilot group. The aim was to verify the suitability of each item to the interpretation of subjects with characteristics similar to the sample to be surveyed (Coutinho, 2011).

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4. Results

4.1. Focus group

From the students' answers we were able to group their opinions in 5 categories: perceived importance of mathematics; the influence of parents/society/piers; study method/gender influence, teaching methodology/teacher. In table 1 we present the main results.

Table 1. Results from focus group

Category	Main Results
Perceived importance of mathematics	- The mathematic was essential in their choice of courses; - Mathematics is considered as an essential discipline in course selection and a vital part of their career as engineers
Influences of parents/society/piers	- Society is partly responsible for the negative views about mathematics - The parents' opinion is an important factor that influences the student's view of mathematics.
Study method/gender	- Female students are more methodical and devoted to their studies than their male counterparts, therefore there are able to obetian better results.
Teaching methodology/teacher.	- The lectures, in their exhibition molds, require greater care at a motivation level and at making the students better perceive their importance. - Students would like their courses to address mathematical concepts that are more in line with their future professions - The importance of the instructor is recognized when learning mathematical concepts.

4.2. Questionnaire

A total of 25 items of the instrument was analyzed. The items were presented on the format of a five-point Likert scale (1 - strongly agree, 2 - agree, 3 - not agree nor disagree, 4 - disagree or 5 - strongly disagree). The items which sound negative in their meaning were coded reversely in SPSS. All items were positively coded before proceeding with the analysis. All factors demonstrated good internal reliability, as shown in Table 2.

Table 2. Reliability

Scale	Nº items	Cronbach's Alpha
Perceived importance of mathematics	7 (one item was removed)	.741
Anxiety towards mathematics	5	.794
Self-efficacy	11 (one item was removed)	.813

The characterization of the sample is presented in Table 3. From a total of 72 respondents 42.5% were female and 57.5% of them were male. The majority were MIEGI students (43.8%) followed by MIEMAT students (24.7%), MIEBIOL students (21.9%) and MIEPOL students (9.6%).

Table 3. Profile of Respondents

Respondents' Profile		Number of respondents	Percentage of respondents
Gender	Male	42	57.5
	Female	31	42.5
Course	MIEBIOL	16	21.9
	MIEGI	32	43.8
	MIEPOL	7	9.6
	MIEMAT	18	24.7

Students' level of perceived importance of Mathematics, anxiety towards Mathematics and self-efficacy.

Table 4 indicates descriptive measures of students' level of perceived importance of Mathematics, anxiety towards Mathematics and self-efficacy. The mean of all respondents' perceived importance of Mathematics is 3.90, the mean of their anxiety towards Mathematics is 2.15 and the mean of students' self-efficacy is 3.69.

Table 4. Students' level of perceived importance of Mathematics, anxiety towards Mathematics and self-efficacy

	N	Minimum	Maximum	Mean	Std. Deviation
Perceived importance of Mathematics	72	2.57	5	3.90	0.51
Anxiety towards Mathematics	71	1	3.80	2.15	0.75
Self-efficacy	71	2.18	4.55	3.69	0.45
Valid N	72				

Gender differences on students' level of perceived importance of Mathematics, anxiety towards Mathematics and self-efficacy.

Table 5 shows that the mean of perceived importance of Mathematics of female is 3.80 and the mean of perceived importance of Mathematics of male is 3.97. There isn't significant difference between male and female groups on their perceived importance of Mathematics ($t = 0.159$, $p>0.05$). This table also shows the mean of anxiety towards Mathematics of male is 2.19 and the mean of anxiety towards Mathematics of female is 2.09. There isn't also significant difference between male and female groups on anxiety towards Mathematics ($t = 0.60$, $p>0.05$). The mean of self-efficacy of male is 3.68 and the mean of self-efficacy of female is 3.70 which indicates there isn't significant difference between male and female groups on self-efficacy ($t = 0.88$, $p>0.05$).

Table 5. Students' level of perceived importance of Mathematics, anxiety towards Mathematics and self-efficacy by gender.

		N	Minimum	Maximum	Mean
Perceived importance of Mathematics	Male	41	2.71	5	3.97
	Female	31	2.57	4.71	3.80
Anxiety towards Mathematics	Male	41	1	3.80	2.19
	Female	30	1	3.80	2.09
Self-efficacy	Male	41	2.18	4.55	3.68
	Female	30	3	4.55	3.70

Table 6. T-test analyzes based on gender

		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Perceived importance of Mathematics	Equal Variances Assumed	0.983	0.325	1.422	70	0.159	0.12098
Anxiety towards Mathematics	Equal Variances Assumed	0.030	0.863	0.532	69	0.596	0.09691
Self-efficacy	Equal Variances Assumed	0.002	0.965	-0.168	69	0.867	0.01818

Students' level of perceived importance of Mathematics, anxiety towards Mathematics and self-efficacy by course.

Results presented in Table 7 indicate that the mean of perceived importance of Mathematics, anxiety towards Mathematics and self-efficacy of the four courses are similar. Hence further analyses indicated that there is no significant difference between groups on perceived importance of Mathematics ($sig=0.274$, $p>0.05$). There isn't also significant difference between courses on anxiety towards Mathematics mean ($sig=0.52$, $p>0.05$)) and self-efficacy mean ($sig=0.940$, $p>0.05$) (Table 8)

Table 7. Students' profile based on course.

		N	Minimum	Maximum	Mean
Perceived importance of Mathematics	MIEBIOL	16	3.14	5	4.11
	MIEGI	32	2.57	4.71	3.83
	MIEPOL	7	3.29	4.43	3.76
	MIEMAT	17	2.57	4.71	3.87
Anxiety towards Mathematics	MIEBIOL	15	1.20	3.60	2.12
	MIEGI	32	1	3	1.99
	MIEPOL	7	1.20	3.60	2.86
	MIEMAT	17	1	3.80	2.18
Self-efficacy	MIEBIOL	15	3.18	4.55	3.75
	MIEGI	32	2.18	4.55	3.67
	MIEPOL	7	3	4.45	3.73
	MIEMAT	17	3.18	4.27	3.66

Table 8. Analyzes based on course (Anova)

		Sum of Squares	df	Mean Square	F	Sig.
Perceived importance of Mathematics	Between Groups	1.027	3	0.342	1.325	0.274
	Within Groups	17.581	68	0.259		
	Total	18.609	71			
Anxiety towards Mathematics	Between Groups	4.307	3	1.436	2.709	0.52
	Within Groups	35.510	67	0.530		
	Total	39.817	70			
Self-efficacy	Between Groups	0.083	3	0.028	0.133	0.940
	Within Groups	13.975	67	0.209		
	Total	14.058	70			

5. Conclusions

Results show that students have a high self-efficacy and a high perception that the learning of mathematical concepts and the development of mathematical skills is essential for progression in their future career. It is evident from this study that students generally see the relevance of mathematics to engineering courses. Mathematics is considered as an essential discipline in course selection and a vital part of their career as engineers. The importance of the instructor is recognized when learning mathematical concepts. Students would like their courses to address mathematical concepts that are more in line with their future professions. We consider these results as preliminary results, which require future evidence with a bigger sample and a comparison with other engineering students.

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