Journal on Teaching Engineering, 3:1 (2024) 50-60
ISSN 2795-4005
DOI: 10.24840/2183-6493_003-001_1872

Received: 24 October, 2022
Revised: 30 November, 2022
Published: 2 December, 2024

Forget the past: Students' academic performances at FEUP's Integrated Master in Mechanical Engineering

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Author Keywords

Consumer Decisions, Undergraduate Students, Mechanical Engineering.

Type: Research Article

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Abstract

Knowing how academic performances of students evolve along their stay at University, and how those are conditioned by background, personal and institutional factors is fundamental to delineate policies towards excellence. This paper investigates possible correlations between six variables that characterize the academic performances over a period of five years of students admitted in 2016-2017 at the Integrated Master in Mechanical Engineering (MIEM) at the Faculty of Engineering of the University of Porto (FEUP). The analysis is performed considering all students at once and students organized in eight groups, giving their gender (Male/Female), type of secondary school they came from (Public/Private), living residence prior to university (Away/Porto), and rank of MIEM on the University application forms (Option 1/Option 2-6). From the correlation analysis, a pattern emerges revealing that "the memory of the university application marks is progressively lost as time passes". In other words, students with higher (lower) application marks tend to perform better (worse) in their first year. But, as time passes, the students' performances evolve (getting better or worse) and, at the end of their fifth year at FEUP (no matter if they concluded MIEM or not), the students' performances are practically unrelated to their application marks. The pattern reveals the strength of FEUP/MIEM to take heterogeneous groups and give equal opportunities to all, no matter their past, thus fulfilling democratization and inclusiveness goals.

1. Introduction

There are many research works emphasizing that the academic performances of university students are consequences of complex interactions among individuals' background, personal and institutional dynamics (Le et al. 2020; T. Stinebrickner and Stinebrickner 2000; R. Stinebrickner and Stinebrickner 2003; Nelson et al. 2012; Teresa Duarte, Lopes, and da Silva 2021; Dotong, Hicaro, and Laguador 2019). Several studies claim that students' university application marks are memories of previous performances that influence future achievements (T. Stinebrickner and Stinebrickner 2000). Others focus on the association between gender and performances at university, sustaining that female outperform male students (Silva, Camanho, and Barbosa 2020; Geiser and Santelices 2007). From a psychological viewpoint, the transition from secondary school to university often encompasses deep changes in acquired routines, and requires adjustments to new living styles. This includes students' adapting to new residential and social environments (Le et al. 2020; Fisher and Hood 1987). For those who have to leave home, stress arises when sharing accommodation, budgeting and setting own restrictions (Le et al. 2020; Teresa Duarte, Lopes, and da Silva 2021). The challenges for university newcomers also emerges from possible unaccomplished expectations about classes' methods and necessary workload to succeed (Le et al. 2020; Lowe and Cook 2003; Smith and Hopkins 2005; Crisp et al. 2009; Hassel and Ridout 2018). Besides, stress and frustration affects some who enter cycles of studies (CS) that are not their first option, which has negative impact on the university academic performances (Teresa Duarte, Lopes, and da Silva 2021).

From 2006-2007 up to 2021-2022 the undergraduate program in Mechanical Engineering at the Faculty of Engineering of the University of Porto (FEUP) was offered via the Integrated Master in Mechanical Engineering (MIEM), which was a 5-year CS merging a bachelor (3 years) and a masters (2 years) degrees. MIEM successively revealed strong attraction for young students seeking engineering CS (Teresa Duarte, Lopes, and da Silva 2021). In spite of the MIEM responsibles' efforts to delineate policies towards excellence, a key step is to understand how the academic performances of students evolve along their stay at MIEM, and how those are influenced by background, personal and institutional factors.

The present work investigates possible correlations between six variables that characterize students' academic performances over a period of five years at MIEM, no matter the students concluded their CS or not. The sample includes 150 students admitted in 2016-2017. The variables analyzed are: *Application Mark*, *1st Year Mark*, *Weighted 1st Year Mark*, *5th Year Mark*, *Weighted 5th Year Mark*, and *Conclusion Mark*. The study considers the whole sample, as well as students divided into eight groups, according to their gender (Male/Female), type of secondary school they came from (Public/Private), living place before university (Away/Porto), and rank of MIEM on the University application forms (Option 1/Option 2-6). From the correlation analysis, a pattern emerges revealing that "the memory of the university *Application Marks* is progressively lost as time passes". In other words, students with higher (lower) *Application Marks* tend to perform better (worse) in their first year. But, as time passes, the students' performances evolve (either getting better or worse) and, at the end of their fifth year at FEUP (no matter they concluded MIEM or not), the students' performances are almost unrelated with their *Application Mark*s. The pattern reveals the strength of FEUP/MIEM to take heterogeneous groups and give all opportunities to succeed, fulfilling democratization and inclusiveness goals.

The paper is organized as follows. Section 1 presents the Mechanical Engineering degree at FEUP. Section 2 characterizes the students' performances over the five years' period 2016-

2017 to 2020-2021. Section 3 addresses the correlations between representative variables and analyses the results. Finally, Section 4 summarizes the main conclusions.

2. Mechanical Engineering

A Mechanical Engineer deals with the design of almost everything, from medical devices to power plants, car engines and airplanes. Mechanical Engineers use fundamental sciences, as mathematics, physics, and materials, among others, and concepts such as energy/motion conversion, to obtain systems for helping people in daily problems. Designs and maintenance of equipment, energy production and distribution, accounting, planning and management, control and automation, and new materials and processes, are key areas. Mechanical Engineers play a crucial role to economy growth, security increase, and individuals and societies' development. Mechanical Engineers' career opportunities are diverse, ranging from local companies to multinationals, and passing through consultancy, services, and self-employment.

2.1. *Mechanical Engineering at FEUP*

In 1885 the academic degrees in Engineering of Public Works, Mines and Industry were established at the Polytechnic Academy of Porto. These were the predecessors of Mechanical Engineering in the University of Porto. In 1915 Mechanical Engineering emerged as an autonomous degree, and in 1926 FEUP was established. In 1974 the Department of Mechanical Engineering (DEMec) was created in FEUP, and became responsible for the five years of the Mechanical Engineering degree. In 2006-2007 the Bologna process changed the higher education system in Europe (Wächter 2004; Heitmann 2005; Fernandes et al. 2007). This led to the Mechanical Engineering degree at FEUP to become a CS joining a bachelor (3 years) and a masters (2 years) into a single 5-year CS, titled MIEM. In 2019 the Portuguese Government decided to separate the integrated masters' into two different CS, to facilitate the mobility of students across European higher education institutions (HEI). The structure based on 3 + 2 years was recovered by the new CS, but incorporating measures to mitigate some known MIEM's weaknesses (da Silva, Seabra, and Lopes 2021; Lopes, da Silva, and Seabra 2021). The new bachelor is a non-professional CS of preparation for the masters (https://paginas.fe.up.pt/~estudar/mem/, November 2022). The new masters is a CS distinct from others offered in Portugal. The objective is to achieve innovative content, aligned with the needs of industry and incorporating the scientific research existing at DEMec.

2.2. *Mechanical Engineering Entry Marks*

The admission of students to the Portuguese public higher education system obeys to *numerus clausus* that are established annually for each HEI/CS. Students apply to the desired HEI/CS. Their *Application Mark* is the weighted average of their secondary school grades, $H \in [0, 200]$, and their national exams grade, N:

$$Application\ Mark = c \cdot H + (1 - c) \cdot N \quad (1)$$

where the value $c \in [0, 1]$, and the minimum *Application Mark* and N are established by the HEI/CS. For MIEM, in 2016-2017, these parameters were set to $c = 0.5$, minimum *Application Mark* = 130 and $N = 130$. There is a national competition, and the applicants may select up to 6 HEI/CS combinations in decreasing order of preference. Students are ordered, for each HEI/CS pair, by their *Application Mark*, and accepted until the *numerus clausus* is complete.

For the Mechanical Engineering Integrated Masters, all Portuguese HEI require the students to do the national exams "Mathematics A" and "Physics and Chemistry", and calculate *N* as:

$$N = \frac{M + PQ}{2} \quad (2)$$

where the symbols *M*, *PQ* $\in$ [0, 200] stand for "Mathematics A" and "Physics and Chemistry" scores. In the past years, MIEM has attracted many students when compared to other Portugal similar CS (TMGP Duarte, Lopes, and Silva 2021).

3. Students Performances

Six variables are selected to characterize students' academic performances over a period of five years at MIEM (2016-2017 to 2020-2021), meaning the minimum required to conclude the CS:

- *Application Mark* $\in$ *[100, 200] – measures students' performances prior to university, thus reflecting student's backgrounds;*
- *1st Year Mark* $\in$ *[100, 200] – students' marks as calculated by FEUP's Academic Department*;
- *Weighted 1st Year Mark* $\in$ *[0, 200] – this is computed by the formula Weighted 1st Year Mark = 1st Year Mark* x R_1, and takes into account a penalty for failed courses. The symbol R_N denotes the ratio between the number of ECTS the student has passed and the sum of ESTS of all courses until year *N*;
- *5th Year Mark* $\in$ *[100, 200] – students' marks as calculated by FEUP's Academic Department*;
- *Weighted 5th Year Mark* $\in$ *[0, 200] – this is computed by the formula Weighted 5th Year Mark = 5th Year Mark* x R_5. It takes into account a penalty for failed courses, and is used to measure the performances, after a period of five years, of all those that not concluded MIEM in five years;
- *Conclusion Mark* $\in$ *[100, 200]* – this corresponds to the graduation mark of all those that concluded MIEM in five years.

The study considers all students enrolled in MIEM in the academic year 2016-2017. The complete sample is analyzed as a whole, as well as with students divided into eight groups, according to their gender (Male/Female), type of secondary school they came from (Public/Private), living place before university (Away/Porto), and rank of MIEM on the university application forms (Option 1/Option 2-6). These groups are adopted, since they embed individual and social features having impact in academic achievements (TMGP Duarte, Lopes, and Silva 2021). Indeed, empirical studies showed that gender has impact on academic performances. Another issue is related with the teaching/learning methods adopted in public/private secondary schools, which are often too focused on obtaining high marks on the national exams necessary to apply to university. Such practices tend to be different from those that students encounter later at university, requiring time for adapting, and having potential negative effects. Students' geographic origin is also relevant, since many need to move and adapt to a new life in a different city, away from home, which often has consequences at the academic level. Finally, some students are compelled to accept CS that are not their first

options (since their *Application Marks* are not high enough), which may be a cause of hindrance with negative impact on their academic behavior.

3.1. ***Characterization of the MIEM Students at Entrance***

In the academic year 2016-2017 a total of 150 students enrolled in MIEM at FEUP. This number considers just those entering via the ordinary national contest. **Figure 1** depicts the *numerus clausus*, the numbers of students accepted, and the numbers of applicants for the 6 Portuguese HEI that offer integrated masters in Mechanical Engineering (left): Universities of Aveiro, Coimbra, Lisboa, Minho, Nova of Lisboa, and Porto. Universities of Aveiro and Coimbra have more students accepted than applicants, since students entering via second round and non-ordinary national contest applications are being considered. The distribution of *Application Marks* of all MIEM's students admitted in 2016-2017 at FEUP is also shown (right). Indeed, in the last years the students' *Application Marks* for MIEM at FEUP was the highest among all national HEI. **Figure 2** shows FEUP students' distribution according to gender (Male/Female), type of high school they came from (Public/private), living place prior to university (Away/Porto), and MIEM rank on the university application form (Option 1/Option 2-6) (left), and the corresponding distributions of *Application Marks*, with their means and standard deviations. Students enrolled in MIEM at FEUP are mostly male (Borges et al. 2022), come from public secondary schools and live in the region of Porto prior to university. Most choose MIEM in first option, but there is a no negligible portion that prefer other CS.

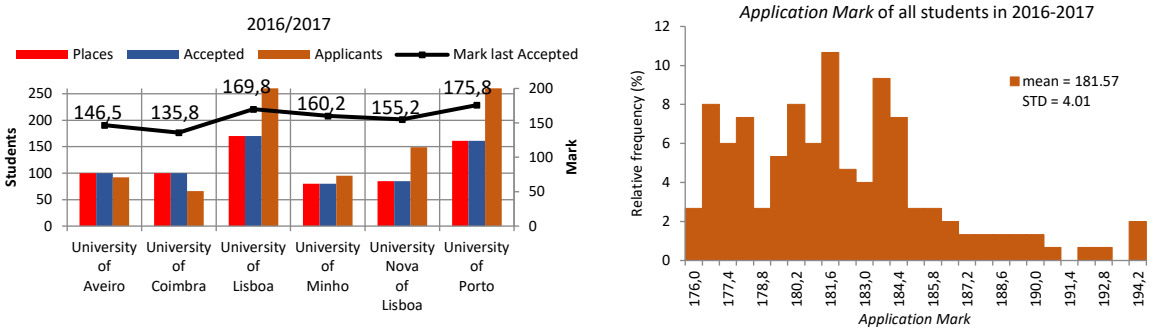

Figure 1. Left: the *numerus clausus*, students accepted, and applicants for the 6 Portuguese HEI that offer integrated masters in Mechanical Engineering; Right: the distribution of *Application Marks* for all MIEM students admitted in 2016-2017.

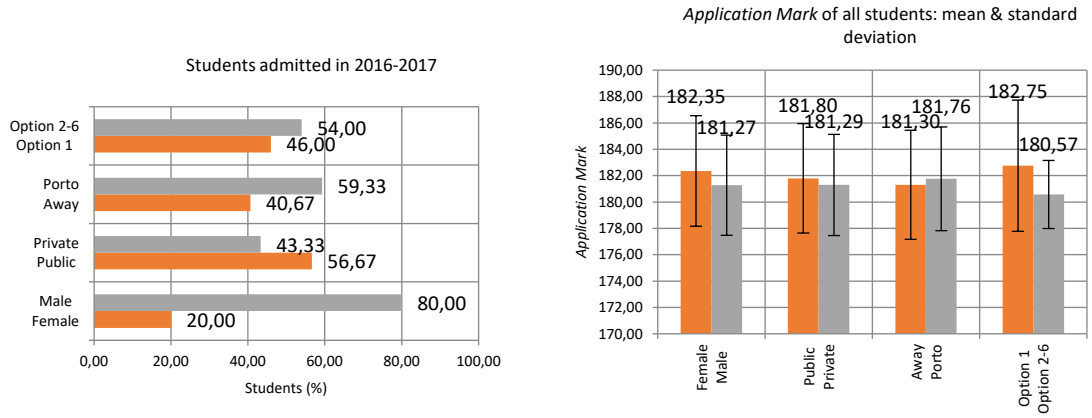

Figure 2. Left: students' distribution according to gender, type of high school they came from, living place prior to university, and MIEM rank on the university application form; Right: the corresponding distribution of *Application Marks*, with their means and standard deviations.

3.2. *Academic Performance at the End of First Year*

It is considered the students' academic performance at the end of first year, as measured by the variable *1st Year Mark*, calculated by FEUP's Academic Department, and the *Weighted 1st Year Mark* = *1st Year Mark* x R_1, which takes into account a penalty for failed courses. **Figure 3** and **Figure 4** present results regarding the *1st Year Marks* and *Weighted 1st Year Marks*, respectively. Per groups of students, the patterns are similar to those observed in the *Application Marks*, with the exception of the *Weighted 1st Year Marks* of the group Away/Porto that changed slightly. However, in value, the *1st Year Marks* decreased about 50 points out of 200. The histograms changed considerably, when compared with that of the *Application Marks*, meaning that the one of the *1st Year Marks* is now more similar to a Gaussian distribution, while the one of the *1st Year Weighted Mark* shifted to the right, reflecting the courses' failure rate.

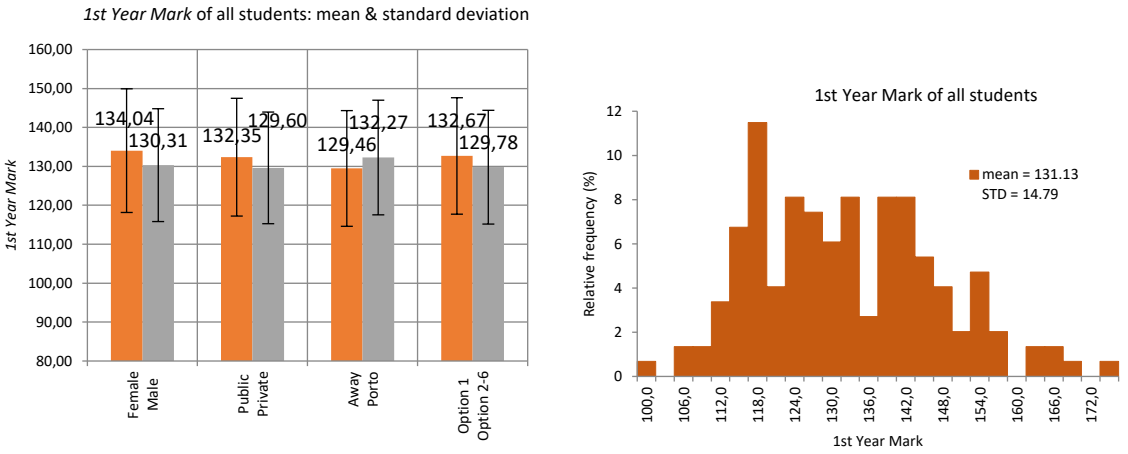

Figure 3. Left: the *1st Year Marks* per group of students, with the corresponding means and standard deviations; Right: the distribution of *1st Year Mark*s for all MIEM students admitted in 2016-2017.

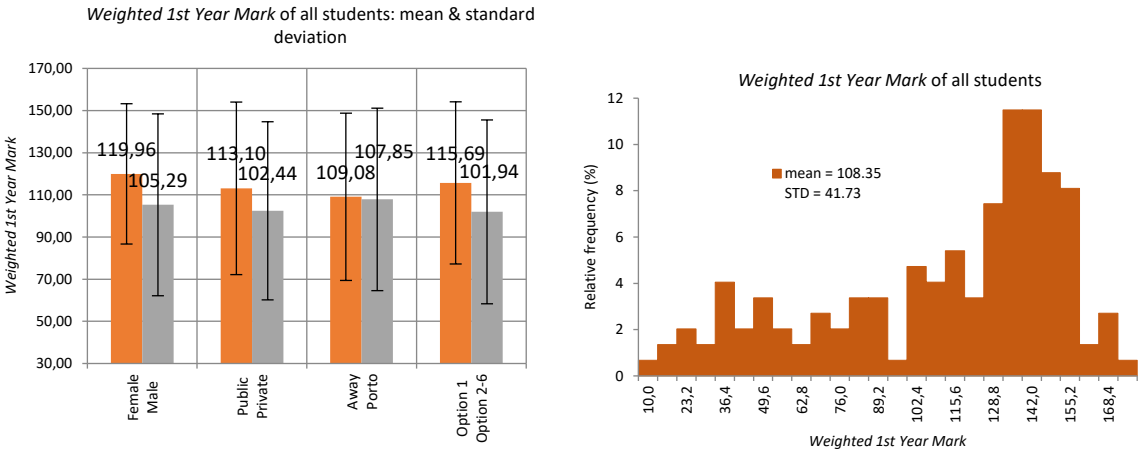

Figure 4. Left: the *Weighted 1st Year Marks* per group of students, with the corresponding means and standard deviations; Right: the distribution of *Weighted 1st Year Mark*s for all MIEM students admitted in 2016-2017.

3.3. *Academic Performance at the End of Fifth Year (students not concluding in 5 years)*

From the of 150 students joining MIEM in 2016-2017, a total of 77 concluded the CS in five years, while 73 still had courses to do by the end of that period.

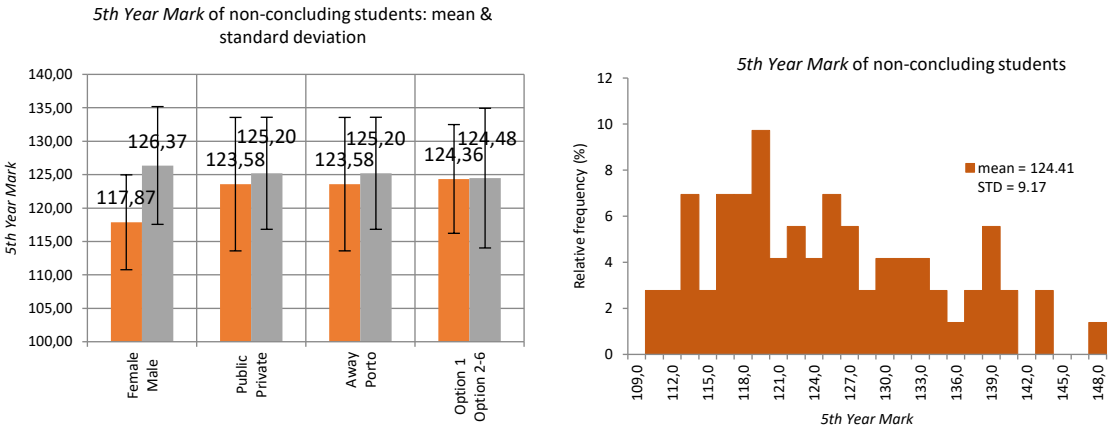

Figure 5. Left: the *5th Year Marks* per group of students, with the corresponding means and standard deviations; Right: the distribution of 5*th Year Mark*s for all MIEM students admitted in 2016-2017.

Following a procedure similar to the one in the previous subsection, herein, the students' academic performances at the end of fifth year are characterized by means of the variables *5th Year Mark*, calculated by FEUP's Academic Department, and *Weighted 5th Year Mark* = *5th Year Mark* x R_5. As before, this takes into account a penalty for every failed course, and is useful to measure the students' performances after a period of five years for all those that not concluded MIEM in five years. **Figure 5** and **Figure 6** depict the *5th Year Marks* and *Weighted 5th Year Marks*' results of the 73 out of 150 students not concluding the CS in five years. The per group patterns of both variables are similar. However, when compared with the results observed at the end of 1st year, it can be seen that those patterns evolved, namely the ones corresponding to the groups Female/Male and Public/Private. The Away/Porto reveals some awkward behavior. The histogram of the *Weighted 5th Year Marks* presents an interesting bi-modal distribution. However, other possible patterns embedded in the data are unclear, demanding a deeper analysis.

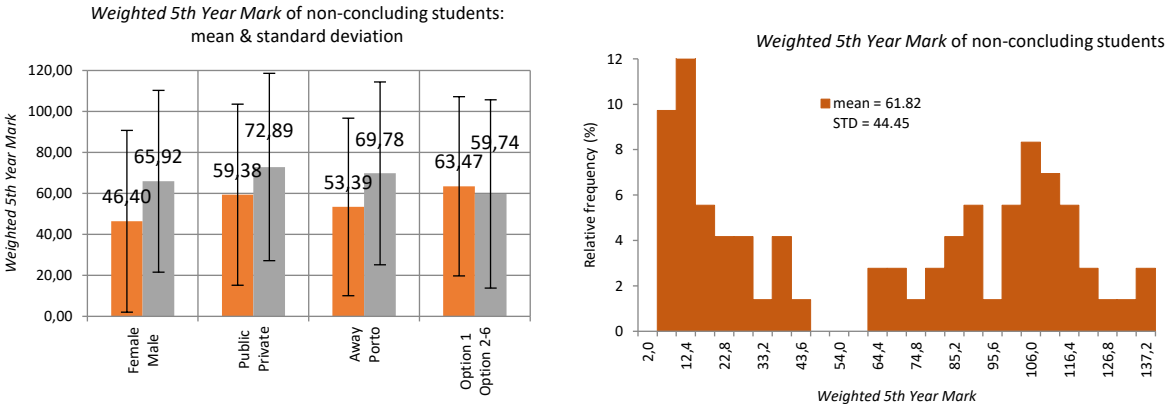

Figure 6. Left: the *Weighted 5th Year Marks* per group of students, with the corresponding means and standard deviations; Right: the distribution of *Weighted 5th Year Mark*s for all MIEM students admitted in 2016-2017.

3.4. ***Academic Performances at Conclusion (after 5 years)***

As mentioned, a total of 77 out of 150 students concluded MIEM in 5 years. As shown in **Figure 7**, better performances was verified for those who are female, come from public schools, live away from Porto prior to university, and choose MIEM in first option. **Figure 8** represents the

*Conclusion Mark*s of the 77 students, per group, and the distribution of the *Conclusion Mark*s of the 77 as a whole.

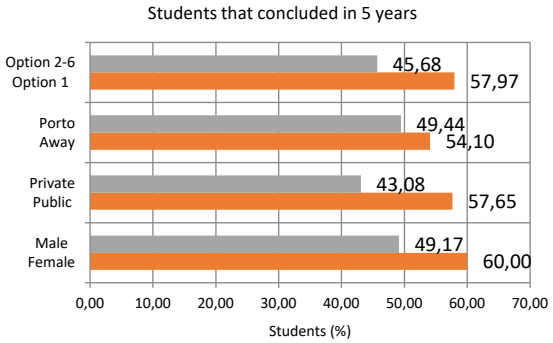

Figure 7. Students that concluded MIEM in five years: distributions according to gender, type of high school they came from, living place prior to university, and MIEM rank on the university application form.

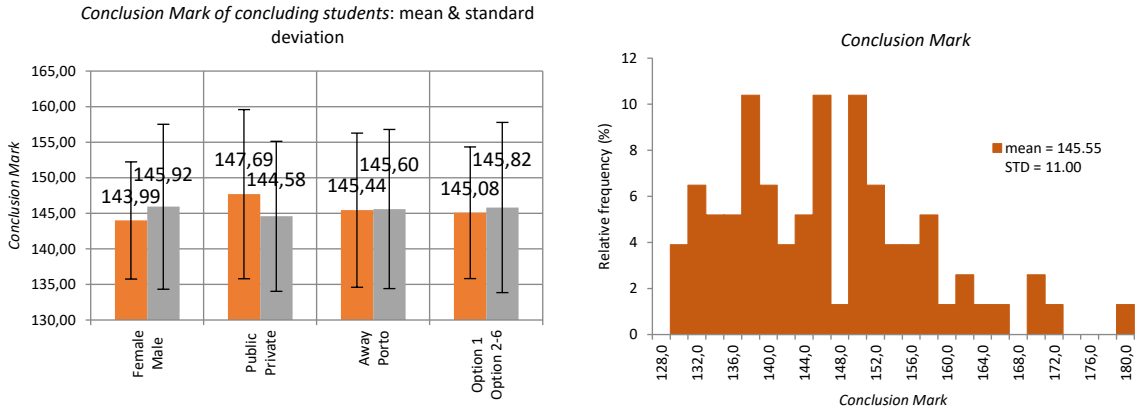

Figure 8. Left: the *Conclusion Mark*s per group of students, with the corresponding means and standard deviations; Right: the distribution of *Conclusion Mark*s for all MIEM students that concluded in five years.

4. Correlation Analysis

Seeking for possible correlations in the data, Pearson correlation is performed between all combinations of the six variables: *Application Mark*, *1st Year Mark*, *Weighted 1st Year Mark*, *5th Year Mark*, *Weighted 5th Year Mark*, and *Conclusion Mark*. **Figure 9** depicts the results when considering all 150 students enrolled in 2016-2017. Higher correlation values of interest are marked in bold and bigger font size. A pattern is unveiled, in which three pairs of variables have significant correlation, namely {*Application Mark* vs. *Weighted 1st Year Mark*}, {*Application Mark* vs. *Weighted 5th Year Mark*}, and {*Application Mark* vs. *Conclusion Mark*}. For the other pairs the correlations are negligible. Moreover, the Pearson correlation values are found to follow a specific trend, decreasing from the 1st pair to the 2nd and, further, to the 3rd. Additionally, this is visible not only when considering the whole sample of students simultaneously, but also when the students are organized in groups (male, female, public, private, away, Porto, option 1, option 2-6), as illustrated in **Figure 10**.

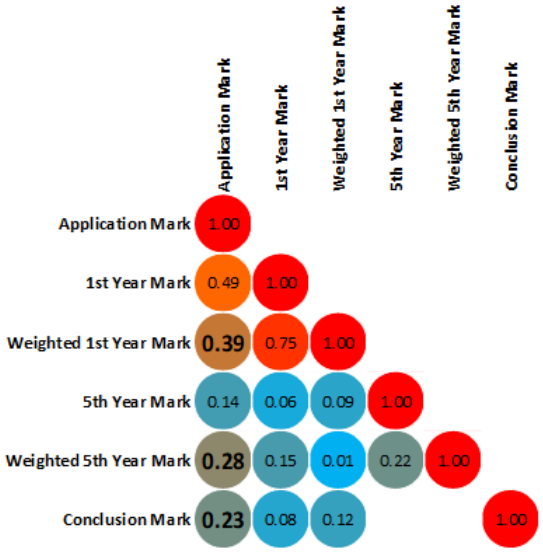

Figure 9: Correlations for the whole sample of 150 students admitted in 2016-2017.

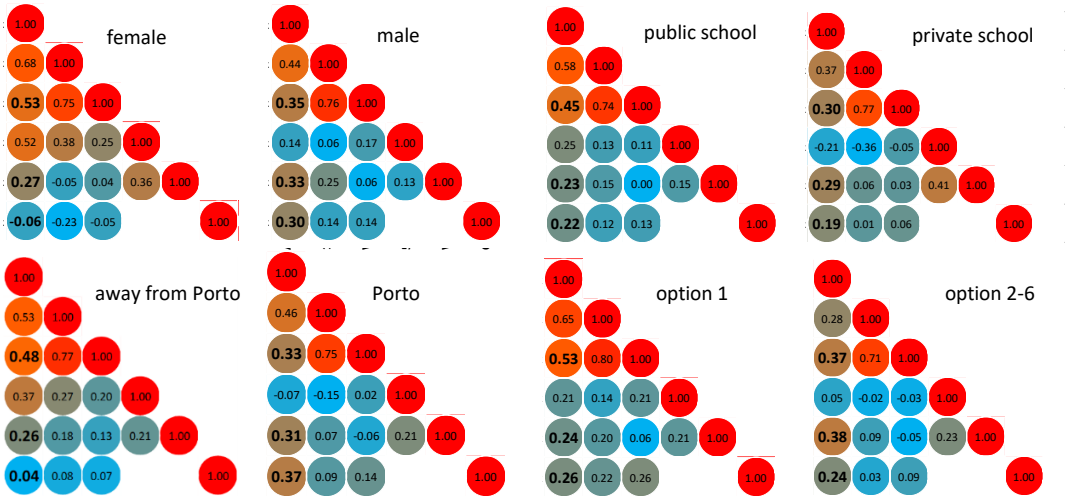

Figure 10: Correlations for the 150 students admitted in 2016-2017, divided per group.

5. Conclusions

This paper sought possible correlations between the students' academic performances over the period of five years needed to conclude their CS. A total of 150 students admitted in 2016/2017 in MIEM was considered, and the analysis was performed taking all students at once and students organized in eight groups, according to their gender, type of secondary school they came from, living place before university, and rank of MIEM on the University application forms. Six variables were selected to characterize student's academic profiles, namely the *Application Mark*, *1st Year Mark*, *Weighted 1st Year Mark*, *5th Year Mark*, *Weighted 5th Year Mark*, and *Conclusion Mark*. The Pearson correlation index was adopted to measure correlations between all pairs of variables. The results showed that:

- Three pairs of variables are correlated: {*Application Mark* vs. *Weighted 1st Year Mark*}, {*Application Mark* vs. *Weighted 5th Year Mark*}, and {*Application Mark* vs. *Conclusion Mark*}, while for the other pairs the correlations are negligible;
- The values of those correlations decrease, meaning that for the 1st pair the correlation is higher, then decreases for the 2nd pair and, finally, decreases further for 3rd pair.

This is visible when considering the whole sample of students simultaneously, as well as when the students are considered organized in groups (male, female, public, private, away, Porto, option 1, option 2-6);

- The pattern means that "the memory of the *Application Marks* is progressively lost as time passes". In other words, students with higher (lower) *Application Marks* tend to perform better (worse) in their first year. But, as time passes, the students' performances evolve (getting better or worse) and, at the end of the 5th year at FEUP (no matter if they concluded MIEM or not), the students' performances are practically unrelated with their *Application Marks*.

To sum up, the findings reveal the strength of FEUP/MIEM to take heterogeneous groups and give equal opportunities to all no matter their past, fulfilling democratization and inclusiveness goals.

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