Women in Surveying Engineering Courses – a Greek experience

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Key words: women, surveying engineering, undergradute studies, postgraduate studies

SUMMARY

In the EU, from the 18 million scientists and engineers, about 59% are men and 41% women. In northern European countries less than one third of scientists and engineers are women. In Greece, this situation is more pronounced. Although Greek women are over-represented in undergraduate engineering studies, their proportions quickly decrease as one moves up the academic scale. To date, the average percentage of qualified women engineers comprise less than 25% of the Greek total qualified engineers, which is lower than the European average. Overall, about 20% of undergraduate engineering degrees are awarded to women, but only 13% of the engineering workforce is female. This paper explores the "leaking pipeline" in a specific engineering discipline, that of surveying engineering from bachelor to postgraduate research programmes in two Greek universities (National Technical University of Athens and University of Western Attica) which offer dedicated programs in surveying engineering. The main findings indicate that females appear to enter the surveying engineering courses with higher secondary school mean grades but graduate with lower mean grades. Females perform the same as males in MSc course degrees and when continue with doctoral studies only half will complete compared to their male counterparts.

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1. INTRODUCTION

During the last century, women have made an impressive progress in society, education and the workplace, increasing considerably their participation in historically male-dominated fields such as business, law and health sciences. However, women's involvement in science and engineering has been less dramatic, and their progress in the respective workplace (especially senior posts and decision-making bodies) is even slower. In the EU, from the 18 million scientists and engineers, 59% were men and 41% women (statistics of 2017). It is interesting to note that in three EU member states, the majority of scientists and engineers comprise women, specifically in Lithuania (58% female), Bulgaria (54%) and Latvia (52%) whilst less than one third of female scientists and engineers work in Luxembourg (25%), Finland (28%), Hungary (31%), Austria (32%) and Germany (33%).

In Greece, this situation is even more pronounced. Although Greek women are over-represented in undergraduate studies (more than the European mean), their proportions quickly decrease as one moves up the academic scale. The engineering profession is male dominant in Greece. The first woman engineer, an architect, graduated in late 1920s from the National Technical University of Athens. To date, the average percentage of qualified women engineers comprise less than 25% of the Greek total qualified engineers. Overall, about 20% of undergraduate engineering degrees are awarded to women, but only 13% of the engineering workforce is female. Numerous explanations have been offered for this discrepancy, including a lack of mentorship for woman in the field; a variety of factors that produce less confidence for female engineers and the demands for woman of maintaining a balance between work and family life.

This paper explores the "leaking pipeline" in women's participation rates in a specific engineering discipline, that of surveying engineering from Bachelor to postgraduate research programmes. By examining the statistics at a number of parameters from two Greek universities (National Technical University of Athens and University of Western Attica) offering dedicated degrees in surveying engineering (5-year and 4-year course degrees respectively), the paper focus on three points of "leakage" for women's participation between Bachelor degree programmes, postgraduate programmes, taking up postdoctoral positions, and the links between them.

The paper is organised in four sections. In section 2 a brief discussion regarding gender differences in engineering studies and a brief review on reasons behind this is given. Section 3 describes the statistical analysis on data from two universities in Greece that provide dedicated Surveying Engineering courses and section 4 summarises the presented work.

2. GENDER DIFFERENCES IN ENGINEERING STUDIES IN EU

The gender gap in Science, Technology, Engineering and Mathematics (STEM) is well documented. Numerous studies have considered the different steps in the STEM educational and professional pipeline, from high school to post-secondary education and beyond, to understand why fewer women enrol in STEM programs and pursue STEM careers (e.g., Smith and Gayles, 2018; Hunt, 2016; Glass et al., 2013; Kaminski and Geisler, 2012; Diekman et al., 2010). The failure of science and engineering programs to attract equal numbers of women and men is also documented where only about 23% of women with high scores in mathematics pursue engineering related degrees as compared to 45% of men with the same scores (e.g., Smith, 2012; Eccles, 2007). Major findings of prior work that indicate why women are less likely to pursue engineering degrees is clearly not due to a difference in technical ability. It is interesting to note that men's interest in engineering was stable over their high school years but women's interest declined near graduation (e.g., Sadler et al., 2012). Also, it has been noted that individuals with high mathematical and verbal abilities preferred non-STEM careers while those with high mathematical but moderate verbal ability were more likely to pursue STEM.

Suggested barriers that prevent women from entering into engineering courses include early gender identification, the expectation of secondary school teachers, mathematics and science experience, lack of confidence in mathematics and science abilities, and familial influence. Also, women often do not see how engineering degrees lead to societal improvement. Finally, a major issue noted in the literature for the lack of women in engineering is that there are fewer female role models, mentors, and educators and images of engineers, or young women of the future because in order for some women to develop confidence in their ability to succeed in an engineering career, it may be beneficial for them to see other women who have succeeded in engineering.

The literature also suggests that many countries have developed programs and initiatives in an effort to address the low enrolment of women in undergraduate engineering programs. Despite these efforts, enrolment of women in undergraduate engineering programs has either been stagnant or has seen minimal increase (ACAD, 2017). The lack of women entering undergraduate engineering programs creates a situation whereby the pipeline of engineers required to allow Europe and other countries throughout the world to remain competitive in the global economy is not sufficiently filled. This gender imbalance can skew professional cultures, lead to less effective outcomes and result in Engineering being less popular with females.

In 2017, women accounted for 54.0 % of all tertiary students in the EU-28 (ec.europa.eu/eurostat). Focusing on students studying for bachelor's degrees, Cyprus (48.7 % share for women), Greece (47.3 %) and Germany (46.4 %) were the only EU Member States where there were more men than women studying in 2017. The highest share of female students among those studying for bachelor's degrees was recorded in Sweden (63.5 %). Among students studying for master's degrees, women were in the majority in all of the EU Member States. The second most common field of education in the EU as in 2017, was engineering, manufacturing and construction-related studies which accounted for 15.3 % of all tertiary education students. In this field, almost three quarters of all students were male (Fig. 1). An

analysis of the number of graduates by field of education shows that in the fields of engineering, manufacturing and construction-related studies only 14.6 % graduate out of the 15.3 % proportion of tertiary education students. This may suggest that fewer students had started this type of study in recent years, or that either drop-out rates or average course lengths were higher in these fields. The differences in these shares might also depend on the magnitude of the respective population cohorts. Out of these, there were 2.6 times as many male (compared with female) graduates in the specific fields.

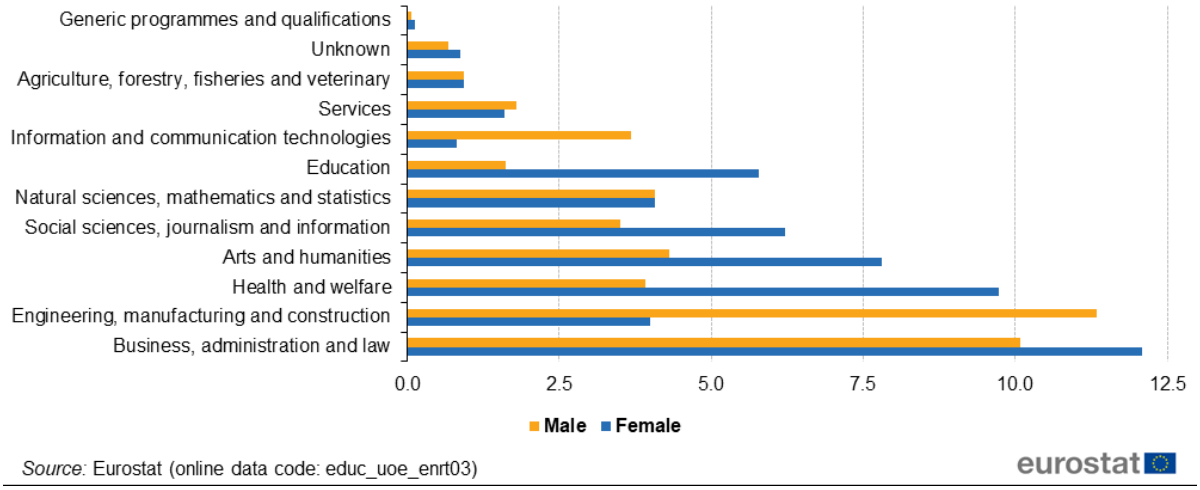


Figure 1: Distribution % of tertiary education students by broad filed and sex, EU-28, 2017 (source: Eurostat)

Figure 2 depicts as in 2017 the majority of women in science and engineering that are found in eastern-European and Scandinavian countries (such as Bulgaria, Latvia, Portugal, Denmark). Reasons for this gender parity are often suggested that eastern formerly communist states may have had greater gender balance than other countries. Another reason might be down to science or engineering jobs in these regions that have comparatively low wages, which might push men towards higher-paying positions in other sectors or countries.

Greece presents statistics for STEM graduates below the EU average of 41% (Fig. 2). Historically, in Greece, there was significant involvement of women in the making of philosophy and mathematics. A striking example is the Pythagorean School where women entered on an equal basis with men (Salisbury, 2001). Pythagoras himself was surrounded by women. His teacher was Themistocleia, a Delphic priestess, and his wife, Theano, was a mathematician herself and the director of the School after Pythagoras' death. Three of their daughters, Damo, Myia and Arignote were also distinguished mathematicians and philosophers. Later, Pythagorean women include Periktione, who is commonly identified as Plato's mother, and the well-known mathematician and astronomer Hypatia of Alexandria in the 4th c. A.C.

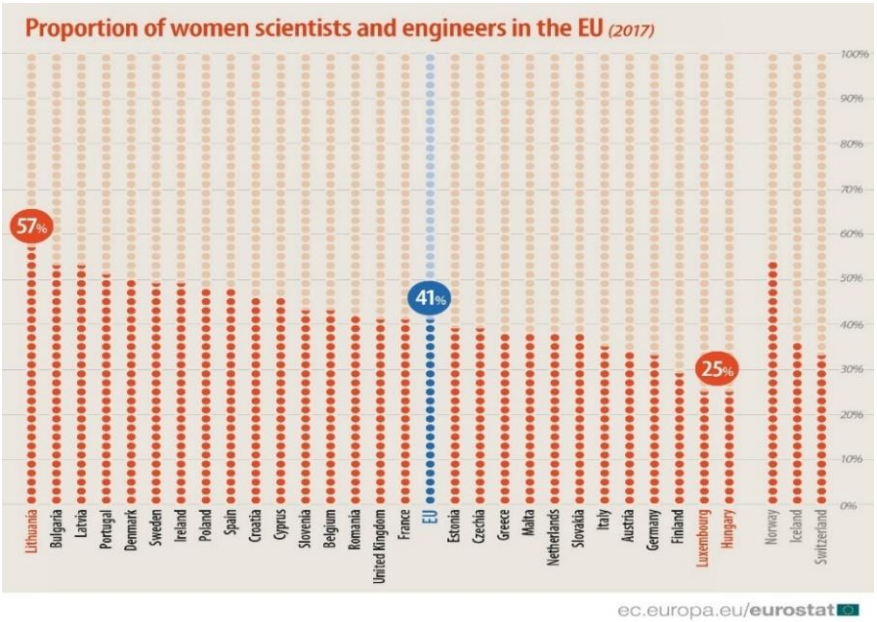


Figure 2: Proportion of women scientist and engineers in the EU countries for 2017 (source: Eurostat)

Greece today is still mostly a patriarchal society, but there are continuous improvements on gender equality due to women's obligatory education and the overall socio-economic development. There is no specific gender mainstreaming plan, but rather a general gender equality plan. According to an official report (Greek Ministry of Interior, 2017) during the past 50 years there is an impressive increase of women's representation in the educational system and a gradual reduction of the gender gap. Women constitute almost half of the student population of the higher education institutes and gradually start prevailing over men. Although gender-based differences in student's participation in various scientific fields are being reduced, a difference among sciences still exists. Thus, in Humanities, Arts, Law and Social Sciences women outnumber men. Women's participation in the Natural Sciences has increased significantly to 43% (in 2014). In the field of engineering, the women's ratio increased to about 25% for the same period. In 2004, Greece was one of the seven European countries that had reached the point at which one third of women graduates in engineering were women, a level that the European Commission had suggested as the target for 2010 (Ministry of Interior, 2017).

3. STATISTICS FROM TWO SURVEYING ENGINEERING COURSES

Only engineering graduates from public universities in Greece may work as licensed (professional) engineers in Greece. The universities in Greece that offer engineering degrees (up to 2019) are the following: National Technical University of Athens, University of Thessaloniki, University of Patras, University of Thrace, University of Crete, University of Thessaly and University of the Aegean. Recently (in 2019), it was decided that all technological institutes, offering education of technological nature, would be upgraded and offer all the engineering majors as the aforementioned universities. The types of engineering majors available are architectural engineering, chemical engineering, civil engineering, computer

engineering and informatics, electrical and computer engineering, environmental engineering, industrial engineering, mechanical engineering, metallurgical and mining engineering, naval architecture engineering, production engineering, and surveying engineering. As in many European countries, the years of study for all university engineering majors is five, leading to a Diploma in the specific area of engineering. The last year of the study consists of graduate level courses and includes a mandatory thesis. Starting in the third or fourth year of studies, students choose areas of specialisation and follow this usually on their thesis at the fifth year.

When graduated, female engineers are noticeably underrepresented in electrical and mechanical engineering (less than 10%). Women civil engineers are about 15%, while architectural, surveying and chemical engineers have the largest percentage of women engineers, over 30% (Greek Technical Chamber of Engineers, 2015).

The following analysis comprises data for over 1000 students who are pursuing a degree in Surveying Engineering courses. Specifically, up to 2019 there were only two universities that offering a five-year degree course in surveying engineering (i.e. the National Technical University of Athens and the Aristotle University of Thessaloniki). To-date, there are more higher education institutes, as discussed above, that offer courses (usually 4-year degree courses) leading to the degree of surveying/geospatial/geoinformatics engineering. The data used in this study refer to students from the School of Rural and Surveying Engineering (National Technical University of Athens, NTUA) and the Department of Surveying and Geoinformatics Engineering (University of Western Attica, UNIWA). The latter institution is newly established and has evolved from its predecessor Technological Educational Institute of Athens.

The data used for this study have the following details recorded:
- gender;
- secondary schooling data (the overall secondary school admission rank);
- university degree data: enrolled undergraduate and postgraduate degree program (course code, course name);
- list of each University subject/unit of study attempted (unit code, unit name) and the result in each unit;
- final degree grade;
- list of each University subject/unit of study attempted (unit code, unit name) and the result in each unit for the postgraduate course (NTUA only);
- list of doctoral candidates and doctorate holders.

From these data, the students' average mark across certain units in the degree course were derived. The certain units refer to mathematics, physics and information technology/computing/programming. The data are used to assess a range of specific questions related to the relative performance of male and female students, as discussed in the following.

3.1 Undergraduate Studies

3.1.1 Entrance in Surveying Engineering Courses

In Greece, the educational system is as follows: nursery, elementary school consisting of six years, Gymnasium (equivalent to Junior High school) consisting of three years, and Lyceum (equivalent to High School) consisting of three years. Lyceum graduates can take national entrance exams to enter higher educational institutes (HEI). These include universities, technical educational institutes and military colleges, all of which are public. In addition, there are private colleges and institutes that operate under their own rules and regulations pertaining to their scope of training.

During the second year of the lyceum, students must choose either a science direction or a theoretical direction with respective courses and will follow this at the final year of the lyceum. At the end of the final year, students will take national exams on four compulsory subjects of the chosen direction to enter the preferred university faculties. For engineering courses, the four compulsory subjects examined at a national level are Greek language, Mathematics, Physics and Chemistry. The 20-point grading system is used for each course and the final admission grade of each student is given at the thousand-scale for the university entrance. The success in entering a university course depends on the number of first year students set by each university for every courses, the popularity of the course and the final admission grade of the student. This means that popular degrees such as medicine, law, electrical and computing engineering accept students with over 19,000 points as admission grades. In case a student does not adequately meet the threshold admission grading for his/her first choice of a course, it automatically goes to the second, third, etc choice till the admission grade meets the specific threshold and that represents the student's position within the overall cohort (i.e. admission rank).

The courses in surveying engineering in both NTUA and UNIWA are not necessarily the first option in the entrance examination lists for most students that are eventually accepted in the two courses. There are several reasons for this including lack of familiarity with the specific degree, traditional societal barriers in engineering career for lesser paid job, etc. In Figure 3, the gender distribution of the total entry for the last five years in NTUA and the last four years in UNIWA, respectively is seen. For the NTUA sample of 780 first year students (period 2014-2019), the male average is 79.3 and female average is 52. In Figure 4 it is seen that while the gender difference is greater in years 2014 and 2015, there is a slight increase of first-year female students in 2018 and 2019, in both universities.

Figure 3: Proportion of male and female students in the total entry for NTUA, period 2014-2019 (left) and UNIWA, period 2016-2019 (right)

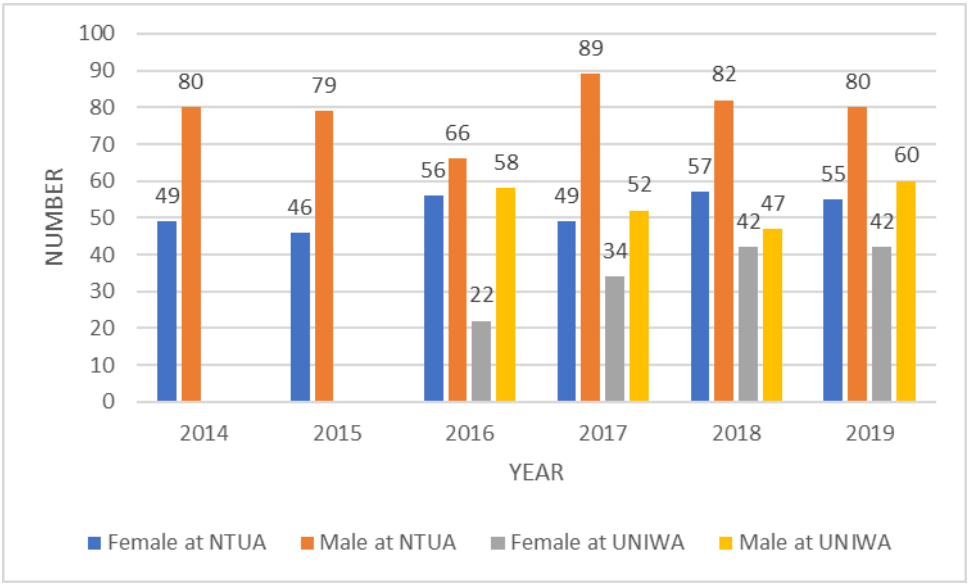


Figure 4: Number of students in the first year for NTUA (2014-2019) and UNIWA (2016-2019)

A worthwhile question to explore, is *why* there is such a difference in the entry of females and what is the prior academic performance of males and females. It might be hypothesised that the nature of engineering programs (and their academic culture) is such that only females who are more confident in their academic abilities (relative to males) are choosing to undertake an engineering degree. Figure 5 depicts the admission grade achieved by students who entered the Surveying Engineering course in NTUA, in the period 2014-2019. It is noted that whilst there is a decrease of the overal admission grades from 2014 to 2019, the average grade for females outperform the males.

To compare the overall performance (and standard deviation) of female and male students using their admission grade, a t-test is performed to test the means:

Females (N=219) $\mu = 15351.38$ $\sigma = 601.20$
Males (N=317) $\mu = 15219.52$ $\sigma = 583.92$

Applying a 2 sample t-test to test if these means are different, gives a p value of 0.0114, indicating that the difference in admission grades for males and females is statistically significant at α=0.05, thus it is concluded that it is likely that females are indeed performing at a higher academic level than males in this particular set of entrance admission grades.

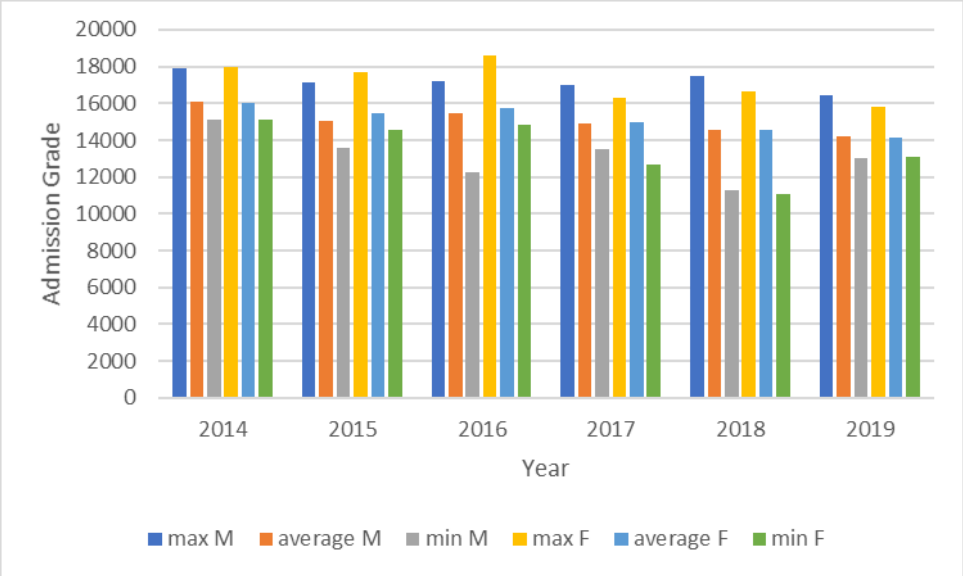


Figure 5: Statistics for Admission Grades in Surveying Engineering - NTUA (2014-2019)

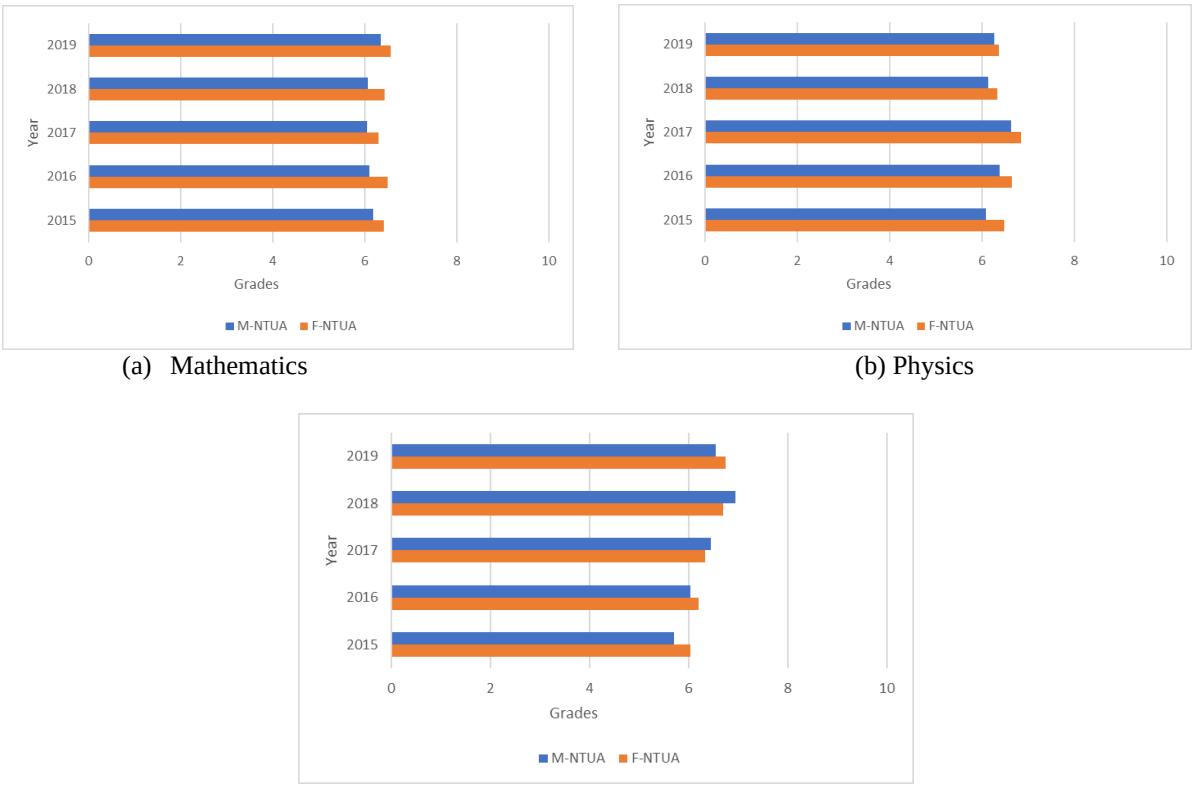
3.1.2 Studying for the Surveying Engineering degree

For undergraduate students, it is interesting to examine the *performance in STEM* subjects of males and females which are compulsory in the first two years of the degree, ie Mathematics, Physics and Information Technology (IT) subjects. For NTUA, Mathematics comprise 6 different units, Physics comprise 2 different units and IT comprise 2 different units. For UNIWA, Mathematics, Physics and IT comprise 2 different units, each. It is noted that the grading system for a subject to be considered as pass, is to achieve at least 5 with maxium 10. Figure 6 depicts the performance for NTUA students in Mathematics, Physics and IT subjects and Figure 7 shows the performance in Mathematics, Physics and IT for female students in UNIWA. To compare the overall performance (and standard deviation) of female and male students using their grades in STEM subjects, a t-test is performed to test the means (Table 1).

	Mathematics (N_M= 2940, N_F= 1980)		**Physics** (N_M= 980, N_F= 660)		**IT** (N_M= 980, N_F= 660)	
	mean	σ	mean	σ	mean	σ
Males	6.154	0.121	6.297	0.209	6.340	0.478
Females	6.444	0.121	6.536	0.219	6.404	0.304

Table 1: The results of the t-test for the overall performance of female and male students in STEM subjects

Applying a 2 sample t-test to test if these means are different in Mathematics, Physics and IT respectively, gives p values of <0.001 with standard deviation of 0.011 for all three, indicating that the differences in Mathematics, Physics and IT grades for males and females are statistically significant at α=0.05, and we can therefore conclude that it is likely that females are indeed performing at a higher academic level than males in these particular sets of subjects for the period 2014-2019.



(a) Mathematics (b) Physics

(c) IT

Figure 6: Performance in STEM subjects - NTUA (2015-2019)

From Figure 7 it is seen that, for 2017-2019, female students in UNIWA perform rather averagely compared to their male counterparts in STEM subjects. A slight improvement is shown in Mathematics and Physics whilst IT subjects do not indicate improved performance for the same period. It is possible that females suffer a disadvantage in the early stages of their engineering studies regarding IT which is present in the results.

An interesting issue to be examined is the *extent* of the undergraduate studies in both HEIs. Figure 8 depicts the average study duration for males and females in NTUA where a clear precedence of females is noticeable. Specifically, males require on average 7.2 years compared to females requiring 6.5 years to complete their degree. On the contrary, females in UNIWA require longer period (8.25 years) to finish their studies. This could be attributed to the fact that UNIWA was up to recently a technological institute where students with lower admission grades would enter the course resulting in a slower progression through the degree program.

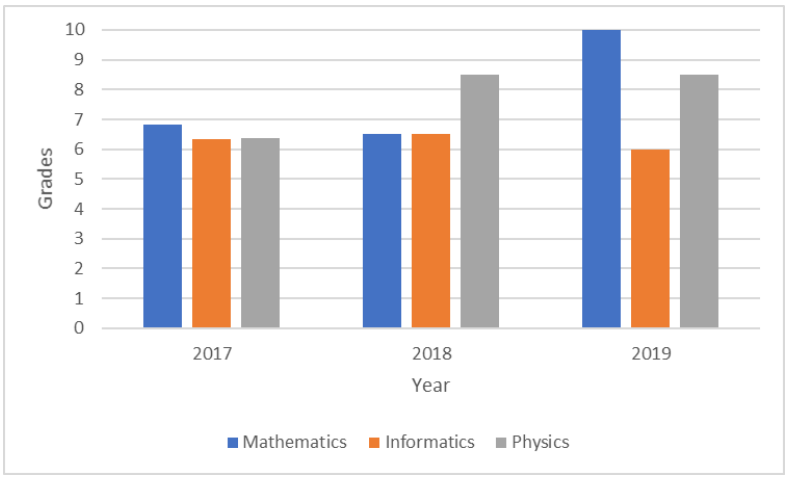


Figure 7: Performance in STEM subjects for female students- UNIWA (2015-2019)

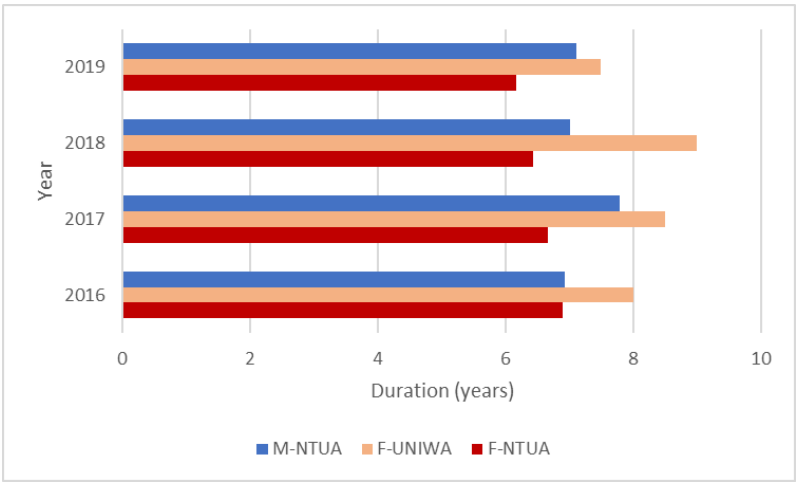


Figure 8: Duration of undergraduate studies for NTUA and UNIWA (2016-2019)

The question to be answered regarding the progression of the studies is the *number of graduates* and the *degree grade* achieved amongst male and female students. Figure 9 depicts the number of male and female graduates in NTUA and UNIWA. Specifically, an average of 43.4 females vs. 49.8 males graduate annually from NTUA. Similarly, an average of 12.5 females vs. 17 males graduate annually from UNIWA. Considering that from an average of 52 females in the first year (cf. Fig. 4) only an average of 43.4 females graduate and from an average of 79.3 first-year males only an average of 49.8 males graduate, it is interesting to assess if there is a statistically significant difference between the average number of males and females that graduate in NTUA. In order to do this, a statistical testing on the differences between two populations $p1$ (females) and $p2$ (males) is performed. For a null hypothesis Ho:$p1 \leq p2$ and based on the above information, for significance level $\alpha=0.05$, the critical value for a right-tailed test is $zc=1.64$ and the z statistic is $z=2.531$. The p-value is $p=0.0057$, and since $p=0.0057<0.05$, it is concluded that the null hypothesis is rejected. In conclusion, the null hypothesis Ho is rejected. Therefore, there is enough evidence to claim that population proportion $p1$ is greater than $p2$, at the 0.05 significance level. This means, that the proportion of female students graduating is higher. Male students tend to stop studies more due to several

reasons such as working, military service, family reasons, etc. The UNIWA results show that in average 12.5 out of 35 females and in average 14.5 out of 54.25 males have graduated in the period 2016-2019. Again, the proportion of female students that is graduating is statistically higher compared to the proportion of males.

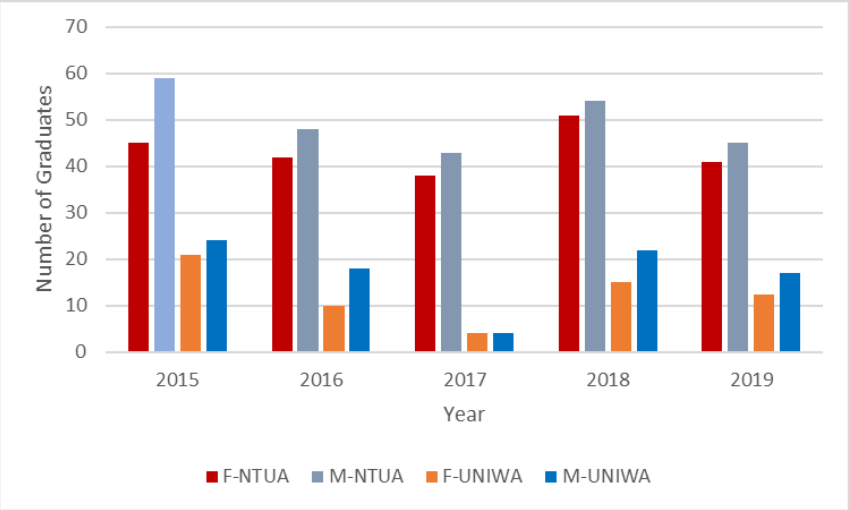


Figure 9: Number of male and female graduates for NTUA and UNIWA (2015-2019)

The final grades achieved by males and females for their awarded degree by NTUA is given in Figure 10. An average of 6.57 for females and 7.19 for males (maximum grade is 10) has been achieved in the period 2015-2019. To compare the overall performance (and standard deviation) of female and male students using their final grade for their degree, a t-test is performed to test the means:

Females (N=217) $\mu = 6.57$ $\sigma = 0.26$
Males (N=249) $\mu = 7.19$ $\sigma = 0.34$

Applying a 2 sample t-test to test if these means are different, gives p value < 0.0001 (difference -0.620 with standard deviation of 0.028), indicating that the difference in the final degree grade for males and females is statistically significant at α=0.05, and we can therefore conclude that it is likely that males are indeed performing at a higher academic level than females in this particular period 2015-2019. Interestingly though, whilst the average graduation grade is higher for males, more females achieve a final grade of over 8 than their male counterparts. Figure 11 shows that for those students that achieve a grade over 8, 58% are females and 42% are males.

The final grades achieved by females for their degree from UNIWA is given in Figure 12. Females obtain final average grades between 5.92 (±0.09) and 7.37 (±0.81), while the equivalent figures for all students are minimum average 5.74 (±0.33) and maximum average 8.045 (±0.34). Again, a t-test is performed to compare the minimum and maximum average of females (N=50) against the equivalent of all graduate students (N=118). For the minimum, a difference of 0.18 (±0.047) and a p value of 0.0002 and for the maxium a difference of 0.67 (±0.087) and a p value of 0.0001, indicating that the final average grade of females is statistically singificant from the overall minimum and maximum grades for the period 2016-2019.

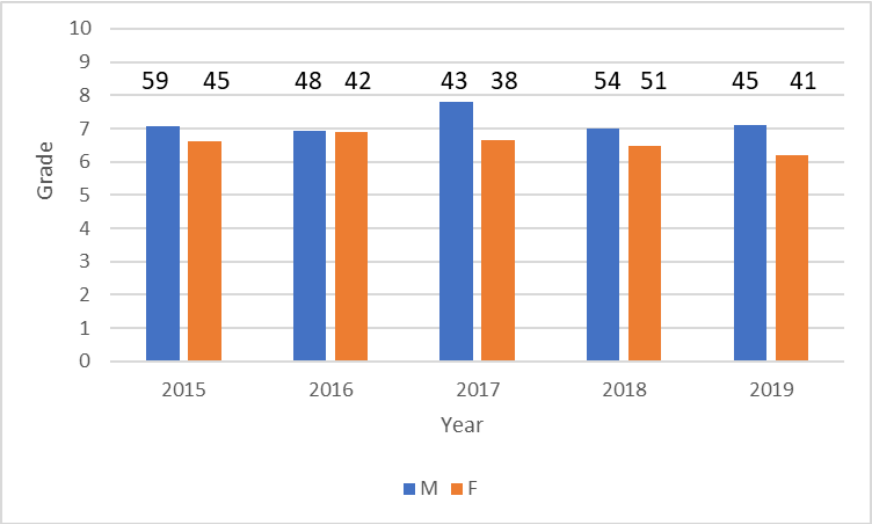


Figure 10: Final grades for the degree in Surveying Engineering in NTUA (2015-2019)

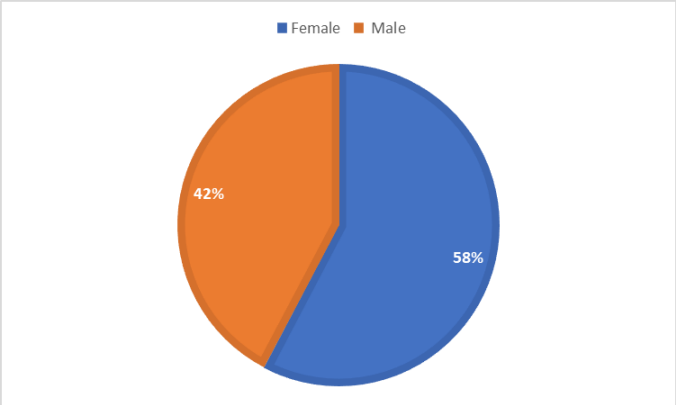


Figure 11: Degree performance over 8 for males and females in NTUA (2015-2019)

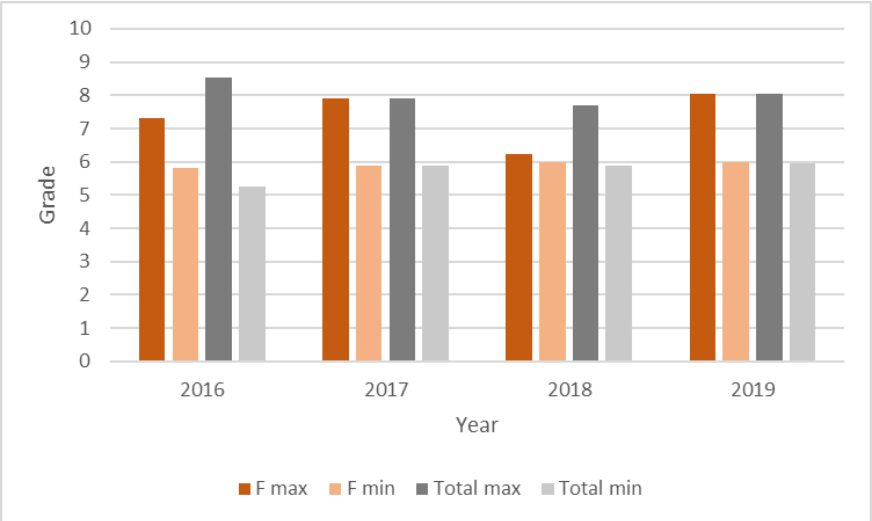


Figure 12: Final grades (females only) for the degree in Surveying Engineering in UNIWA (2016-2019)

3.2 Postgraduate Studies

Irrespective of the reason for the disparity in the final grade for their degree, a natural question is to assess *how many females continue with postgraduate studies*. Figure 13 presents the number of graduates that continue with MSc studies in both NTUA and UNIWA. It is interesting to note that in NTUA, on average 9.5 (±1.5) females (out of 43.4) continue with MSc level studies vs. 6.5 (±1.8) males (out of 49.8). In UNIWA, on average 3.3 (±3.4) females (out of 12.5) continue with MSc level studies vs. 4.6 (±4.5) males (out of 17). Clearly, the average number of females pusruing MSc studies is higher in UNIWA vs. the average females in NTUA. A possible reason is that graduates from UNIWA were up to recently of technological level (4-year degree) and in order to have comparable professional avenues as the graduates from NTUA (5-year degree) they were keener to continue with postgraduate studies. It is anticipated to see if this trend will continue with the recent upgrade of UNIWA to 5-year degree.

Applying a 2 sample t-test to test if these means are different, gives p value < 0.0001, indicating that the average number of females pursuing MSc studies is significantly greater than the average numer of their male countrparts at α=0.05 for NTUA. The opposite occurs in UNIWA, where the the average number of males pursuing MSc studies is significantly greater than the average numer of their female counterparts. Whilst there is no evident reason why this is happening, an observation may be that males that have graduated many years ago and are working professionally as surveyors seem to require up-to-date knowledge and new skills for their profession. However, in both HEIs it can be noticed that there is a slight decrease over the years for students wishing to pursue MSc studies. It is not clear why this is happening but an explanation may be the opening of more jobs in recent years after the long recession in Greece.

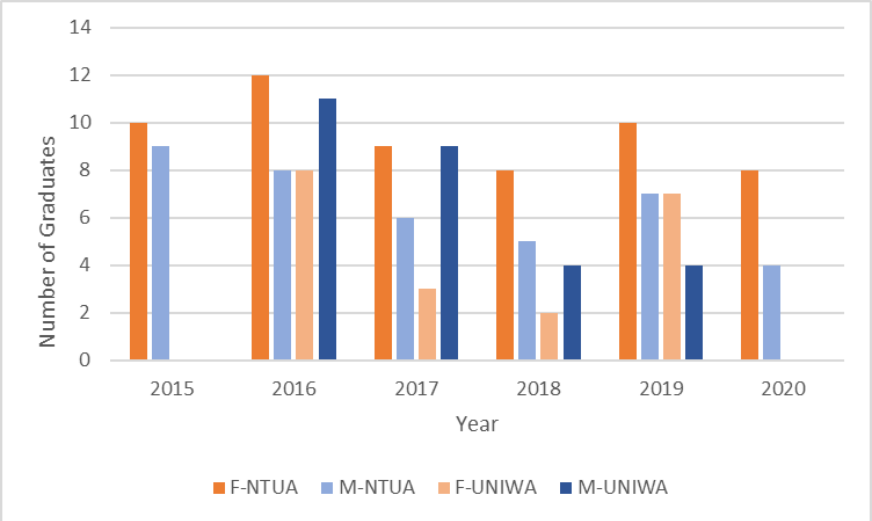


Figure 13: Number of graduates pursuing MSc level studies in NTUA and UNIWA (2015-2019)

Figure 14 shows the number of post-graduates in both NTUA and UNIWA. It is interesting to note in NTUA, on average 35.4 (±10.08) females have graduated with MSc degree vs. 26 (±5.2) males. It can be noticed though that the growth of female MSc graduates is varying from year to year with a slight decrease in 2019.

In UNIWA, on average 0.7 (±1.15) females have graduated with MSc degree vs. 2.3 (±3.2) males. The reason for the difference on the graduate numbers between the two HEIs, is that NTUA runs two MSc programs relevant to surveying engineering/geomatics since 2000 whereas UNIWA runs only one MSc program in the last three years.

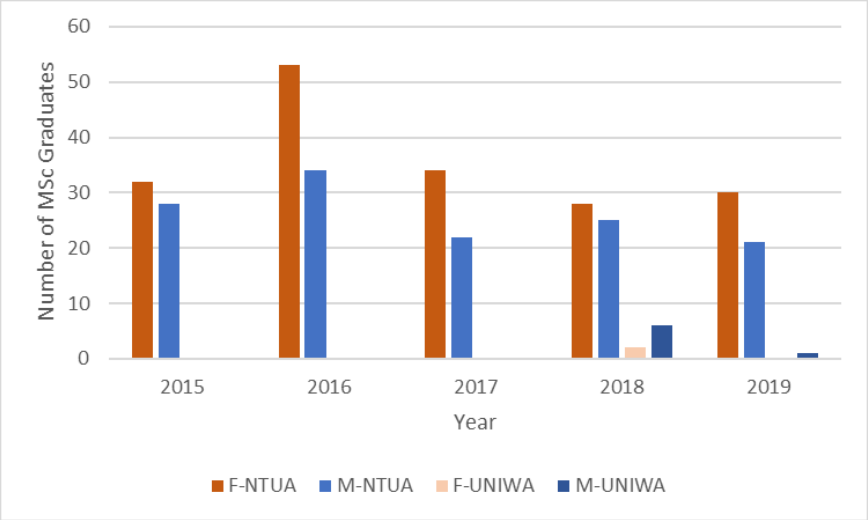


Figure 14: Number of MSc graduates in NTUA and UNIWA (2015-2019)

A further question to answer is *how many* students are pursuing *doctoral studies* after completion of their MSc degree or how many new students are entering the doctoral program. Whilst universities mainly in US differentiate between PhD and doctoral studies, in this paper it is assumed the same degree. Figure 15 shows the number of enrolled students in the period 2015-2020. Clearly, the number of students pursuing doctoral studies is decreased compared to the number of students doing MSc studies. The data refer only to NTUA, as UNIWA could not offer doctorate degrees up to 2019 due to its previous academic status. The average number of female students enrolled as doctorate candidates is 6.5 (±3.44) and for male students is 7.7 (±4.9) for the period 2015-2020. A t-test is used to assess the significance of the difference between the number of females and males enrolled as doctorate candidates. The test result indicates that the means of females and males enrolled are not significantly different at $p<0.05$, thus there is no disparity between males and females enrolling in the doctoral program of NTUA.

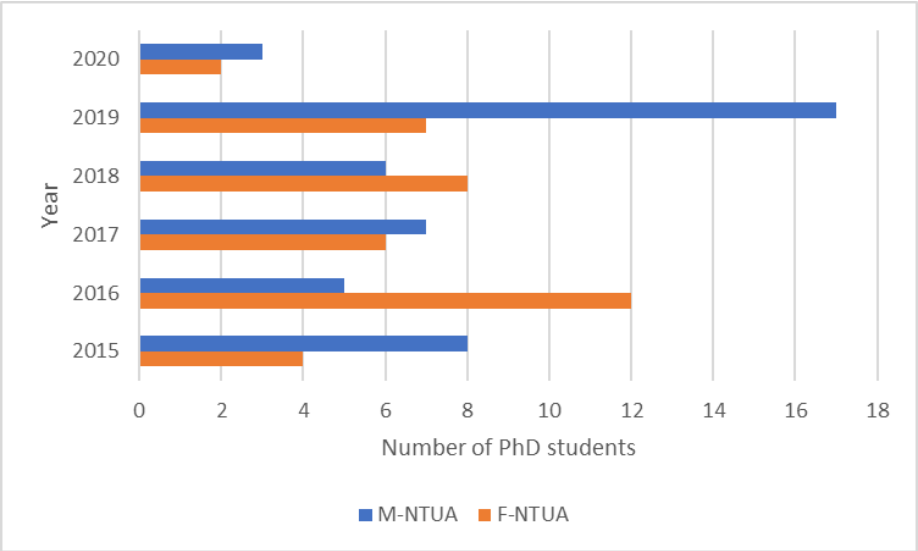


Figure 15: Number of enrolled doctoral candidates in NTUA (2015-2020)

A last question to answer is *how* many female students complete their doctoral research and become doctors in engineering. Figure 16 shows the number of graduated Drs in the period 2015-2019 and clearly the males outperform the females, with an average male of 3.4 vs. average female of 1.8. This is conveyed to 65% males and 35% females completing their doctoral studies (Fig. 17).

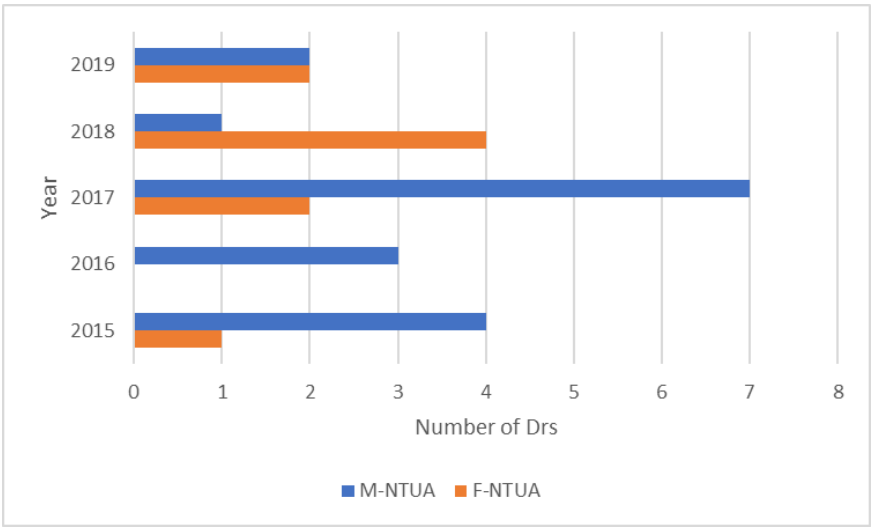


Figure 16: Number of completed Drs in NTUA (2015-2019)

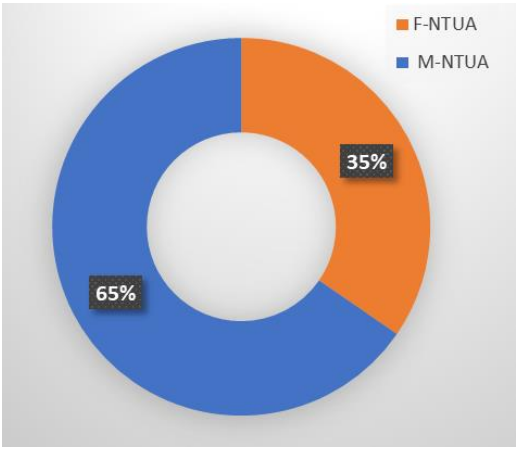


Figure 17: Proportion of completed Drs in NTUA (2015-2019)

3.3 Discussion

The detailed statistical analysis of a relatively large cohort of students over the last five years has provided a number of interesting insights:

1. Females are performing at a lower overall academic level than males in the two Surveying Engineering degree program (NTUA and UNIWA). This result could not be misinterpreted as suggesting that the females are coping worse than their male counterparts, and hence mask the existence of deeper issues.
2. Females enrolling in the Surveying Engineering programs have a higher mean secondary school performance than males. Given this observation, when we look just at a cohort with comparable secondary school performance, the females generally are performing worse in the University degree program, suggesting that there may be factors that are being overlooked.
3. Female students' overall performance in STEM subjects (Mathematics, Physics, IT) in the first two years is higher than their male counterparts. This may suggest that the factors leading to higher female performance is focused on the earlier years but there may be other issues that affect an ability to maintain the high performance until graduation.
4. Females show a positive disparity in pursuing MSc level studies and perform well with higher graduation figures compared to their male counterparts.
5. There is no disparity between males and females following doctoral studies, however males outperform their female counterparts in completing the doctoral studies.

4. CONCLUDING REMARKS

Ensuring a strong and sustainable engineering capability into the future is essential part in building Europe's innovation and productivity potential. Addressing the underrepresentation of women in engineering is a workforce development strategy that will play a major part in ensuring this capability in the longer-term. There is no doubt that the current focus on

encouraging greater numbers of women and girls to undertake STEM subjects at secondary school and engineering courses at university is vital to improving the participation of women in engineering - the problem is that this approach belies the complexity of the factors contributing to the underrepresentation of women in engineering.

The key to increasing the number of female engineers may not just be mentorship programs or role models, although those are important. It may be about reframing the goals of engineering research and curriculums to be more relevant to societal needs. It is not just about gender equity — it is about doing better engineering for us all.

Addressing the attrition of women from the engineering workforce is vital but removing the obstacles, barriers and biases which operate as disincentives for women to remain in engineering is just as fundamental as increasing the participation of in engineering education. An effective long-term solution to encourage females into engineering will require addressing the complex range of factors that operate to disadvantage women in employment generally.

ACKNOWLEDEMENTS

The authors are grateful to the Secretariat of the School of Rural and Surveying Engineering, NTUA and the Secretariat of the Department of Surveying and Geoinformatics Engineering, UNIWA for providing the data used in this paper.

REFERENCES

Australian Council of Engineering Deans (ACED), 2017. Position Statement: Increasing the Participation of Women in Engineering Education, https://www.sciencegenderequity.org.au

Diekman A.B., Brown E.R., Johnston A.M., Clark E.K., 2010. Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. Psychological Science 21(8): 1051–1057.

Eccles J., 2007. Where are all the women? Gender differences in participation in physical science and engineering. In: “Why aren't more women in science? Top researchers debate the evidence”, American Psychological Association, pp. 199-210.

Glass J.L., Sassler S., Levitte Y., Michelmore K.M., 2013. What’s so special about STEM? A comparison of women’s retention in STEM and professional occupations. Social forces 92(2), pp. 723–756.

Hunt J., 2016. Why do women leave science and engineering? ILR Review 69(1), pp. 199–226.

Kaminski D., Geisler C., 2012. Survival analysis of faculty retention in science and engineering by gender. Science 335, 6070 (2012), pp. 864–866.

Greek Ministry of Interior, 2017. Women in power and decision making. E-bulletin No12, General Secretariat for Gender Equality, November, Greece.

Sadler P.M., Sonnert G., Hazari Z., Tai R., 2012. Stability and volatility of STEM career interest in high school: A gender study. Science education 96(3), pp. 411–427.

Salisbury E.J., 2001. Encyclopaedia of Women in the Ancient World. ABC-CLIO Inc., Santa Barbara, CA.
Smith K.N., Gayles J.G., 2018. Girl Power: Gendered Academic and Workplace Experiences of College Women in Engineering. Social Sciences 7(1), 11 p.
Smith A.Y., 2012. They chose to major in engineering: A study of why women enter and persist in undergraduate engineering programs. PhD thesis, University of Massachusetts, Dept of Education, USA.

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