Diversity and the academic engineering positioning test in Flanders: Impact on female students and students with disabilities

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INTRODUCTION

A new positioning test for the Bachelor of Engineering Science was broadly and uniformly implemented in Flanders in the summer of 2013 [1]. The non-mandatory test measures the ability of future engineering students to solve engineering problems and compares a student's mathematical skills with the required previous knowledge. This paper is the first one to study the impact of the positioning test on two target groups: students with disabilities and female students. These target groups are of particular interest since KU Leuven wants to offer students with disabilities equal opportunities and Flanders' engineering education suffers from a gender imbalance (15% female) while lacking engineers for the labour market.

1 POSITIONING TEST FOR BACHELOR ENGINEERING SCIENCE FLANDERS

1.1 Context

Historically a multi-topic entrance exam for the study of Engineering Science has existed in Belgium for more than 100 years, stimulating, as a preparation, a high level of mathematics education in high schools and resulting in an international high reputation of the Flemish mathematics high school education (see PISA assessments in 2003 [2]). But, despite academic opposition, the entrance exam at Flemish universities was abolished in 2004 following a decision of the Flemish Government. The bachelor of engineering science study program was consequently adapted to accommodate more students and to introduce more basic mathematics in the first year in order to maintain the same level of expectations for the other courses. Despite these efforts the success rate dropped from 70% with

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the entrance exam to less than 50%. Almost a decade later, the evolutions in high schools, student populations, and industry expectations have triggered a renewed effort to deploy new tests taking into account this new context.
This effort is supported by the results of the SOHO report [3], which expressed a number of concerns and actions concerning mathematics education in high school among which the need for a positioning test before the start of university studies in fields that rely strongly on mathematics.
The result of this effort is a positioning test called “ijkingstoets”. The non-obligatory and non-mandatory test measures the ability of future engineering students to solve engineering problems and compares a student’s mathematical skills with the required prior knowledge. The goal of the test it threefold: firstly, to encourage students who succeed; secondly, to stimulate students who are less successful to better prepare by entering a remediation trajectory; thirdly, to advise students who badly fail against entering the engineering studies.

1.2 History of the Positioning test

After a pilot version in 2012, the “ijkingstoets” positioning test for engineering students in Flanders was fully implemented for the first time in 2013. This test is organized twice: in July and September. Students are free to enrol in both. As described before [1], the test consists of 35 multiple choice questions to meet the requirements of a high throughput and multi-location (three different universities, four locations) test with the possibility of quick feedback. For each question five possible answers are mentioned and negative marking was applied as a scoring rule, with a score of +1 for marking the unique correct answer, -1/4 for marking a wrong answer and 0 for unanswered (blank) questions. The final scores are recalculated to a score on 20. The questions are designed based on the concepts taught in the high school curriculum (six hours of mathematics in the final years) relevant for the courses of the first year of the Bachelor of Engineering Science and cover several topics: mathematical reasoning, mathematical concepts, mathematical skills, spatial visualization ability, and mathematics in an applied context. Special focus lies on questions that combine different parts of mathematics and questions that cannot be solved with ‘off-the-shelf’ recipes. Students can use a list of formulas but no calculators.

2 LITERATURE

“European industrialists are sounding the alarm over a growing skills shortage on the continent that threatens their competitiveness and leaves manufacturing companies scrambling to find enough engineers.” Who hasn’t heard similar news items during the last years? Since no talent should be wasted in engineering education it is important to look at minority groups. This paper focuses on female students and students with disabilities.
Female students are underrepresented in engineering studies in Europe as shown, among many, by the Attract project [4]. Belgium, Flanders, and KU Leuven are no exceptions (see Section 3.3).
Heylen et al. [5] studied the background and motivation of first-year engineering students in relation to gender at the Flemish university KU Leuven. Interestingly they found that despite the significantly higher overall **high school score** of the female students compared to the males, their better motivation profile, and the more time spend for studying their courses, they did not score better in their first year. For the more general courses like Calculus, and Philosophy the female students score significantly better; on the other hand, for more **typical engineering courses** such as Applied Mechanics and Informatics, the male students score slightly better. This confirms the results of Felder et al. [6]. In agreement with Besterfield-Sacre et al. [7], Heylen et al. [5] found that female students have less self-confidence, which can explain their lower results compared to male students.
Literature studies shows that negative marking in MPQ-tests, as a means to discourage guessing, results in a possible gender bias [8,9]. Risk-averse students tend to leave more questions unanswered (blank) while risk-prone students tend to guess when the odds are favourable. Female students are often considered more risk-averse than male students hereby introducing a gender bias.
Supported by the above evidence, the paper investigates the **gender imbalance in the positioning test** scores by looking at (1) the prior education of the male and female students, (2) the type of questions, and (3) the effect of negative marking used in the MPQ positioning test.
While less literature and data is available on the position of **students with disabilities** in engineering education, the Attract project [4] showed, while studying socio-economic factors, that the proportion of students with disabilities in faculties like Engineering, Math, and Science is lower in comparison to other faculties. Therefore, it is important that the positioning test accommodates for this group. One of

the disabilities frequently encountered in the bachelor of Engineering Science is dyslexia [10]. Literature shows that unlike typical readers, the improvement of IQ and reading track diverge over time [11]. For most dyslexics reading and writing is more difficult and time-consuming than non-dyslexics. This can be overcome by granting students additional time during the examination (25% is usual). Triggered by the above literature, we study the impact of the positioning test on student with disabilities in this paper.

3 STUDY OF 2013 POSITIONING TEST

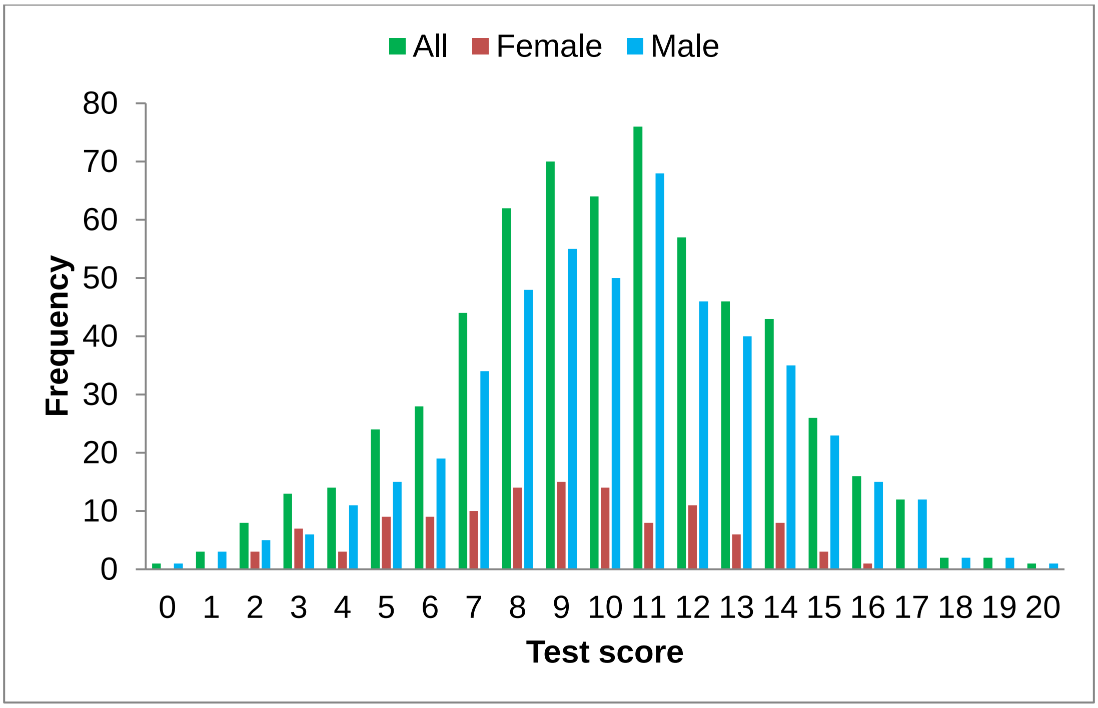

Fig. 1. Test scores in the July 2013 positioning test for all, female, and male students

3.1 Results of the 2013 positioning test

612 students participated in the first positioning test organised in **July 2013** across three universities in Flanders. The overall success rate was 56% and average score 10.03/20 (SD 3.47) with a normally distributed test score as shown in *Fig. 1*. 107 of the 267 failed students took the second positioning test in **September 2013** of which 50% succeeded. 137 new students participated as well in September, of which 84 succeeded (61%).

Fig. 2 presents the student flow diagram considering the positioning tests of July and September, distinguishing the students that pass and fall. Furthermore, this figure already sheds light on the gender issue.

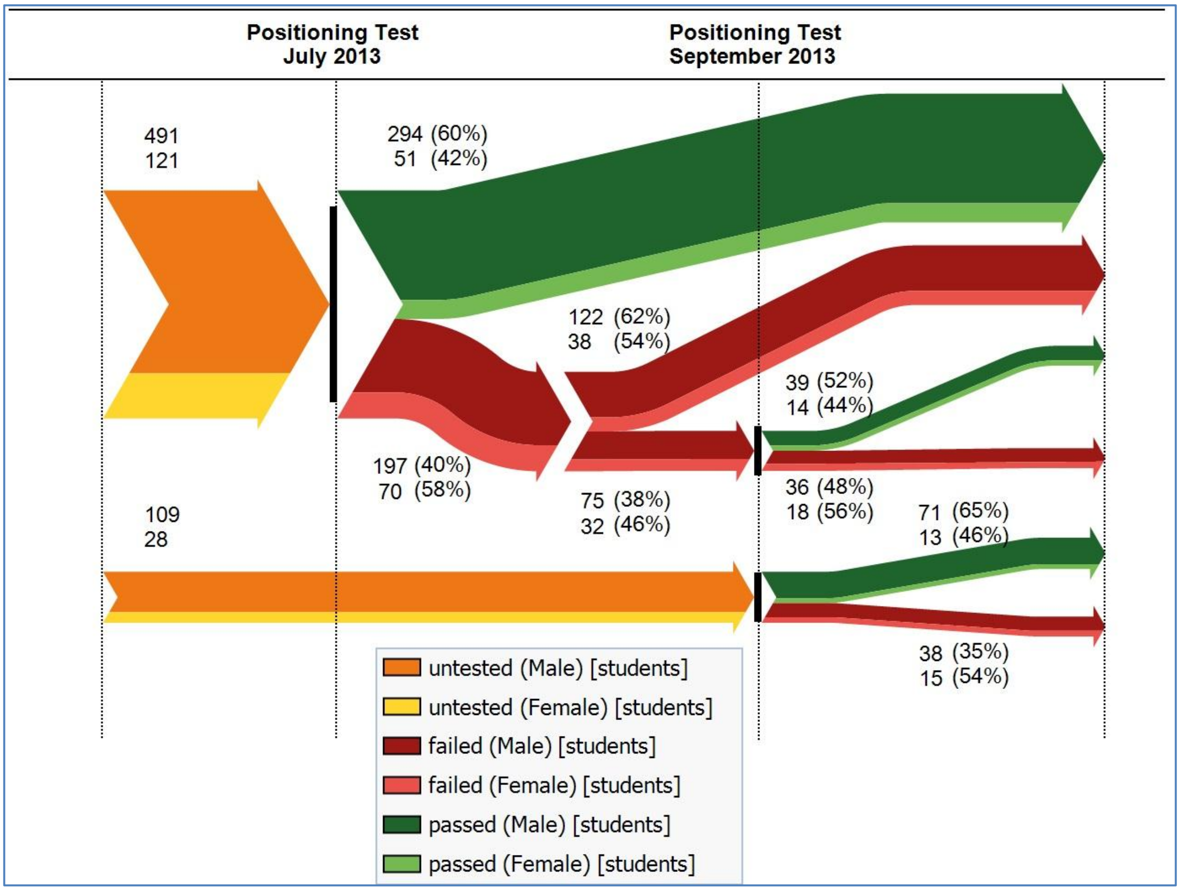

Fig. 2. Student flow diagram across the positioning tests of July and September 2013 for Male and Female students. The values alongside the arrows indicate the number of students (top-bottom:male-female); the percentages indicate the fraction within a specific gender (i.e. 60% of the male students passed the July positioning test).

3.2 Students with disabilities

An inclusive approach

KU Leuven wants to offer students with disabilities equal opportunities and has a tradition of supporting these students. The central KU Leuven Service for Students with Disabilities assesses on an individualised basis the eligibility for accommodations (instructional settings, exams, etc.) based on (clinically) documented impairments [12]. Typically, these students are allowed extra time for testing. The positioning test uses an inclusive approach regarding students with disabilities. The test designers assessed that three hours of examination time should suffice to solve the 35 MPQs. The maximum test time was set at four hours however, hereby granting all students 1/3th extra time (inclusive approach). The above target was met, since only few students took the full four hours to complete the 2013 positioning test.

Positioning test results

Of the 15 students with disabilities enrolled for the BSc Engineering studies (2013-2014) at KU Leuven, 13 participated in the 2013 positioning test. 10 out of these 13 (77%) succeeded in the positioning test, compared to the general success rate of 75% (of all students participating in the positioning test and enrolled in the bachelor). This shows that the inclusive approach is successful.

3.3 Female students

Female students are underrepresented in the Bachelor of Engineering Science as shown in Fig. 3. The percentage of female students varies between 11 and 16%. Comparable percentages have been reported in the past [5].

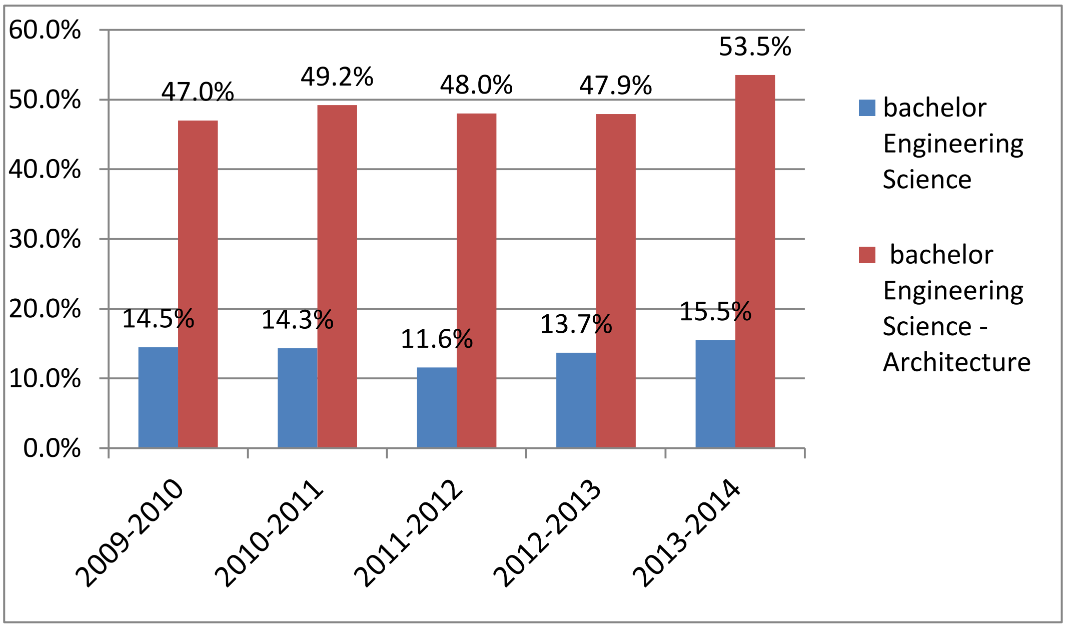

Fig. 3 Percentage of female students in the first year of the Bachelor Engineering Science and Bachelor Engineering Science – Architecture at KU Leuven during the last five academic years.

Positioning test results

The gender imbalance is already visible in the enrolment numbers for the 2013 positioning tests of July and September (*Fig. 2):* only 20% of the (unique) participants in the positioning tests are female. Moreover, the success rate of female participants was significantly lower than their male counterparts in the July positioning test (42% vs 60%) and in the September positioning test (45% vs 60%). The average score for female students was significantly lower (Student's T-test) as can be seen in *Table 1.*

Table 1. Average (and standard deviation (SD)) scores for the July and the September positioning test for different subsets based on gender (female vs male) and hours of mathematics in high school. Student's T-test significance for the gender difference (*: p<0.05, **:p<0.01,***:p<0.001, ns: not significant)

Test Scores	**July positioning test**			**September positioning test**		
	All	Female	Male	All	Female	Male
Average (SD)	10.03 (3.47)	8.81 (3.35)***	10.33 (3.44)	9.89 (3.40)	8.85 (3.40)**	10.23 (3.34)
8hrs math	10.87 (3.21)	9.61 (3.02)**	11.10 (3.20)	11.13 (3.19)	10.31 (3.04)^{ns}	11.35 (3.20)
6hrs math	8.61 (3.45)	7.94 (3.89)^{ns}	8.82 (3.47)	8.88 (2.95)	7.84 (3.20)*	9.26 (2.78)

What causes the gender difference?

Different possible explanations for the gender difference were further investigated.
First, the level of high school education is a determining factor for the individual test scores: the more hours of mathematics in high school curriculum, the higher the test scores. When taking the number of hours of mathematics in high school into account for the gender difference, the difference is

only significant for the eight hours math group in the July positioning test and for the six hours math group in the August positioning test (*Table 1* and *Fig. 4)*. The overall difference is related to the fraction of female participants that followed eight hours of math in high school: only 45% of female participants belonged to the eight hour-group versus 59% of the male participants in July (43% and 50% respectively in August). The pre-education level can thus not fully explain the gender difference.

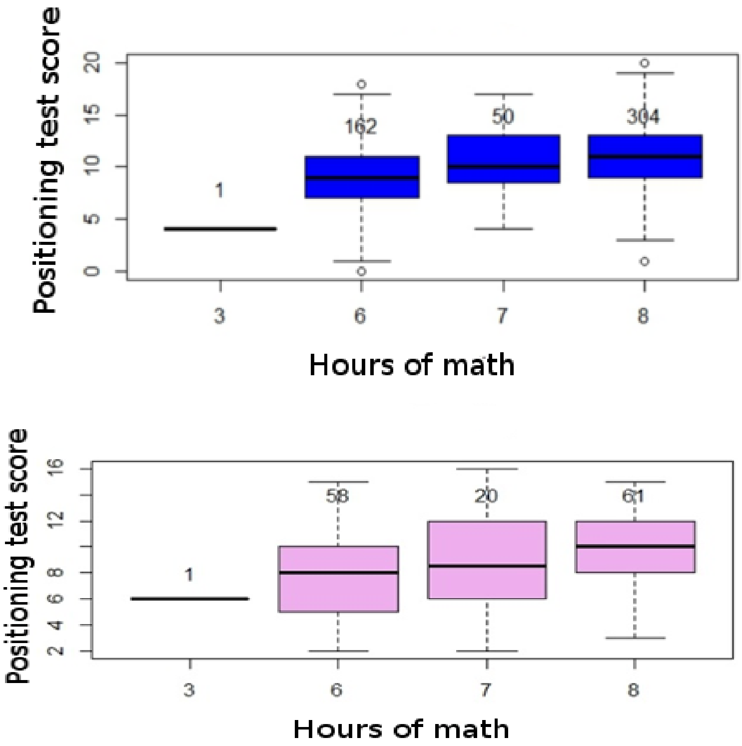

Fig. 4. Boxplots showing the positioning test results related to the pre-education (hours of mathematics in in high school).

Second, the score differences were further explored by looking at **the type of questions.** Female students perform worse on questions requiring graphical and spatial reasoning and more engineering-oriented questions. But, they score higher on questions requiring analytical skills and questions testing the application of mathematical theorems taught in secondary school. This is in accordance with literature [13].

Third, the effect of negative marking on the scores was investigated. As explained during the literature survey, several studies concerning the use of negative marking in MPQ-tests, as a means to discourage guessing, have pointed out a possible gender bias [8,9]. Risk-averse students tend to leave more questions unanswered (blank) while risk-prone students tend to guess when the odds are favourable. When some options of the MPQ can be eliminated, the possible gain from guessing between two answers (+1) is larger than the possible loss (-1/4) and thus, statistically, guessing is a good strategy. Female students are often considered more risk-averse than male students and thus the difference in test scores, when using negative marking, could be a consequence of not only more wrong answers, but also more unanswered questions. A detailed analysis revealed that both aspects contribute to the difference. As *Table 2* shows, female students indeed leave more questions unanswered. This difference is significant both for the July and the September positioning test. 0.98 of the 1.54 average difference in test score is explained by female students leaving more questions unanswered than male students. The other 0.56 of the 1.54 average difference in test score is explained by the fact that female students have more wrong answers than male students, for which the negative marking attributes a negative score (-1).

Table 2. Average (SD) number of unanswered questions for the July and the September positioning test for female and male students. Student's T-test significance for the gender difference (*: p<0.05, **:p<0.01,***:p<0.001, ns: not significant)

Unanswered questions (out of 35)	July positioning test			September positioning test		
	All	Female	Male	All	Female	Male
Average (SD)	4.69 (3.76)	6.07 (3.82)***	4.35 (3.67)	6.60 (3.40)	7.88 (3.40)**	6.18 (3.34)

3.4 Impact on enrolment

The impact of test results on the decision whether or not to enrol in the BSc Engineering studies does not seem to differ significantly between male and female students. Although the number of drop-outs before enrolment is too small to be statistically valuable (*Table 3*), the same trends can be observed for both sexes. The lower the positioning test score, the more students drop out before enrolment. This is particularly encouraging since literature [13] showed that female students have less self-confidence. Despite this lower self-confidence female students are not discouraged more by low positioning test results than male students. Furthermore, the female students with good positioning test results (>13), all enrolled. We therefore hope that the positioning test will increase the self-confidence of female students and attract more female students to engineering education.

Table 3. Number of participants in the 2013 positioning test that did not enrol in the Bachelor of Engineering at KU Leuven. Numbers are categorised depending on the test result and by gender.

	Number participants			Number of participants that did not enrol			% participants that did not enrol		
best score positioning test	**all**	**male**	**female**	**all**	**male**	**female**	**all**	**male**	**female**
<5	25	15	10	10	7	3	40,0%	46,7%	30,0%
5 -> 9	145	100	45	36	27	9	24,8%	27,0%	20,0%
10 -> 13	219	178	41	19	14	5	8,7%	7,9%	12,2%
>13	98	87	11	3	3	0	3,1%	3,4%	0,0%
TOTAL	**487**	**380**	**107**	**68**	**51**	**17**	**14,0%**	**13,4%**	**15.9%**

4 CONCLUSION

A new positioning test for the Bachelor of Engineering Science was broadly and uniformly implemented in Flanders in the summer of 2013. The non-mandatory test measures the ability of future engineering students to solve engineering problems and compares a student's mathematical skills with the required previous knowledge. This paper studied the impact of the positioning test for two target groups: students with disabilities and female students. These target groups are of particular interest: KU Leuven wants to offer students with disabilities equal opportunities and Flanders' engineering education suffers from a gender imbalance (15% female).

The positioning test uses an inclusive approach regarding students with disabilities. One of the findings it 77% of the students with disabilities who entered the bachelor studies passed the positioning test (compared to the general success rate of 75%). This shows that the inclusive approach is successful.

The statistical study regarding the target group of female students leads to these conclusions:

- Female students have a significantly lower success rate than male students. This can only be partially explained by the number of hours in mathematics in secondary education however.
- Regarding the impact of negative marking female students have a significantly higher number of blank answers. This is in accordance with literature, which attributes this effect to the more risk-averse behaviour of female students.
- Female students score lower on questions requiring graphical and spatial reasoning and typical engineering questions. But, they score higher on questions requiring analytic skills and questions testing the application of mathematical theorems taught in secondary school, which is in accordance with literature.

- The impact of positioning test results on the decision whether or not to enroll in the Bachelor of Engineering Science does not seem to differ significantly between male and female students. Even more, female students are not discouraged more by low positioning test results than male students. Furthermore, the female students with good positioning test results, all enrolled in 2013. We therefore hope that the positioning test will increase the self-confidence of female students and attract more female students to engineering education.

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