

Research Paper

Recommended Citation

A. Parul, & T. van Waterschoot (2024). Correlation Among Courses In Mathematics Trajectory Of Engineering Technology. Proceedings of the 52nd Annual Conference of SEFI, Lausanne, Switzerland. DOI: 10.5281/zenodo.14254760

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SEFI ANNUAL CONFERENCE 2–5 SEPTEMBER 2024 LAUSANNE

CORRELATION AMONG COURSES IN MATHEMATICS TRAJECTORY OF ENGINEERING TECHNOLOGY

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Conference Key Areas*: Improving higher engineering education through researching engineering education, Teaching foundational disciplines of Mathematics and Physics in engineering education*
Keywords*: Mathematics in engineering, Correlation analysis, Admission tests*

ABSTRACT

Mathematics has been an integral component in every engineering curriculum. This paper attempts to study the trajectory of the mathematics courses taken in the engineering technology curriculum of KU Leuven, Belgium, examining factors such as admission test scores, language and the ‘success’ scores for each mathematics course. The objective is to quantitatively analyze the performance of students at various stages in their mathematics trajectory. This paper utilizes correlation coefficients to comprehend the relationship between mathematics scores and students' diverse admission requirements. The study aims to uncover trends regarding the role of admission tests in determining their course ‘success’ rates. It also formulates conclusions about the mathematics courses taught in the program. The results provide valuable insights for students and teachers to make informed choices about students’ mathematics trajectory in engineering education.

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1 INTRODUCTION

There is a wave in universities, especially in Europe, that have introduced bachelor programs in English in order to attract international students. It is also not uncommon to see bachelor programs running in two launguages, simultaneously. One such example is, the Bachelor of Engineering Technology at KU Leuven, Belgium. The trajectories illustrated in this paper are using the data from this programme. We could ask the question, if it is possible to combine the different language programs in engineering education. But before we answer that question, it is essential to research if the current system elucidates certain inter-relationships within the same language medium as well as a different one keeping in mind clear distinguishing factors. One such factor is the admission requirements.

Students perceive mathematics as part of a degree program, a basis for other subjects or a tool to understand the outside world (Booth 2004). Fundamental mathematics courses are integral to engineering programs, often requiring students to pass them for degree completion. This motivates us to conduct a correlation analysis in order to observe relationships (positive or negative) that might already exist among the trajectories comprising of mathematics courses. Questions raised by students such as 'Will we ever use this math?' or 'Why do I need to pass this course?' highlight the need to analyze math scores and provide effective remediation and support. Students have varying attitudes towards mathematics, with 20% to 66% perceiving it as difficult. This attitude stems from students' educational background and prior math knowledge (Shaw & Shaw 1997,1999). Understanding students' views and performance is crucial to guide them and ensure their successful completion of the math curriculum. Mathematical tests are better predictor tests than those of other disciplines (Fonteyne et al. 2023, Pinxten et al. 2019). These predictions help provide students with insights into their progress toward trajectory completion. In this paper we focus our attention on student performances before and during the program. This leads to two research questions:

RQ1: What is the relation between the admission tests and courses in the mathematics trajectory of the students in engineering technology?

RQ2: What is the relation between the 3 fundamental courses in the mathematics trajectory of the students during the program?

For the former we use results from the IJkingstoets: Industrieel ingenieur industriële wetenschappen, which comprises of multiple choice questions on mathematics from Flemish secondary school level, and the mathematics section of the Scholastic Assessment Test (SAT) for international students. For the latter, exam results during the program are compared with each other.

The methodology used in this paper is correlation analysis, as the first quantitative step. Correlation research is non-intrusive and unbiased as we do not influence the data set and it provides a “very natural view” (Field 2009). Establishing correlations allows for interventions aimed at improving student performance beyond predicted scores. Institutes can then optimize their resources, time, and finance allocation. The optimization (or change) could be as magnanimous as having a single programme with different admission requirements or a single global exam for the programme in the two languages. Descriptive statistics, including mean and percentiles, are utilized to determine passing score thresholds in mathematics courses. Linear regression is employed to visualize any linear relationships between these scores.

A first hypothesis established at the beginning of this research was that the Ijkingstoets will have a higher correlation with the mathematics exams within the trajectory of the program than the SAT. A second hypothesis is that there will exist a sufficient correlation between the courses within the program itself, indicating an association in courses within the trajectory as well as between the ones taught in Dutch and English. Both these hypotheses have been validated by the results, although there are limitations to the analysis and factors that still need to be analyzed.

2 METHODOLOGY

2.1 Data set

Two data sets of students' scores are distinguised, one being drawn from the Dutch language program (NL) and the other from the English language program (ENG). The courses in each trajectory and their timeline are highlighted in Fig 1.

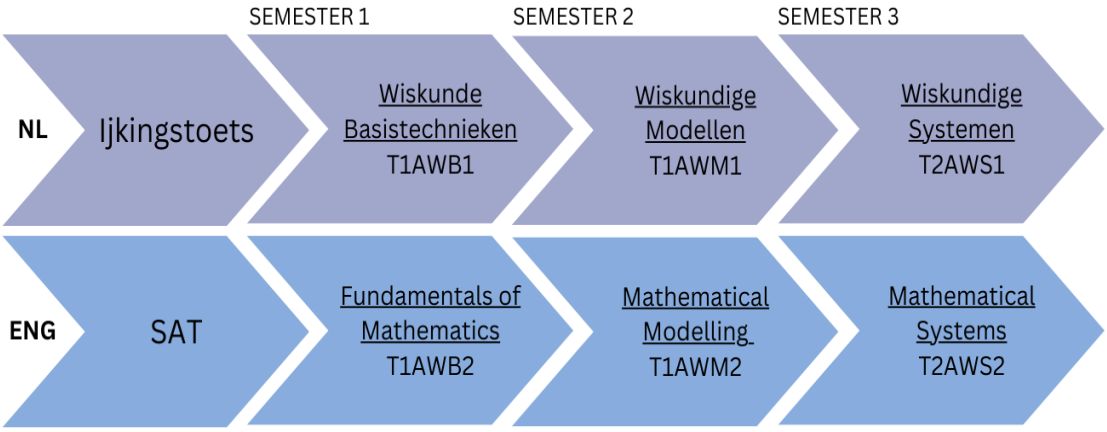


Fig 1: The NL and ENG trajectories with their respective admission tests, mathematics courses and corresponding course codes.

Both data sets consist of students' scores from the years 2020-2024. It should be noted that scores from 2020-2021 were obtained through a different evaluation procedure due to the COVID-19 pandemic. However, coursework and teaching structures remained consistent between equivalent courses taught in different languages. Table 1 shows the current stage of students for each admission year. Consequently, all analyses in the paper are conducted separately for each course in ENG and NL, annually.

Admission year	Graduation year	Currently in semester	Courses evaluated
2020	2023	/	All
2021	2024	6	All
2022	2025	4	All
2023	2026	2	T1AWB1/2

Table 1. The table shows courses evaluated for students in ENG and NL, as well as their current state in the program.

T1AWB1/B2 is a 1st semester course teaching three fundamental pillars of mathematics: analytic geometry, linear algebra, and single-variable calculus. It is followed by T1AWM1/2 in the 2nd semester, which covers multivariate calculus of scalar functions, differential equations, and vector-valued functions. The last course in the trajectory is T2AWS1/2, a second-year course, which focuses on signal transforms and mathematical systems theory.

2.2 Correlation Analysis, Means and Percentiles

Correlation study is as the third most commonly used method for quantitative analysis in educational research journals (Case & Light 2011). Several correlations coefficients can be used to study interdependence for various kinds of variables (Asuero 2006). In this study, both Pearson's correlation coefficient (*r)* and Spearman's rank correlation (ρ) were calculated between the samples from both datasets.

All tests are scored on a 20-point scale, except the SAT scores. However, since these are interval variables, they can undergo bivariate correlation analysis (Bryman 2015). To check the null hypothesis $\boldsymbol{H_0}$, a significance test (t-test) was used.

$\boldsymbol{H_o}$: No correlation exists between the two sample sets.

$\boldsymbol{H_A}$: There exists a significant correlation between the two sample sets.

$$\boldsymbol{\alpha} = .05$$

A significance level of $\boldsymbol{\alpha}$ =.05 was chosen, as is common practice in educational research (Del Siegle 2023).This analysis is used to answer both research questions. For **RQ1**, we start with finding correlation coefficients between Ijkingstoets scores and each of the NL program courses' scores: T1AWB1, T1AWM1 and T2AWS1. This is also done with SAT and ENG courses T1AWB2, T1AWM2, and T2AWS2. We further use values of means and percentiles of Ijkingstoets scores of students who successfully passed in the Math courses during the program. This helps us find a threshold bracket for the Ijkingstoets. For **RQ2**, we have used that same bivariate correlation analysis with $\boldsymbol{\alpha}$ =.05 on courses that are taken in 1st, 2nd and 3rd semester. The results are included in a joint plot comprising of histograms and scatter plots with a line of best fit with 95% confidence interval, providing a visual representation of the interdependence of the sample sets.

3 RESULTS

Limitations should be stated before discussing the results. There is an absence of information about those students who did not complete the course or left the program midway. There are students who switch from ENG to NL or vice-versa, whose scores have not been considered. Additionally, if a student attempted a course exam multiple times, only their best score was retained. The size of the data set for each bivariate comparison ranges between 80-700. For further details, the author can provide the code for each sample set considered. Each correlation coefficient has a variance that is dependent on the sample size, these are limits within which 80% of sample *r* values are found (Hole 2015). All course codes and colours used in this section are based on Fig. 1 explaining the trajectories. The analysis was also carried out for ρ, it yields similar values as *r.* Those results have been left out due to conciseness.

3.1 RQ1: Admission Tests vs Mathematics Courses

Table 2 shows the correlation coefficients for NL and ENG and for each admission year. The table is divided into two sections, one for Ijkingstoets and the other for SAT, showing the Pearson's correlation coefficient and the respective p-value for that sample set. Cases where H_A is accepted (p < .05) are shown in green, while cases where H_o is accepted (p ≥ .05) are shown in red. Indicated in yellow are the correlations that may or may not be significant, as their p-values are very close to .05

Ijkingstoets		T1AWB1	T1AWM1	T2AWS1	SAT	T1AWB2	T1AWM2	T2AWS2
2020	*r*	0.41	0.23	0.25		0.10	0.16	0.13
	p	<.001	.02	.04		.54	.34	.57
2021	*r*	0.17	0.12	0.12		0.42	0.40	0.03
	p	<.001	.05	.13		<.001	<.001	.87
2022	*r*	0.24	0.22	0.16		0.23	0.11	-0.02
	p	<.001	.01	.16		.02	.29	.90
2023	*r*	0.49				0.17		
	p	<.001				.09		

Table 2. Correlation coefficient r and two-sample t-test with p values, for courses in NL(Left) and ENG(Right).

3.2 RQ1: Ijkingstoets vs Passed in Mathematics Courses

Admission year	Ijkingstoets	T1AWB1 ≥ 10	T1AWM1 ≥ 10	T2AWS1 ≥ 10
2020	Mean	14.99	14.90	15.17
	Q1-Q2-Q3	12 - 17 - 18	14 -15 -17	12-17-18
2021	Mean	9.60	9.34	9.35

	Q1-Q2-Q3	6 - 10 - 13	6 -10 -13	6 -10 -13
2022	Mean	9.82	10.53	10.79
	Q1-Q2-Q3	8 - 10 -12	8.5 -11- 12	9 -11-12
2023	Mean	15		
	Q1-Q2-Q3	14 -15 -17		

Table 3. Mean and Quartiles (25,50 and 75) for Ijkingstoets scores, from students who passed the respective courses in NL.

To pass a course, a student must receive a score of 10/20 or higher in the evaluation, which is considered a 'success'. In Table 3, the mean score of Ijkingstoets for the years 2021 and 2022 differs from the ones in 2020 and 2023, as the test had a different method of grading. We do this only for Ijkingstoets as there are more significant correlations than that for SATs.The mean indicates the average score in the Ijkingstoets of those students who passed the course.

3.3 RQ2: Correlation among Mathematics Courses

Course pairs	Language	*N*	*r*
T1AWB1-M1	NL	717	0.75
T1AWB1-S1		441	0.38
T1AWM1-S1		432	0.22
T1AWB2-M2	ENG	381	0.82
T1AWB2-S2		209	0.41
T1AWM2-S2		201	0.33

Table 4. Sample size and r-value for course pairs in NL (purple) and ENG (blue)

The scatter plots in Figure 2 indicate a line of best fit, created using the regression plot. The shaded edge of each line indicates the confidence interval. The histograms display frequency on the y-axis. Unlike the previous analysis, the data set for each course is not divided annually. The scores from the years 2020, 2021 and 2022 are combined into one data set, for each course, as the correlations for each year showed similar *r* values. The sample size *N* and the *r* values for each of the pairings in ENG and NL are indicated in Table 4.

4 Discussion & Conclusions

RQ1: The first thing to notice is that the *r*'s for which we accept the alternate hypothesis are indeed all positive correlation values. In general, Ijkingstoets has a higher correlation to exam results than SAT. As stated previously, we must treat results carefully in ENG. In contrast to NL, students in ENG come from various countries with different educational systems. While rejecting H_A for most cases in ENG it is possible that we made a type I error and those variables would be correlated. The data set for ENG has more factors than NL that may have had an effect on the r values to show non-linearity.

There are twice as many significant correlations in Table 2 for Ijkingstoets than for SAT. These correlations are not very high but more significant than the ones between ENG courses and SAT. This is most clear for T1AWB1 and T1AWM1, which are taken in the first year of the program. However, the linear relation is not as strong as students move into the 2nd and 3rd semesters. This indicates that the interdepedence of the admission tests with courses decreases as time passes.

SAT is a standard test that international students can take. However, it may not be the best indicator of admission requirement. Perhaps students starting in ENG need to be informed about their SAT scores not being the best indicator of their success in it. Comparing the topics tested in Ijkingstoets vs. SAT reveals that the latter does not test calculus, whereas it is a recurring topic in the three courses.

Another factor to consider is that the Ijkingstoets is a Flemish examination based on the secondary school curriculum that is taught in Flanders, which are aligned better with the topics of T1AWB1/2, T1AWM1/2 and T2AWS1/2. The nature of this test is mandatory but not binding, which means the low scorers can also start the program and also contribute to the *r* value. This is another major difference between the SAT and the Ijkingstoets. Since the SAT has a cut-off admission criterion, only high scorers are in the data set. These low scores that exist for the Ijkingstoets contribute to the positive yet low value of the correlation coefficient for NL, unlike the SAT scores.

The above discussion suggests that we could use Ijkingstoets as a predictor for student "success".

We find the range of the Ijkingstoets scores that would predict the passing of the course ($\geq$10) using Table 3. Each year shows a mean score greater than 9, which indicates that students who “almost pass” the Ijkingstoets are highly likely to pass the courses. This conclusion needs to be made keeping in mind the nature of the Ijkingstoets as there are students who might not percieve the test as an important one or one that is high stakes. Table 2 also shows quartiles, which gives us a range for each year. A recurring pattern that is observed is that the quartile range is consistent for all courses, in a single year. The years 2021 and 2022 have a range of 6-13 and 8-12 already indicating that if a student is in this range they pass all 3 mathematics courses.

RQ2: The *r* values in Table 3 are all significant based on the t-test, hence indicated in green. This shows that each mathematics course in the curriculum is interdependent with each other as well as across the two language mediums. It is important to note that the topics taught in each of these courses are different but not mutually exclusive and each introduces pre-requisite knowledge for other disciplines such as mechanics, dynamics, and statistics.

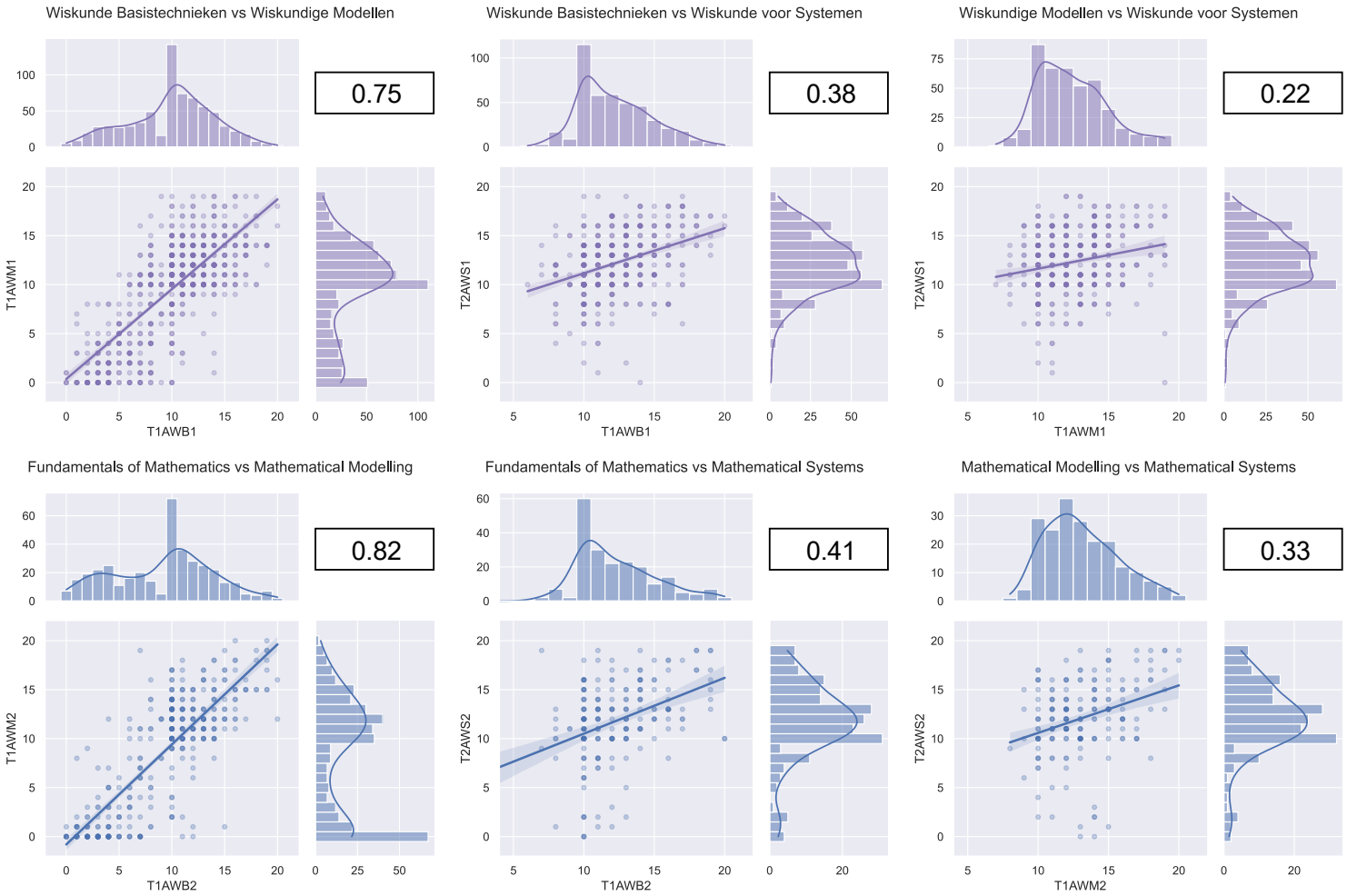


Fig 2: Each plot contains a scatter plot and line of best fit for the scores obtained on two courses. It also shows a histogram with its kernel density estimator (KDE) for each course. The value r is shown in the black box. Purple (top row): NL Blue (bottom row): ENG

The correlations between T1AWB1/M1 is 0.75 and T1AWB2/M2 0.82. These values are signifcantly higher compared to the ones calculated with the admission tests. The sample set is larger as there are no dropouts. T1AWB1/S1 and T1AWB2/S2 show 0.41 and 0.38 respectively, which is positive but lower than between the 1st year courses. The line of best fit for ENG shows slopes higher than those of NL, analogous to the correlation values. We notice the value of N in Table 4. reduces for the 2nd and 3rd courses and the drop out percentage is higher for NL students.

New research questions arise based on this analysis: Do Flemish students realise that the program is not fit for them based on first year scores? Are international students motivated to perform better? Some students' perceptions are affected based on their scores, especially the scores of the Ijkingstoets (Hanssens 2023). We also see a higher correlation between T1AWB1/2 and T2AWS1/2 than T1AWM1/2 and T2AWS1/2 indicating that students get more positive results in the 3rd semester/2nd year. This could be because they take time to adapt to the evaluation procedure or to understand the curriculum better and that students are confident about their choice of program. Reading into the histograms of Figure 2, for the course T2AWS1/2 and T1AWM1/2 we notice the count being higher for grades ≥ 10. The curves peak at values higher than the passing grade, indicating students aim and manage to score higher than how they performed in the 1st semester.

5 RECOMMENDATIONS & FUTURE WORK

Interpretation of attempts as a factor in the future analysis: This study only retained each student's highest score for each course as the data points in ENG and NL. However, all students get multiple chances to pass the course and each attempt familiarises the student with the course content as well as the exam questions. We propose to use the factor of average number of attempts for a student to successfully pass a course. This could be used to check the difficulty level of the course. However, even though it has the same content, no two tests are the same, so this would be a difficult factor to implement while finding these correlations (DePascale & Gong 2020).

Non-significant p values to be studied further: We have said that some correlations are insignificant based on p values ≥ .05. These non-significant results are common and often misrepresented in educational research. These misinterpretations have to be corrected, mostly via theory and practice. The non-significant r values in this paper could be interpreted further using models. (Edelsbrunner & Thurn 2024, Andrade 2019).

Using Positioning Test as a control group: The Ijkingstoets in English, also known as the Positioning Test, is available to students. This is mostly accessible to European students who manage to arrive in Belgium in time for the test. This set could serve as a good control group, but the frequency of these data points does not compare to those of SAT and Ijkingstoets. There are several international tests that are also accepted as pre-requisites: ACT, OPMDT and Benchmark Tests. They have the same limitation as the positioning tests.

Predictive Models to create informed remediation: Admission tests help students make an informed decision about the program before they start it. They could choose to drop out and start another program or choose remediation. The other option is to build a predictive model that informs them about their progress during the study. The prediction with a confidence interval would make them aware of where they stand in the trajectory. This could also have a major counter effect: instead of motivating students, it might lead students to taking their coursework lightly.

6 ACKNOWLEDGEMENTS

This work is a part of research conducted by Research and Education – Educational Development and Study Career Guidance, Group T Leuven Campus and is supported by KU Leuven Internal Funding.

REFERENCES

Andrade C. (2019). The *P* Value and Statistical Significance: Misunderstandings, Explanations, Challenges, and Alternatives. *Indian journal of psychological medicine*, *41*(3), 210–215. https://doi.org/10.4103/IJPSYM.IJPSYM_193_19

Asuero, A. G., Sayago, A., & González, A. G. (2006). The correlation coefficient: An overview. In *Critical Reviews in Analytical Chemistry* (Vol. 36, Issue 1, pp. 41–59). https://doi.org/10.1080/10408340500526766

Booth, S (2004), 'Learning and teaching for understanding mathematics', Paper presented at 12th SEFI seminar on teaching mathematics, 2004/06/14.

Booth, S. (2008). Learning and teaching engineering mathematics for the knowledge society. *European Journal of Engineering Education*, *33*(3), 381–389.

https://doi.org/10.1080/03043790802090232

Bryman, A. (2015). *Social Research Methods* (5th ed.). Oxford University Press.

Shaw, C. T., & Shaw, V. F. (1997). Attitudes of first-year engineering students to mathematics—A case study. *International Journal of Mathematical Education in Science and Technology*, *28*(2), 289–301. https://doi.org/10.1080/0020739970280210

Case, J. M., & Light, G. (2011). Emerging methodologies in engineering education research. *Journal of Engineering Education*, *100*(1), 186–210. https://doi.org/10.1002/j.2168-9830.2011.tb00008.x

DePascale, C., & Gong, B. (2020). Comparability of individual students' scores on the "https://naeducation.org/wp-content/uploads/2020/04/2-Comparability-of-Individual Students'-Scores-on-the-"Same-Test".pdf

Del Siegle, University of Connecticut, Accesesed on 01/12/2023 https://researchbasics.education.uconn.edu/correlation/

Edelsbrunner, P. A., & Thurn, C. M. (2024). Improving the utility of non-significant results for educational research: A review and recommendations. *Educational Research Review*, *42*. https://doi.org/10.1016/j.edurev.2023.100590

Field, A. P. (2009). Discovering statistics using SPSS : (and sex and drugs and rock "n" roll). SAGE Publications.

Fonteyne, L., Acke, S., Hanssens, J., Marconato, A., Schütz, J., Tambuyzer, B., de Laet, T., & Melis, I. Validiteitsrapport Ijkingstoetsen *February 2023*.

Hanssens Leuven, J. K., Greet Langie Leuven, B. K., Carolien Van Soom Leuven, B. K., Hanssens, J., Langie, G., & van Soom, C. (2023). Students' Perceptions of Low Stakes Positioning Tests at the Start of Higher STEM Education: A Mixed Methods Approach. *International Journal of Education in Mathematics*, *11*(5), 1094–1112. https://doi.org/10.46328/ijemst.2889

Hole, G. (2015) *Research Skills One, Correlation interpretation, Graham Hole v.1.0.*. *Eight things you need to know about interpreting correlations*.

IJkingstoets : Industrieel ingenieur industriële wetenschappen (in)

https://www.ijkingstoets.be

Pinxten, M., Van Soom, C., Peeters, C., De Laet, T., & Langie, G. (2019). At-risk at the gate: prediction of study success of first-year science and engineering students in an open-admission university in Flanders—any incremental validity of study strategies? *European Journal of Psychology of Education*, *34*(1), 45–66. https://doi.org/10.1007/s10212-017-0361-x

The Digital SAT ® Suite of Assessments Specifications Overview. (n.d.). 2024 https://satsuite.collegeboard.org/media/pdf/digital-sat-test-spec-overview.pdf