2018 ASEE Annual Conference & Exposition
Paper ID #22975

Study Success of Transfer Students in Engineering Technology: the Effect of a MOOC and a Math Diagnostic Test

Mrs. Lynn Van den Broeck, Faculty of Engineering Technology, Leuven Engineering Science and Education Centre (LESEC), KU Leuven

Lynn Van den Broeck has a master in Engineering Technology and is doing a PhD. Her research focuses on predicting academic achievement of transfer students by setting up a validated diagnostic test for professional bachelor students in their third year, who are thinking about bridging. The second goal is to develop interventions and investigate their effectiveness.

Prof. Tinne De Laet, KU Leuven

Prof. dr. ir. Tinne De Laet is tenure track professor at the Faculty of Engineering Science, KU Leuven. She obtained a doctoral degree in Mechanical Engineering in 2010 at KU Leuven, Belgium supported by a scholarship of the Research Foundation – Flanders (FWO). She was a post-doctoral researcher of the Research Foundation – Flanders (FWO) at KU Leuven from 2010-2013. In 2013 she obtained a tenure track position, focusing on engineering education and supporting and counselling of students in particular during the transition from secondary to higher education. She is the Head of the Tutorial Services of Engineering Science, providing her with first-hand experience on the transition from secondary to higher education.

Prof. Carolien Van Soom, KU Leuven, Faculty of Science, LESEC

Carolien Van Soom is associate professor at the Faculty of Science of KU Leuven and head of Tutorial Services in Science. Her research interest focuses on predictors of study success and dropout in first year STEM-programs. Topics include the interrelationship of cognitive and motivational factors related to a successful transition into higher STEM-education, and changes in motivation and self-concept during the first year of higher STEM education, with special focus on gender differences.

Prof. Marlies Lacante, KU Leuven & University Free State (South Africa)

Marlies Lacante is professor at the faculty of Psychology and Educational Sciences of the KU Leuven and at the Leuven Statistics Research Centre. She is also Associated Research Fellow at the University of the Free State (South Africa). Her research is focused on educational career choice and career development, transition from secondary to higher education, drop out in higher education, learning and study strategies, role of gender, methodology used in educational research (including test construction).

Prof. Greet Langie Langie, KU Leuven

Greet Langie holds a MSc degree and PhD in Physics from the University of Leuven (Belgium). From 2009-2011 she was the chair of LESEC (Leuven Engineering and Science Education Center, http://set.kuleuven.be/LESEC), a research center focusing on applied educational research in engineering and science HE-programmes. From 2012 until now she's the vice dean of the Faculty of Engineering Technology (KU Leuven, Belgium). In her research she's focusing on the transition from secondary to university within the STEM-field. She's the project coordinator of the two following Erasmus+ projects: (1) readySTEMgo, in which she focuses on early identification of STEM readiness and on targeted academic interventions (see http://iiw.kuleuven.be/english/readystemgo) and (2) PREFER, in which she studies professional roles and employability of future engineers (see http://preferproject.eu/). Greet Langie is committee chair capacity building within SEFI, she's a member of the SEFI Physics Working Group (http://www.sefiphysics.be/) and she is the co-organizer of the PTEE-conferences.

Study success of transfer students in Engineering Technology: The effect of a MOOC and a math diagnostic test

1. Introduction

The demand for engineering graduates is so high that employers struggle to fill the vacancies [1], [2]. The number of engineering students is increasing and due to a more flexible higher education system even more students can gain access to an engineering program. Although it can be applauded that more students can enter higher education, the question emerges if all these students are prepared for university. Many studies already investigated the readiness of traditional first-year students [3], [4], [5]. In this study the focus is on the transfer students in Engineering Technology and how their math readiness can be improved.

1.1 The Flemish education system

There are no admission requirements in Belgium, except in medicine and dentistry. As a consequence, students are free to enroll in almost every study program in higher education. More specifically for STEM, even students who had little mathematics during secondary education are allowed to enroll in a STEM study program without any restrictions. Obviously some of these students have some catching up to do in Mathematics, since they lack the appropriate prior training and knowledge. Admission requirements, however, do not always solve the problem of deficiencies in the core mathematical knowledge [6].

Figure 1 provides an overview of the Flemish higher education system. There are two types of Bachelor's degrees: a professional and an academic one. Both Bachelors have a total weight of 180 ECTS, resulting in a three-year study program (60 ECTS/year). The purpose of a professional Bachelor's degree, organized at a University College, is to prepare the student for a professional occupation. An academic Bachelor's degree, organized at a University, is intended to acquire all the necessary knowledge and skills to start a Master's program. The professional Bachelor's program has a more practical approach, while the academic Bachelor's program is more conceptual and theoretical.

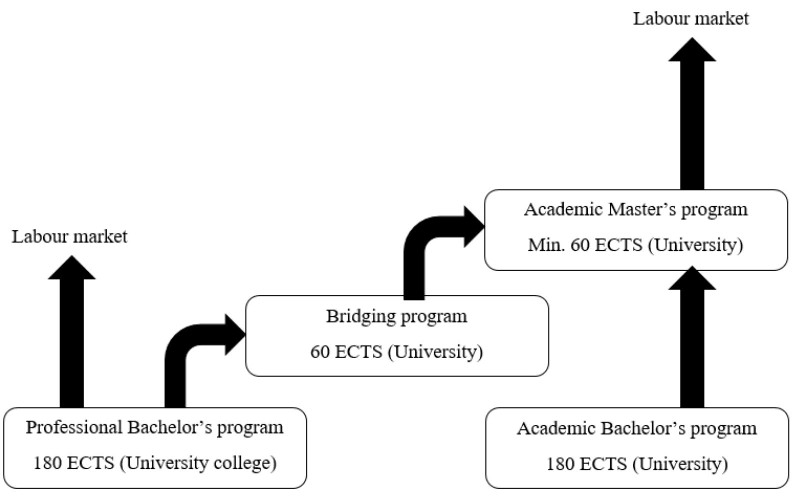

Figure 1. Flemish higher education system

In order to stimulate flexible lifelong learning, the educational system of Flanders (and also that of other countries, such as the US, Finland, Ireland, and Denmark) provide alternative ways to enter a Master's program in addition to the traditional academic Bachelor's program. In Flanders, students who obtained a professional Bachelor's degree can enroll into an academic Master's program on the condition that they successfully complete a transfer program. A transfer program focuses on the missing competences that are required to start a Master's program. Transfer programs are designed for 1) students who discover during or immediately after the professional Bachelor's program that they are interested in more conceptual and theoretical knowledge about their discipline, 2) students with low academic self-concept who hope to become more mature and more self-confident when they obtain a professional Bachelor's degree first or 3) professionals who need supplementary certificates for new job opportunities.

1.2 Transfer programs

The Faculty of Engineering Technology (FET) at KU Leuven organizes regular programs and transfer programs in Engineering Technology. Each year, about 6000 students are studying at FET. In the academic year 2017-2018 a total of 1169 new students started the academic Bachelor program and 561 new students enrolled in the transfer program.

The structure of the two programs is very comparable: 1) a discipline independent, general program at the beginning that focuses on courses such as mathematics, mechanics, and electricity of three semesters. 2) followed by a discipline specific specialization afterwards, e.g. Mechanical Engineering, Chemical Engineering, and Electrical Engineering. The academic Bachelor students have this general program during the first three semesters. The transfer programs are mostly one-year study programs, of which the first semester consists of a reduced discipline independent general program

Unfortunately, the transfer program has a high dropout rate (30-40%). Possible explanations for this limited number of successful transfer students are: the level of difficulty of the program, and the fact that not all the transfer students possess the proper prior knowledge or learning strategies [7]. The low success rate of this large population of students combined with the fact that these students already possess a valuable degree in Technology identifies them as an interesting research population.

A previous study revealed that the transfer students at FET have similar characteristics as first-year engineering students [8]. During focus group discussions both lecturers and transfer students indicated mathematics as a major stumbling block. Transfer students, even more than first-year students, are in need of an opportunity to refresh their mathematical knowledge since the PBA contains no or little math courses. In addition, a majority of the transfer students followed a secondary education with low (< 4 hours of mathematics/week) or medium (4 or 5 hours of mathematics/week) level of math.

2. Math in Engineering education: diagnostic tests and interventions

Since mathematics is defined as a major stumbling block and because the majority of the transfer students lack the proper prior math training, it becomes clear that transfer students are in need of 1) a tool to refresh their mathematical knowledge and 2) a test to define possible math deficiencies before starting the transfer program. In this section the role of mathematics in engineering education, diagnostic testing, and the benefit of interventions (both on-campus as online) are discussed. Combining this information, will lead to the scope of our paper and corresponding research questions.

Mathematics has a key role in every engineering program, so it is not surprisingly a significant predictor for academic achievement [9], [10]. Pinxten et al. [11] found that Math level and math/science GPA in secondary school are strongly related to the GPA of first-year STEM students. Moses et al. [12] and Hall et al. [13] concluded that math readiness is predictive for retention at University. They found that SAT math and ALEKS scores, which is a calculus readiness exam that is administered to each student during the summer before starting with the program in the fall, are both significant in the performed logistic regression. In a study of Ackerman et al. [14] the variables SAT math and math/science self-concept were significant for predicting STEM students' grades. Another study revealed that the academic self-concept of STEM students is a significant predictor of academic achievement [15]. This indicates that not only the cognitive part of mathematics is important, but also the non-cognitive aspect is noteworthy. Nihan er [16] carried out a study in which he asked the perspectives of a total of 737 lecturers about the math readiness of their first-year students. His findings indicate that lecturers belief that students lack some mathematical ability of what they consider as important knowledge before entering higher education. This illustrates the widespread need for math diagnostic testing and interventions for transfer students..

2.1 Diagnostic tests

At many universities diagnostic tests are organized at the beginning of the academic year [17], [18], [19]. Using diagnostic tests can have numerous purposes such as gathering information about a cohort of students, identifying students at risk, identifying mathematical deficiencies, or finding out if and where remedial support is needed. Another possibility is to give the students the opportunity to fill in the diagnostic test before enrollment. The diagnostic test is then used as a tool to identify the students at risk in advance and provide them with this important information before enrollment so that they can use the test result in their educational choice process and eventually decide to choose another program [20].

2.2 Interventions

Identifying deficiencies or students at risk is important, but exploring possible remedial programs is equally important. Since students sometimes enter university with very heterogeneous backgrounds, it is of great importance to provide students with the possibility to catch up. For example Johnson and 'O Keeffe [18] examined the effect of a pre-university math transfer course for adult learners. They concluded that there was an increase in retention rates of students who participated in the transfer course. A similar study investigated the effect of a summer math intervention program. The participants took a math readiness exam before and after the intervention program and the scores were significantly higher [21]. Another option is to offer remedial support after enrollment. For instance at Budapest University of Technology and Economics students who failed the diagnostic test can enroll in a transfer course of math. Thanks to this transfer course, more students passed the 'Mathematics 1' course [22]. In another institution, the remedial support included setting up individual action plans and/or offering help through sessions in the Mathematics Learning Support Centre [19]. In a study of Forrest et al. [23] at-risk students were encouraged to use a math tutorial to increase their chances of passing the course. Results showed that at-risk students who successfully completed the math tutorial increased their odds of passing the course.

All the initiatives mentioned above take place on-campus, but in a world with continuously improving technology, online learning environments receive more and more attention. One of these fairly new online learning environments are MOOC's (Massive Open Online Course). The number of MOOC's is rapidly increasing. Over the past five years they gained popularity and at the end of 2017 there were more than 9000 MOOC's with a total of 78 million learners[1].

Many studies about MOOC's investigate participation patterns and motivations for predicting completion or performance [24], [25], [26], [27]. The reason for this is that in general the completion rate of MOOC's is very low. In another type of study of Daza, Makriyannis, and Riera [28] a MOOC with the aim of closing the gap between pre-university and university mathematics was developed and student perceptions of the MOOC were very positive.

3. Research questions

In this study a math diagnostic test and basic math MOOC are developed for transfer students at FET (see section 4.2). In these two tools the emphasis is on the core mathematical knowledge since math was defined as a major stumbling block and also because math has an important role in engineering programs. Students who intend to participate in the diagnostic test are advised to enroll in the MOOC first, in order to refresh the required knowledge on their own pace. The MOOC can also function as a remedial tool, when the diagnostic test results are not sufficient but students still decide to enroll in the transfer program.

In this study we are interested in the perceptions of the transfer students after following the MOOC, and in the actual knowledge gain they have made. The scope of this paper is to formulate an answer on the following four research questions:

> RQ1. Are there differences in the descriptive and item-analysis statistics of the diagnostic test between the two included cohorts?
>
> RQ2. What are the transfer students perceptions about a MOOC focusing on basic mathematics?
>
> RQ3. Do transfer students obtain better results on the diagnostic test if they prepare themselves via the MOOC?
>
> RQ4. What is the effect of this preparation on the predictive value of the diagnostic test?

---

[1] https://www.class-central.com/report/mooc-stats-2017/

4. Method

4.1 Sample

This paper includes the transfer students who participated voluntarily in the diagnostic test in 2015-2016 (Cohort 1, N=124) and 2016-2017 (Cohort 2, N=254). We checked if there were differences in prior academic achievement (i.e. GPA of the professional bachelor) between the two cohorts, but this was not the case. Only students of the cohort of 2016-2017 had the opportunity to refresh their mathematical knowledge via the MOOC. In some analyses fewer students were included due to missing information.

4.2 Tools

4.2.1 Diagnostic test

The objective of this diagnostic test is to 1) provide students information on their possible future academic achievement in the transfer program and thus stimulate them to make a well thought-out educational choice; and 2) encourage students to participate, if necessary, in intervention initiatives before or during their transfer program.

To construct the diagnostic test, the math lecturers selected five categories of subjects (i.e. algebra, calculus, elementary arithmetic, graphics, and geometry & trigonometry) and three levels of difficulty (i.e. easy, average and difficult). Every lecturer developed multiple choice (MC) questions for every category and difficulty level. Next, they answered each other's MC questions and indicated the difficulty level they found appropriate for every question. Only the questions they unanimously designated the same answer as correct, were retained. The difficulty levels of all the questions were discussed and changed, if necessary. Of all the retained MC questions, the aim was to select one easy, two average and one difficult question for each category. This set-up was selected to create a test that properly differentiates.

The mathematics test consists of 19 multiple choice questions and was organized in 2015-2016 (N=124) and in 2016-2017 (N=254). No adaptations were made to the diagnostic test, so both cohorts filled in the same multiple choice questions.

4.2.2 MOOC

Figure 2 shows the theoretical framework for the design and evaluation of MOOC's composed by Grover et al. [29]. In this framework the learning process depends on three main elements: interactive learning environment (ILE), learner background & intentions, and technology structure. These three factors also interact with each other to improve the learning process. By checking learning outcomes and gathering feedback from the learners via surveys or forums it will be possible to improve the MOOC based on evidence.

Figure 2. Theoretical framework for the design and evaluation of MOOC's - Grover et al. [29]

This framework was used during the development of the math MOOC. This development was a cooperation between the math lecturers, IT, and pedagogical supporters. The course consists of four modules (ILE – Content), which are divided in numerous subsections. The modules are enumerated below:

- Elementary arithmetic's A
- Elementary arithmetic's B
- Trigonometry, Geometry, Equations, Inequalities, & Linear systems
- Derivatives & Integrals

Every module contains video's, step-by-step exercises, study material, and self-tests (ILE – Instruction and Assessment). The estimated effort for completion the MOOC is between 8 and 12 hours. The MOOC was only available for the students of the cohort of 2016-2017.

Like the diagnostic test, participation to the MOOC is voluntary and not required to enroll in the transfer program. Students who wanted to participate in the MOOC were asked to fill in some demographic questions and the reason why they enrolled in the MOOC (Learner background and intentions). Although MOOC participation was non-compulsory and non-binding, there was a pass/fail mark after having completed this course, which was 70%.

4.3 Analyses

The first part of the analysis focused on the diagnostic test by comparing the test results of the two cohorts. To check the internal consistency, Cronbach's alpha and item-total correlations were calculated. The perception survey consisted of four questions: 1) Was the course a good preparation for the diagnostic test? 2) What did you think about the content of the course? 3) What did you think about the level of the course? and 4) Thanks to the course I have more confidence in my math knowledge. To investigate effects of MOOC participation, Independent Sample t-tests were performed to compare test results of students who participated in the MOOC and the ones who did not. To determine and compare the predictive value of the diagnostic test for study success of the two cohorts, the correlation between the test result and academic achievement (i.e. study percentage, a weighted average of exam results cf. GPA) was calculated.

5. Results

5.1 Diagnostic test

Table 1 shows the descriptive statistics of the diagnostic test. For both cohorts, the mean score is under the 50%, but the cohort of 2016-2017 obtains significant higher test results (t=3.601, p<.001).

Table 1. Descriptive statistics diagnostic test

Descriptive statistics	Mean	SD	N
2015-2016	42.15%	15.39%	124
2016-2017	49.19%	18.93%	254

Figure 3 and 4 present the distribution of the test result. The red vertical line represents the mean score.

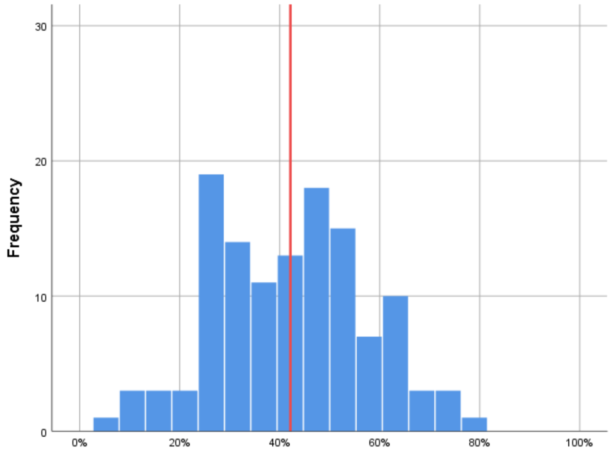

Figure 3. Histogram diagnostic test 2015-2016

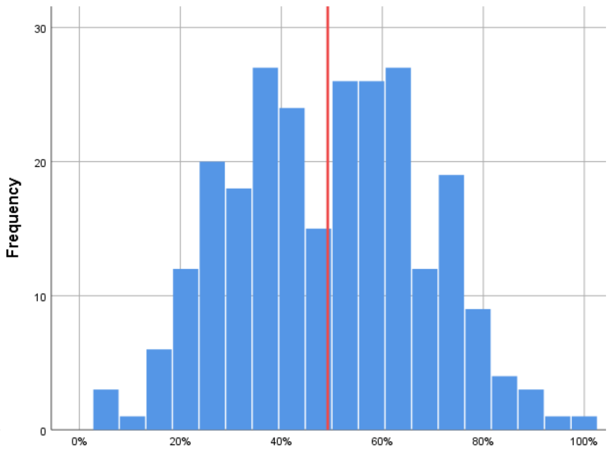

Figure 4. Histogram diagnostic test 2016-2017

Table 2 and 3 include the proportion of correct answers for every question of the diagnostic test. In 2015-2016 the proportion of correct answers varied between 0.12 and 0.69. In 2016-2017 the range was between 0.14 and 0.79. Also the item difficulty, as indicated by the lecturers, is mentioned in these tables. It should be noted that the item difficulty does not always match with the actual proportion of correct answers. E.g. Q11 was marked as a difficult question but answered correctly by 74% (2015-2016) and 79% (2016-2017) of the students.

Table 2. Proportion correct/distractor 2015-2016

p/d values 2015-2016	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19
a	0.02	0.19	0.11	0.10	0.02	0.06	0.02	0.07	0.19	0.09	0.04	0.06	0.01	0.09	0.05	0.02	0.27	0.08	0.68 $^{\alpha}$
b	0.39 $^{\alpha}$	0.25 $^{\alpha}$	0.16 $^{\alpha}$	0.02	0.52 $^{\alpha}$	0.31	0.45 $^{\alpha}$	0.02	0.13	0.07	0.08	0.09	0.00	0.18	0.02	0.35 $^{\alpha}$	0.06	0.04	0.11
c	0.50	0.06	0.11	0.02	0.06	0.02	0.31	0.06	0.07	0.34 $^{\alpha}$	0.04	0.11	0.10	0.05	0.08	0.11	0.39 $^{\alpha}$	0.69 $^{\alpha}$	0.10
d	0.05	0.02	0.09	0.04	0.08	0.01	0.02	0.69 $^{\alpha}$	0.12 $^{\alpha}$	0.06	0.74 $^{\alpha}$	0.12	0.40 $^{\alpha}$	0.41	0.52 $^{\alpha}$	0.18	0.02	0.05	0.03
e	0.01	0.02	0.15	0.18 $^{\alpha}$	0.17	0.57 $^{\alpha}$	0.15	0.11	0.11	0.04	0.04	0.40 $^{\alpha}$	0.11	0.17 $^{\alpha}$	0.15	0.03	0.04	0.04	0.06
Blank	0.03	0.48	0.37	0.64	0.16	0.03	0.05	0.06	0.37	0.40	0.06	0.22	0.37	0.10	0.19	0.31	0.22	0.10	0.02
Item diff.[1]	*	**(*)	*	**	***	*	**	**	***	*(*)	***	*(*)	**	***	*	**	**(*)	*	*

Note. The correct answer is marked with an $^{\alpha}$, the other options are distractors. [1]The item difficulty as indicated by the lecturers (*=easy, **= average, ***=difficult).

Table 3. Proportion correct/distractor 2016-2017

p/d values 2016-2017	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19
a	0.06	0.18	0.08	0.17	0.04	0.07	0.03	0.04	0.21	0.08	0.04	0.04	0.01	0.08	0.06	0.07	0.25	0.03	0.76 $^{\alpha}$
b	0.49 $^{\alpha}$	0.38 $^{\alpha}$	0.24 $^{\alpha}$	0.04	0.64 $^{\alpha}$	0.21	0.62 $^{\alpha}$	0.00	0.09	0.08	0.04	0.14	0.00	0.21	0.01	0.38 $^{\alpha}$	0.06	0.06	0.11
c	0.39	0.07	0.05	0.04	0.06	0.07	0.17	0.04	0.07	0.50 $^{\alpha}$	0.04	0.11	0.07	0.06	0.11	0.12	0.36 $^{\alpha}$	0.68 $^{\alpha}$	0.06
d	0.04	0.02	0.09	0.06	0.06	0.01	0.01	0.77 $^{\alpha}$	0.14 $^{\alpha}$	0.05	0.79 $^{\alpha}$	0.06	0.63 $^{\alpha}$	0.41	0.58 $^{\alpha}$	0.09	0.03	0.05	0.02
e	0.01	0.02	0.21	0.15 $^{\alpha}$	0.09	0.62 $^{\alpha}$	0.13	0.10	0.14	0.02	0.04	0.50 $^{\alpha}$	0.03	0.16 $^{\alpha}$	0.10	0.07	0.07	0.06	0.04
Blank	0.02	0.33	0.33	0.55	0.11	0.03	0.05	0.05	0.35	0.28	0.06	0.15	0.26	0.08	0.14	0.27	0.24	0.13	0.02
Item diff.[1]	*	**(*)	*	**	***	*	**	**	***	*(*)	***	*(*)	**	***	*	**	**(*)	*	*

Note. The correct answer is marked with an $^{\alpha}$, the other options are distractors. 1The item difficulty as indicated by the lecturers (*=easy, **= average, ***=difficult).

A good internal consistency (i.e. Cronbach alpha) is of great importance, since we want to develop a reliable instrument. In 2015-2016 the Cronbach alpha was 0.54, which is low. In 2016-2017 a much better consistency was found, namely 0.72.

Analyzing every item more in-depth can be done by calculating item-total correlations. Table 4 presents this item-total correlation for every question. Using Ebel's [30] rule of thumb: Poor (Rit < 0.20), Doubtful (0.21 < Rit < 0.29), Good (0.30 < Rit < .039), and Very good (Rit > 0.40), results in 12 poor, 5 doubtful, 1 good, and 1 very good item for the diagnostic test of 2015-2016. In 2016-2017 there were 4 poor, 4 doubtful, 7 good, and 4 very good items.

Table 4. Item-Total correlations

	Rit	
Items	2015-2016	2016-2017
Q1	0.17	0.33
Q2	0.17	0.16
Q3	0.05	0.31
Q4	0.19	0.34
Q5	0.18	0.37
Q6	0.21	0.35
Q7	0.16	0.27
Q8	0.24	0.30
Q9	-0.04	0.07
Q10	0.25	0.54
Q11	0.15	0.22
Q12	0.28	0.28
Q13	0.36	0.42
Q14	-0.05	0.10
Q15	0.40	0.45
Q16	0.15	0.13
Q17	0.17	0.43
Q18	0.29	0.35
Q19	0.13	0.27

5.2 MOOC

After students followed the MOOC and participated in the diagnostic test, they were asked to voluntarily answer some perception questions about the MOOC (N=52). 61% of the respondents found the MOOC a good preparation for the diagnostic test (Figure 5a). 83% found that the difficulty level of the MOOC was good (Figure 5b). 24% found the content too condensed and would have preferred a more elaborate course (Figure 5c). Regarding the confidence in their own math knowledge, 36% agreed that they had more confidence after following the MOOC, whereas 43% of the students answered neutral to this question (Figure 5d).

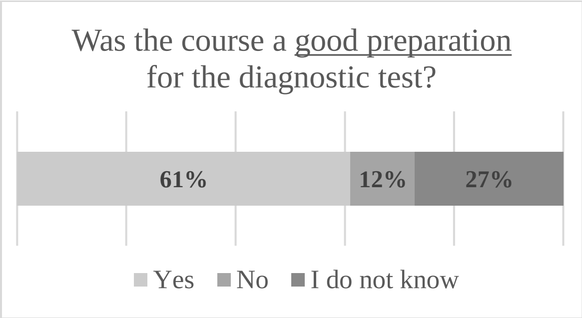

Figure 5a. MOOC perception survey (N=52)

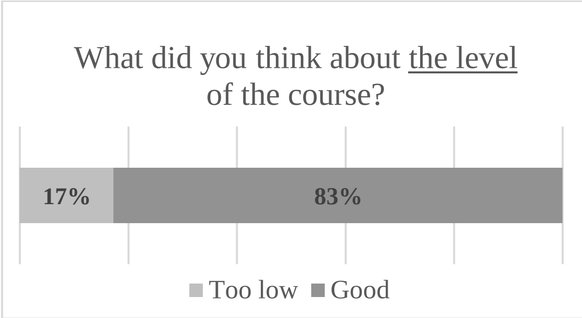

Figure 6b. MOOC perception survey (N=52)

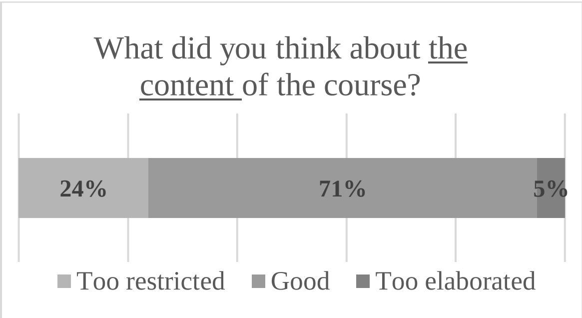

Figure 7c. MOOC perception survey (N=52)

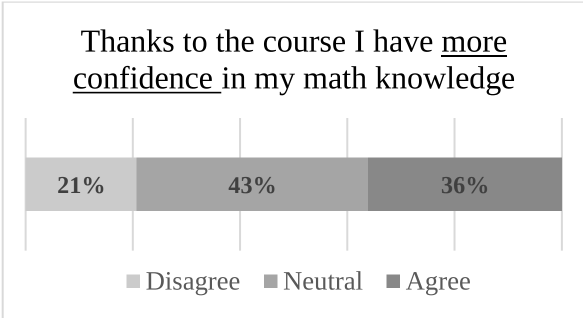

Figure 8d. MOOC perception survey (N=52)

Students who followed the MOOC (N=52) obtain significant higher results (t=3.186, p=.002) on the diagnostic test than the ones who did not (N=40) (Table 5).

Table 5. Differences in diagnostic test

Followed MOOC	N	Mean	SD	t
No	40	38%	23%	3.186
Yes	52	53%	21%	(p=.002)

This difference remained significant even when controlling for the level of math during secondary education (i.e. Low < 4 hours/week; Medium 4 – 5 hours/week; High > 6 hours/week) (Table 6).

Table 6. Differences in diagnostic test, controlled for level of math in secondary education

Level of math	Followed MOOC	N	Mean	SD	T
Low	No	5	18%	13%	1.503
	Yes	8	37%	26%	(n.s.)
Medium	No	17	29%	17%	3.301
	Yes	22	49%	20%	(p=.002)
High	No	17	50%	19%	2.206
	Yes	22	62%	15%	(p=.034)

For cohort 1, consisting of students that did not have the opportunity to prepare for the test (2015-2016), the correlation between the diagnostic test and the students' academic achievement (N=82) was not significant. In contrast, the diagnostic test for cohort 2 (2016-2017 (N=173)) correlated significantly at the 0.01 level with academic achievement (r=.32).

6. Discussions and conclusions

Both the internal consistency (2015-2016 α=.57; 2016-2017 α=.72) and the item-total correlations (Table 4) of the diagnostic test improved from cohort 1 to cohort 2, suggesting that the same test was more reliable in the second year. The fact that students could participate in the MOOC can be a reasonable explanation for this observation. Also the mean score was significant higher for the cohort of students that had the opportunity to prepare themselves (Table 1)(RQ1). In 2016-2017 the diagnostic test differentiated better in the group of participating transfer students, however by extending the test in the future with more questions we hope it will differentiate even more.

The perception survey of the MOOC (Figure 5a-5d) shows that in general transfer-students are satisfied with the course content and level. However a quarter of the students found the course too restricted and they need more modules (RQ2). As a consequence, the math lectures already developed two more modules and they are online since January 2018. This is a first step in an evidence based improvement as mentioned in the framework of Grover et al. [29].

Table 5 reveals that students who followed the MOOC obtain significant higher results on the diagnostic test than the ones who did not. Even after controlling for the level of math during secondary education the difference is significant (Table 6). Therefore there is reason to believe that the MOOC has a positive effect (RQ3). However, it would be worthwhile to repeat this analysis with another cohort to gather more evidence. The fact that MOOC participation was voluntary might have resulted in a self-selection of more motivated and more persevering students, which are known to be associated with higher academic achievement as well [15], [31]. In further research it would be interesting to analyze the profile of the students that participate in the MOOC. Another possibility is to check whether the diagnostic test can identify at-risk students, and determine if there are differences in academic achievement between the at-risk students who followed the MOOC and the ones who did not. The study of Forrest et al. [23] showed that at-risk students who completed the math tutorial increased their odds of passing.

In 2015-2016 there was no significant correlation between the diagnostic test and the students' academic achievement. In 2016-2017, when students had the opportunity to refresh their knowledge, a significant correlation (r=.32) with the academic achievement was found. It is reasonable that thanks to the MOOC students are not graded on their memory (i.e. remaining math knowledge of secondary education) but on their capacities (RQ4).

To conclude, the two mathematical tools (i.e. diagnostic test and MOOC) were found to be very useful. The MOOC is a good preparation and remedial tool. The diagnostic test is an aid for predicting the academic achievement of transfer students and can be used to provide students with information about their possible study success. However, it is important to point out that for students who did not have math in a long time, organizing a diagnostic test is only meaningful when they can refresh their math knowledge before the test.

References

[1] National Academy of Engineering. *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: The National Academies Press. 2004.

[2] UNESCO. *Engineering issues challenges and opportunities for development*. Paris, France. 2010. ISBN 978-92-3-104156-3

[3] D.T. Conley, "Redefining college readiness". Eugene, OR: Educational Policy Improvement Center. 2007.

[4] H. Lowe, and A. Cook, "Mind the Gap: Are Students Prepared for Higher Education?", *Journal of Further and Higher Education*, vol. 27, no.1, pp. 53–76, 2003.

[5] E.P.W.A. Jansen, and J. Van Der Meer, "Ready for university? A cross-national study of students' perceived preparedness for university", *Australian Educational Researcher*, vol. 39, pp. 1–16, 2012.

[6] M. Carr, B. Bowe, and E.N. Fhloinn, "Core Skills Assessment to Improve Mathematical Competency.", *European Journal of Engineering Education*, vol.38, no.6, pp.608–19, 2013.

[7] L. Van den Broeck, T. De Laet, M. Lacante, C. Van Soom, and G. Langie, "Creating an Optimized Diagnostic Test for Students Bridging to Engineering Technology." *Proceedings of the 43rd annual SEFI conference, Orléans, France, June 30–July 2, 2015.*

[8] L. Van den Broeck, T. De Laet, M. Lacante, M. Pinxten, C. Van Soom, and G. Langie, "Comparison between Bridging Students and Traditional First-Year Students in Engineering Technology." *European Journal of Engineering Education*, pp.1–16, 2017.

[9] C.P.Veenstra, E.L. Dey, and G.D. Herrin, "Is Modeling of Freshman Engineering Success Different from Modeling of Non-engineering Success?" *Journal of Engineering Education*, vol.97, no.4, pp. 467–479, 2008.

[10] B.F. French, J.C. Immekus, and W.C. Oakes, "An Examination of Indicators of Engineering Students' Success and Persistence.", *Journal of Engineering Education*, vol.94, no.4, pp. 419–425, 2005.

[11] M. Pinxten, C. Van Soom, C. Peeters, T. De Laet, and G. Langie, "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*, vol.145, no.3, pp. 229–45, 2017.

[12] L. Moses, C. Hall, K. Wuensch, K. De Urquidi, P. Kauffmann, W. Swart, S. Duncan, and G. Dixon, "Are Math Readiness and Personality Predictive of First-Year Retention in Engineering?" *The Journal of Psychology*, vol.145, no.3, pp. 229–45, 2011.

[13] C.W. Hall, P.J. Kauffmann, K.L. Wuensch, W.E. Swart, K.A. Deurquidi, O.H. Griffin, and C.S. Duncan, “Aptitude and Personality Traits in Retention of Engineering Students” *Journal of Engineering Education,* vol.104, no.2, pp. 167–88, 2015.

[14] P.L. Ackerman, R. Kanfer, and M.E. Beier, “Trait Complex, Cognitive Ability, and Domain Knowledge Predictors of Baccalaureate Success, STEM Persistence, and Gender Differences.”, *Journal of Educational Psychology,* vol.105, no.3, pp.911–27, 2013.

[15] C. Van Soom, and V. Donche, “Profiling First-Year Students in STEM Programs Based on Autonomous Motivation and Academic Self-Concept and Relationship with Academic Achievement.” *PloS One* , vol.9, no.11, 2014.

[16] S. Er Nihan,“Mathematics Readiness of First-Year College Students and Missing Necessary Skills : Perspectives of Mathematics Faculty.” *Journal of Further and Higher Education* pp.1–16, 2017.

[17] M. Carr, E. Murphy, B. Bowe, and E. Ni Fhloinn, “Addressing Continuing Mathematical Deficiencies with Advanced Mathematical Diagnostic Testing.” *Teaching Mathematics and Its Applications*, vol.32, no.2, pp. 66–75, 2013.

[18] P. Johnson, and L. O Keeffe, “The Effect of a Pre-University Mathematics Bridging Course on Adult Learners ’ Self-Efficacy and Retention Rates in STEM Subjects”, *Irish Educational Studies,* 2016.

[19] S. Lee, and C.L. Robinson, “Diagnostic Testing in Mathematics: Paired Questions.” *Teaching Mathematics and Its Applications,* vol.24, no.4, pp. 154–66, 2005.

[20] J. Vanderoost, R. Callens, J.P.L. Vandewalle, T. De Laet, “Engineering Positioning Test in Flanders : A Powerful Predictor for Study Success ?”, *Proceedings of the 42nd annual SEFI conference, Birmingham, UK, 15-19 September, 2014*.

[21] J.L. Hieb, K.B. Lyle, P.A.S. Ralston, and J. Chariker,“Predicting Performance in a First Engineering Calculus Course : Implications for Interventions.” *International Journal of Mathematical Education in Science and Technology*, vol.46, no.1, pp. 40–55, 2015.

[22] M. Pinxten, T. De Laet, C. Van Soom, C. Peeters, C. Kautz, P. Hockicko, P. Pacher, K. Nordström, K.Hawwash, and G. Langie “Approaches to the Identification of STEM Key Competencies in European University Systems,” *Proceedings of the 45th annual SEFI Conference, Azores, Portugal, 18-21 September, 2017.*

[23] R.L. Forrest, D.W. Stokes, A.B. Burridge, and C.D. Voight, “Math Remediation Intervention for Student Success in the Algebra-Based Introductory Physics Course” , *Physical review physics education research,* vol.13, pp. 1–8, 2017.

[24] P.G. De Barba, G.E. Kennedy, and M.D. Ainley, “The Role of Students ’ Motivation and Participation in Predicting Performance in a MOOC.”, *Journal of computer assisted learning,* vol.32, pp. 218–31, 2016.

[25] K.S. Hone, and G.R. El, “Computers & Education Exploring the Factors Affecting MOOC Retention : A Survey Study.” *Computers & Education*, vol.98, pp. 157–68, 2016.

[26] B.K. Pursel, L. Zhang, K.W. Jablokow, G.W. Choi, and D. Velegol, “Understanding MOOC Students : Motivations and Behaviours Indicative of MOOC Completion.”, *Journal of computer assisted learning,* vol.32, pp. 202–17, 2016.

[27] L.P. Rieber, “Participation Patterns in a Massive Open Online Course (MOOC) about Statistics”, *British Journal of educational technology,* vol.48, no.6, pp. 1295–1304, 2017.

[28] V. Daza, N. Makriyannis, and C.R. Riera, “MOOC attack: closing the gap between pre-university and university mathematics.”, *The Journal of Open, Distance and e-Learning,* vol.28, no.3, pp. 227-238, 2013.

[29] S. Grover, P. Franz, E. Schneider, and R. Pea, “The MOOC as Distributed Intelligence : Dimensions of a Framework & Evaluation of MOOCs.”, *Proceedings of the 10th Annual International Conference on Computer Supported Collaborative Learning (CSCL), Madison, WI, USA, June 2013.*

[30] R.L. Ebel, *Essentials of educational measurement.* Oxford, England: Prentice-Hall, 1972.

[31] L.E. Bernold, J.E. Spurlin, and C.M. Anson, “Understanding Our Students: A Longitudinal-study of Success and Failure in Engineering with Complications for Increased Retention.” *Journal of Engineering Education*, vol. 96, no.3, pp. 263–274, 2007.