Creating an optimized diagnostic test for students bridging to Engineering Technology

L. Van den Broeck[1]
PhD student at the Faculty of Engineering Technology
KU Leuven, LESEC (Leuven Engineering Science and Education Centre)
Leuven, Belgium
Lynn.vandenbroeck@kuleuven.be

T. De Laet
Head of Tutorial Services Engineering Science and Head of Leuven Engineering and Science Education Center (LESEC)
Tutorial Services, Faculty of Engineering Science, KU Leuven
Leuven, Belgium
Tinne.delaet@kuleuven.be

M. Lacante
Professor at the Faculty of Psychology and Educational Sciences
KU Leuven
Leuven, Belgium
Marlies.lacante@ppw.kuleuven.be

C. Van Soom
Head of Tutorial Services of the Faculty of Science
KU Leuven, LESEC
Leuven, Belgium
Carolien.vansoom@wet.kuleuven.be

G. Langie
Vice dean of the Faculty of Engineering Technology
KU Leuven, LESEC
Leuven, Belgium
Greet.langie@kuleuven.be

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INTRODUCTION

As in most countries, employers struggle to fill vacancies for engineers. The number of students in engineering programmes is increasing, but the dropout rates remain

[1] Corresponding Author
L. Van den Broeck
Lynn.vandenbroeck@kuleuven.be

high [1,2,3]. A lot of research has been done to find out which factors have an influence on persistence in higher education. Especially in STEM (Science, Technology, Engineering and Mathematics) performance in secondary education, math skills, and some personality traits like self-efficacy and conscientiousness seem to be significant predictors for persistence [1,4,5].

Obviously every STEM-institution wants to reduce these high dropout rates. In some countries, such as Belgium and Italy, there are no admission requirements. The first year of university can be considered as a “selection year” and a substantial drop out of first-year students seems inevitable. In Politecnico di Torino new students have to complete a diagnostic test, consisting of three parts namely mathematics, logic, and comprehension. A correlation was observed between a student’s score on the aptitude test and credits obtained during the first year at university [6]. A well-designed test can produce a wealth of information. For example it could allow us to predict study success and help us to pinpoint possible problems for each student individually. Therefore the STEM-faculties of KU Leuven (Belgium) have implemented a similar test, organised before enrolment. By filling in this test we want to stimulate students to reflect on their study choice more intensively and give incentives to participate at intervention initiatives before the beginning of the academic year (for example a mathematics summer course).

In the Belgian education system, there are two types of bachelor’s degree namely a professional and an academic one. The purpose of a professional bachelor’s degree is to prepare the student for a professional occupation. An academic bachelor’s degree on the other hand is intended to acquire all the necessary knowledge and skills to start a master’s programme. In order to stimulate a flexible lifelong learning system a student with a technical professional bachelor’s degree can sign in to a master’s programme provided that he successfully finishes a bridging programme. In Flanders this bridging programme counts a maximum of 90 ECTS points and focuses on the missing competences needed to start a master’s programme. This paper addresses students in the bridging programme from the professional bachelor to the master programme in Engineering Technology.

We will develop a non-compulsory and non-binding diagnostic test for these bridging students. In this paper we discuss the methodology that we implemented to develop an optimized diagnostic test. The main goal of this diagnostic test is to give students information about their possible future study success. If the results of the diagnostic test are not good at all we will stimulate them to reconsider their study choice. And we will encourage them to participate in intervention initiatives if the results are neither very good, neither very bad.

1 PROBLEM

30% of the graduates of technical professional bachelor’s programmes start a bridging programme to Engineering Technology. The Faculty of Engineering Technology at KU Leuven counts almost 900 bridging students. Unfortunately the success rate is comparable with the success rate of the first-year bachelor students and thus rather low. They possess already an economically valuable diploma. This failure however results in a negative experience and retardation in the entrance to the labour market. We need a diagnostic test to better orient and inform students before the start of the bridging programme.

In a preliminary analysis, the predictive value of a diagnostic test, originally designed for freshmen in an academic bachelor’s programme in Engineering Technology, was studied for bridging students. This test focuses on three topics: mathematics

(Mean=36,2% ;SD=14,9%) academic language skills (Mean=48,8% ;SD=21,5%) [7], and scientific reasoning (Mean=66,7 ;SD=18,5%) [8].

There was no correlation between the test scores on academic language skills and the subsequent exam scores of the bridging students in February, nor between the scientific reasoning skills (Lawson Test) and the exam scores. A weak correlation was found between the mathematic test and the exam scores (Pearson correlation 0,26 ; p = 0,040) [9]. This mathematic test consists of 17 questions. Ten of these questions are common with the diagnostic test in the Faculty of Engineering Science. For the Faculty of Engineering Technology the other seven questions are from a lower difficulty.

The Cronbach's Alpha of the mathematic test (17 items) was .40. A test is considered to be reliable when the Cronbach's Alpha is at least .70 [10]. By deleting some negative items the Cronbach's Alpha increases with .10 but this is still insufficient.

Overall, we can conclude that this diagnostic test does not focus on the right skills or doesn't contain the right items and is by consequence not the right one for our target audience. Therefore we are in need of a new test, which is predictive and gives an indication of necessary interventions. The methodology used will be explained in the following paragraphs.

2 METHODOLOGY

As a first step to optimize the test, we identified possible predictors of study success for bridging students by organising a qualitative research based on focus group discussions with different stakeholders.

2.1 General characteristics of the focus group discussions

- Asked questions: open questions, depending on the stakeholder
- Duration: at least one hour, at most two hours and a half
- Reporting method: all the focus group discussions were recorded and written out afterwards
- Relevant info: information was considered as relevant when the majority of participants shared a specific point of view

2.2 Focus group discussion with faculty members

- Number of group discussions: 1
- Number of participants: 12 (3 female, 9 male)
- Age distribution:
  - Between 25 – 35: 3
  - Between 35 – 45: 4
  - Between 45 – 55: 4
  - Between 55 – 65: 1
- Common property: lecturer (theory and/or exercises and/or laboratories) in the bridging programme during the first semester at Technology Campus De Nayer (KU Leuven).

2.3 Focus group discussion with educational and psychological experts specialized in test construction

- Number of group discussions: 1
- Number of participants: 5 (4 female, 1 male)

- Different specific properties:
  - Lecturers: 3 participants
  - Involved in developing and optimizing tests: 3 participants
  - Involved in research: 3 participants
  - Specialized in psych diagnostics: 1 participant
  - Student counselling: 2 participants

2.4 Focus group discussions with bridging students

- Number of group discussions: 5
- Total number of participants: 26 (5 female, 21 male)
- Properties:
  - All the students participated voluntary.
  - Freshmen in the bridging programme (23), repeaters (3)
  - Selected specialities: civil engineering (5), (bio)chemical engineering (6), electronics and ICT engineering (5), electromechanical/energy engineering (7), food industry bioengineering (1), agricultural and horticultural bioengineering (2)
  - Students from Technology Campus De Nayer (20), students from Technology Campus Geel (6) (KU Leuven)

3 MAIN RESULTS FOCUS GROUP DISCUSSIONS

In the following paragraphs we want to make an enumeration of the main results and considerations of the different focus group discussions.

3.1 Faculty members

<u>The profile of a bridging student:</u> In general (but not necessary applying to each student) these students have a well-developed practical understanding and they work hard during the laboratory sessions. Compared to freshmen in the academic bachelor programmes however, they have more problems with learning theoretical derivations, they apply less in-depth study strategies, they are missing a methodology to solve complex problems, they are in need of a critical attitude, and their lab reports are of a lower quality.

<u>Major stumbling blocks:</u> The two most important stumbling blocks according to the lecturers are:

1) study behaviour (in-depth learning, critical reflection, self-knowledge) and
2) basic knowledge of mathematics.

<u>Interventions:</u> The lecturers listed some examples of possible initiatives that can be useful for a bridging student: a summer course in mathematics, self-directed study modules on different topics, and intermediate tests during the academic year.

<u>Which predictors can we use to select good candidates?</u> According to the lecturers the study duration and study result of the professional bachelor's programme is an important predictor. A student who graduates in the normal period is considered to be a better candidate then a student who graduates with a delay. A student who graduates cum laude is more likely to be successful in the bridging programme. Finally, they suggest that the motivation of a student plays a very important role in study success.

3.2 Educational and psychological experts

Explanations for weak correlation and suggestions: The experts gave two possible explanations for the weak correlation of the mathematics test and corresponding suggestions:

1) Students who took this test, haven't had mathematic courses for almost three years. By consequence the test doesn't give a true image of their mathematic potential. Refreshing their mathematical knowledge prior to the test seems recommended.
2) Not all the questions reflect what the teachers expect from the bridging students. For example the test contains some quibbles, on which the students aren't examined during the bridging programme. A new test needs to focus on the prior knowledge, which is deemed necessary for the programme.

Feedback: Since feedback is of great importance, the experts advised to send an individual report to every student. This report consists of the student's scores on every test, the median of the group, and some personal advice. For example a student who is situated in the lower group, will get the advice to make an appointment for a conversation or will be redirected to an intervention programme.

3.3 Bridging students

Experienced difficulties during the bridging programme: In general the students have difficulties with the pace of the courses, the study load, the theoretical and mathematical approach of the courses, the required in-depth learning, and the fact that they need to motivate themselves over and over again to open up their books and study after courses.

Interventions: The students listed some possible interventions that could help them before the start and during the bridging programme: a course adapted to the bridging programme to refresh their mathematical knowledge, more tests and tasks during the academic year, and an introduction to the basic science courses such as chemistry, physics, and mechanics.

Feedback: They want to make an effort to complete a diagnostic test or to participate in several initiatives, but they are in need of feedback at the end.

4 SETTING UP AN OPTIMIZED DIAGNOSTIC TEST

The two major stumbling blocks defined by the lecturers and confirmed by the students were "study behaviour" and "basic mathematical knowledge". As a result, the new battery of tests will contain an optimized mathematics test, the LASSI (Learning and Study Strategies Inventory) test [11], and a cognitive test (based on the CHC-model) [12].

In the following paragraphs the composition of the new diagnostic test and the reasons for withdrawing the tests for language skills and scientific reasoning (Lawson test) is explained.

4.1 Reasons for withdrawing tests

The scores on the test focusing on academic language skills were not correlated to the exam scores of the bridging students (Pearson correlation -0,03; p = 0,829). These skills are however very valuable and meaningful for engineering students since they have to write reports, read documents and compose and defend their Master's thesis. Many bridging students received a technical training during Secondary Education and therefore often lack the required academic language skills.

Rather than testing academic literacy, we will implement intervention tools to improve their academic language skills.

Likewise the score on the Lawson scientific reasoning test was not correlated to the exam scores of the bridging students (Pearson correlation 0,09; p = .506). This scientific reasoning test focuses on problems from chemistry and physics. Most bridging students are missing this basic knowledge, so we have substituted it for a test that focuses on scientific reasoning in general (see cognitive test – logical reasoning).

4.2 Optimized mathematics test

Besides the fact that basic mathematics knowledge is a stumbling block, it is also proven that math readiness and results on a mathematics diagnostic tests are good predictors for study persistence and success in engineering courses [1, ,13,14,15].

By mutual agreement, the math lecturers composed a new mathematics test, adapted to our target audience. They distinguished five main categories for the basic knowledge of mathematics for bridging students: algebra, analysis, elementary math skills (such as fractions and powers), geometry/trigonometry, and graphs. Each question is marked by the lecturers according to the scale of difficulty: easy, normal, and difficult. The optimized version has 20 questions with four questions per category (one easy, two normal, one difficult).

4.3 LASSI (Learning and Study Strategies Inventory)

The second and maybe the most important stumble block for the bridging students is the study behaviour.

The first semester of the bridging programme mainly consists of basic engineering subjects like mechanics, electricity, physics, and chemistry. These subjects are more conceptually oriented than the courses the bridging students were studying before and therefore they need to apply different study strategies.

The LASSI test consists of 77 items, which can be divided into 10 scales namely information processing, selecting main ideas, test strategies, attitude, anxiety, motivation, self-testing, concentration, time management, and study aids. Students need to answer every item on a Likert-type scale, where one stands for “not at all like me” and five stands for “very much like me”. By adding the LASSI in our test battery it will be possible to verbalize statements about the learning and study strategies of an individual student [16]. The purpose here is to encourage more students to think about their study behaviour and give them appropriate advice.

4.4 Cognitive test (based on the CHC-model)

In the CHC-model, one speaks about general intelligence also presented as ‘G’. This general intelligence is subdivided into 10 broad cognitive skills. If you want to describe the general IQ of a person you need to bring all these cognitive skills together. The purpose of our diagnostic test is not to make statements about a person’s intelligence, but to predict study success in the bridging programme. Therefore we will only focus on those cognitive skills that may be predictive.

A good engineer possesses a range of skills such as technical knowledge, the right attitudes, and off course cognitive skills [17] such as logical thinking, problem-solving skills, and communication skills. Based on the skills that are essential for engineers we’ve selected four subtests for our battery: replete point series (Gf), logical reasoning (Gf), proverbs and their meaning (Gc), and folding of boxes in 3D (Gv).

Gf (Fluid intelligence) represents the capacities of someone for reasoning in new situations and is therefore related to logical thinking and problem-solving. Gc (Crystallized intelligence) refers to acquired knowledge and skills which are important in the culture of the person, such as language development. The subtest proverbs and their meaning can consequently be linked to communication skills. Gv (Visual intelligence) focuses on visual images to solve problems and can logically be related to problem solving [18,19].

5 CONCLUSIONS AND FURTHER DEVELOPMENTS

The focus group discussions were an important aid for defining the major stumbling blocks for the bridging students. These stumbling blocks were used for the development of the optimized diagnostic test. The new mathematics test is based on the comments of the experts.

Thanks to the focus group discussions it is clear that students are in need of intervention tools. First of all they need to refresh their mathematical knowledge in advance. Therefore an extra-curricular math course will be developed. This course will be available online and students can enrol when they start their final year of the professional bachelor's programmes.

We also know now that the students consider feedback as very important. That's why we will offer to each student who has completed the diagnostic test, personal feedback by organizing intake conversations. During this intake conversation the student will not only get feedback on the test scores but also an informal study advice (in co-operation with the professional bachelor lecturers).

We already performed a pilot of the diagnostic test with 43 professional bachelor students. In the following months we will invite more students who are considering to enrol in the bridging programme to complete the test. Next year we will perform an in-depth analysis of the test results in combination with the subsequent exam scores of these students in the bridging programme.

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