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Assessing Reading Abilities of Mechanical Engineering College Students: A Prospecting Study*

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Reading is a basic competence that students have to master to be successful. Despite this fact, recent studies show that there may be a significant decline in the reading abilities of college students, one of the most educated segments of any population. This work is a prospecting study regarding the assessment of reading abilities of college students, namely in the context of Engineering education. Based on an existing screening test for assessing reading difficulties of children and teenagers, this work presents the results obtained by administrating that test to students at a top engineering institution in Portugal. An outcome of this study is the determination of a time range suitable for a massive, time limited, use of the previously mentioned test to assess college students, thus enabling a basic tool that will permit, in future works, to screen reading abilities in wider college populations. This work also shows evidence that ca. 20% of college students present a poor reading performance, revealing a strong need for monitoring college students' reading abilities along different generations.

Keywords: engineering education; reading abilities; non-technical skills

1. Introduction

A large scale study about reading skills among adults (ca. 19,000, aged 16 or older) was conducted in the USA in 2003, by the National Assessment of Adult Literacy (NAAL) [1]. The NAAL results for reading skills are divided into prose, document and quantitative literacy. Prose literacy was assessed by tasks demanding search, comprehension and the use of information from continuous texts, such as editorials or brochures. Document literacy was assessed by tasks demanding search, comprehension, and use of information from non-continuous texts in various formats, such as a job application or transportation schedules. Finally, quantitative literacy was assessed by tasks demanding identification and performing computations using numbers embedded in printed materials, such as balancing a checkbook or figuring out a tip. NAAL results were classified according to four literacy levels: below basic, basic, intermediate and proficient.

Along with the 2003 results, the NAAL report presents results from the previous NAAL, conducted in 1992. The comparison between results obtained in 1992 and those of 2003 reveals a puzzling tendency. Within one decade there was a significant decline in the percentage of proficient prose and document literacy among adults with college studies (no significant differences were found for quantitative literacy). Specifically, results indicate that, regarding prose literacy, a sharp decline was observed between 1992 and 2003: the percentage of proficient bachelors decreased from 40 percent (1992) to 31 percent (2003) and the percentage of graduates (or adults who took graduate classes) dropped from 51 percent (1992) to 41 percent (2003). The same declining tendency was observed regarding proficient document literacy, since the percentage of bachelors dropped from 37 percent (1992) to 25 percent (2003) and among graduates (or adults who took graduate classes) the percentage decreased from 45 percent (1992) to 31 percent (2003).

Although the NAAL report did not provide any explanation for this decline, there is an obvious benefit for education policies in tracking the population's literacy, generation after generation. The USA literacy assessment of the adult population policy does not find an equivalent in Portugal, where national assessments have been applied only to elementary and junior school since 2007, and to 15-year-olds in the OECD PISA assessment since 2000 (please cf. [2–5])

In the specific case of engineering students, it is the authors' belief that during the last decade the students' literacy may have suffered a significant decline. Such a belief is based on observations during informal and formal assessments and even during the regular class interaction of two of the authors with engineering students enrolling the Mechanical Engineering Master Degree (MEMD) at the Faculty of Engineering of the University of Porto (FEUP), both in lectures and laboratory sessions. For instance, in laboratory classes, stu-

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dents may be faced with a written problem for which they must provide an analytical solution [6]. The authors of this study observed that, in a considerable number of cases, a common root for the incorrectness of the solutions provided by students is an improper interpretation of the written problem. Another indication sustaining the authors' belief in a possible decrease in students' literacy in the last decade regards written formal exams. It quite often has been found that, after reading a students' answer, the evaluator perception is that the student has not fully understood the question itself. Although it might be argued that this might be the result of an incorrectly formulated question or by the stress caused by exams, the authors experience suggests that, even when faced with simple unambiguous texts in more relaxed scenarios, a non-negligible number of students reveal difficulties in its interpretation.

A further puzzling fact is that this apparent decrease in reading ability seems to contrast with the increase in the average admission grades in MEMD at FEUP. Given this scenario, a formal assessment of the reading skills of the Engineering students of the school to which two of the authors are affiliated, FEUP, might be of great relevance. Although this study is limited to Mechanical Engineering students at FEUP, it is the authors' conviction that the conclusions drawn may be useful for other Engineering Universities, since FEUP is a top Engineering school in Portugal with a good international reputation. In particular, the Mechanical Engineering Master degree is a Second Cycle European Accredited Engineering Program (EUR-ACE certificate). This reputation also applies to research and development competences since, for instance, according to the National Taiwan University ranking [7] in 2012, the Mechanical Engineering knowledge area of the University of Porto was classified in 1st place in Portugal, in 7th place in Europe and in 30th place in the world (in a Universe of 500 Universities).

As far as the authors' knowledge goes, this is the first study in Portugal that assesses engineering college students' reading abilities. Also, studies assessing the reading abilities of college students appear to be scarce, as existing studies appear to be more focused on how external factors may influence the reading experience of college students—see, for example, [8]—rather than assessing the reading capabilities *per se*. Furthermore, the assessment of reading abilities of college students is an important indicator to understand comprehension related failures. Finally, the high value of reading (and writing) skills in an engineering career is long acknowledged to be very important [9] and recent studies indicate a correlation between reading abilities and procrastination for college students [10]. These arguments fully justify the need for an active and systematic screen testing of reading abilities of college students, as performed in this study in a prospecting way. In the absence of an assessment test validated to Portuguese that may be used specifically with an adult population, the authors decided to adopt TIL (*Teste de Idade de Leitura*—Reading Age Test) [11], a validated reading test usually adopted with children and teenagers. TIL assesses two core processes in the reading competence: decoding and understanding. Decoding is the cognitive process that allows the conversion of each grapheme symbol into its corresponding sound; understanding is the cognitive process that allows the extraction of meaning from the decoded material [12, 13]. The decoding process is known to be automatized across fluent readers, thus allowing enough cognitive resources for the understanding process. If this process is not automatized the reading time will be enlarged, negatively affecting the understanding of the written material. Gough proposed the *Simple View of Reading* [12, 14, 15] to explain the cognitive processes underlying reading. The author suggests that reading may be reduced to two basic elements: the knowledge of the spoken language and the knowledge of the orthography. This simple view of reading is expressed by the product of decoding and understanding: *Reading* = *Decoding* × *Understanding*. Each term of the formula varies between zero, when the competence is absent, and one, when the competence is present. Thus if one of the parcels equals zero, so will the reading. This perspective advocates that generally a good decoder is also capable of understanding and a bad decoder is also unable to understand. There are two exceptions to this line of thought: hyperlexics and dyslexics. Hyperlexics are unable to extract the meaning but are good decoders. Dyslexics are capable of understanding any message if it is presented orally, but unable to decode and are therefore unable to understand the same message if it is presented in the written modality. With regard to reading difficulties, the decoding process is the key-process, as it is the foundation of successful reading. The decoding process comprehends two sequential processes [16]. The first process to be developed is the alphabetic principle—an abstract principle according to which one letter corresponds to one sound and *vice versa*—allowing the reader to read a small number of words, by converting each letter into its correspondent sound. The letter–sound decoding process is insufficient to read most words, as the correspondences between letters and sounds are not always bidirectional but instead vary according to the orthographic context (so that the same letter will be read differently depending on the orthographic context, for example the letter <c>: **c**at vs. **c**ylinder). The reader must then develop a more sophisticated decoding process, which consists of the grapheme to phoneme conversion process. The grapheme is an abstract unit created by psycholinguistics in order to try to conform to the alphabetic principle. The grapheme corresponds to one letter (<t>) or more (<th>) and is convertible into one speech sound (a phoneme). Thus, the grapheme to phoneme decoding process will allow the reader to identify not only letters but also larger units, concurring to a more accurate and faster reading. As the reader encounters the same word time after time, he or she will start to develop an orthographic lexicon [17–19], where words are stored in terms of their orthographic characteristics, thus enabling that once a word is stored in that lexicon, it will be read *automatically* (i.e., much faster than it would have been by the more laborious phoneme-to-grapheme process). Having a rich orthographic lexicon is a key condition to being a fluent reader ([13, 17–19]). The reading fluency is, in turn, crucial for the understanding process, as in order to extract meaning from the text, the reader needs a large amount of cognitive resources. If the decoding process is also competing for a significant load on the cognitive processes, the reader will most likely not be able to retain phonological information long enough to extract meaning later (for an extensive discussion on fluency and understanding cf. [20]).

The reading measure adopted in this study is intended to assess reading fluency, demanding the participant to use the decoding process *automatically* in order to complete 36 sentences (incomplete, with one word missing) as fast and as accurately as possible, across five possible alternatives. This study explores results obtained by college students by contrasting them with those obtained by 4th graders. This comparison aims to detect potential poor readers among college students. Our premise is that college students results in TIL should be well ahead of those obtained by 4th graders, given the fluency gain in the result of (at least) eleven more years of education.

Since the time limit used in TIL with 4th graders is too long to allow discrimination between college students' reading levels, another objective of this work is to define a shorter time limit, surpassing that shortcoming. The accomplishment of this goal will allow, in future studies, i) the administration of TIL to screen reading abilities of a wider college population and ii) the definition of normative values for engineering students.

This paper is organized as follows: the next section presents the method used in this work, namely an overview of the participants profile along with a short description of the materials used and the procedure followed. Section 3 presents the results and Section 4 provides a discussion based on those results. Finally, Section 5 draws the main conclusions retrieved from this work and presents several suggestions for future developments.

2. Method

2.1 Participants

A total of 84 college students were assessed, following an appropriate informed consent procedure (cf. Table 1).

The Mechanical Engineering Master Degree at FEUP is one of the top Mechanical Engineering degrees in Portugal, attracting not only a high number of students per year but also, in recent years, students with some of the highest admission grades. Figure 1 presents a graph showing the classifications obtained by the last student to be admitted (with a maximum of 200 points) versus the number of admitted students for the top five Engineering Universities in Portugal: FEUP, Instituto Superior Técnico (IST), University of Minho (UM), University of Coimbra (UC) and University of Aveiro (UA). Data presented in Fig. 1 regards the period 2003–2012, for the first admittance phase, and includes pre- and post- Bologna Engineering degrees. Clearly, FEUP is a top engineering institution in Portugal, both in the quantity and quality of the students. Another important fact in this study is that in recent years the admission grades in Mechanical Engineering at FEUP have significantly increased, as shown in Fig. 2.

The Mechanical Engineering Master Degree at FEUP comprehends the 1st and 2nd Bologna cycles organized in a back to back way: the first three years correspond to the Bologna 1st cycle and the last two years correspond to the Bologna 2nd cycle. The first four years are common to all students and in the last year they have to choose one specialization area. Students participating in this study were tested during the Control Systems course, which is a fourth year course in the Master degree.

2.2 Materials

The TIL test is an adaptation to Portuguese of an original test developed in France named Lobrot L3 [21]. The normative data was derived from the

Table 1. Number and age of participants by gender

		Age (years; months)	
Gender	**Number**	**Average**	**Standard deviation**
Masculine	69	22; 1	0; 10
Feminine	15	21; 7	0; 3
Total	*84*	*21; 11*	*0; 10*

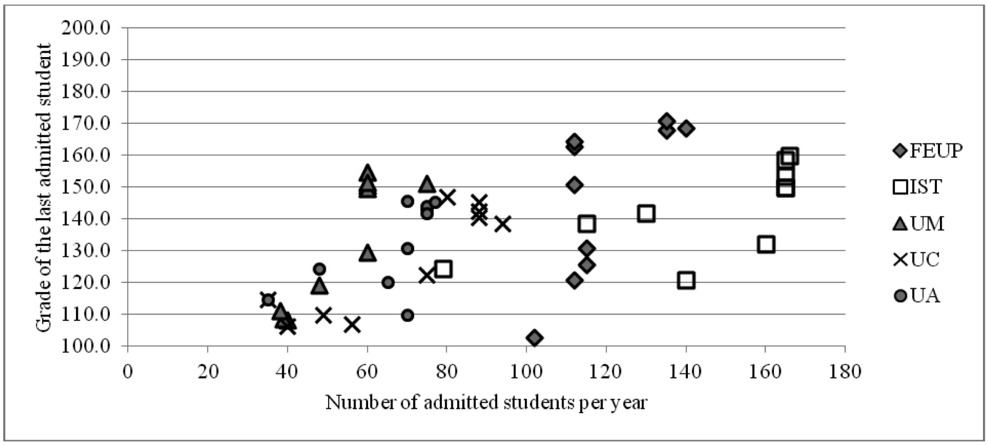

Fig. 1. Engineering degrees in Portugal: a comparison between different institutions during the 2003–2013 period.

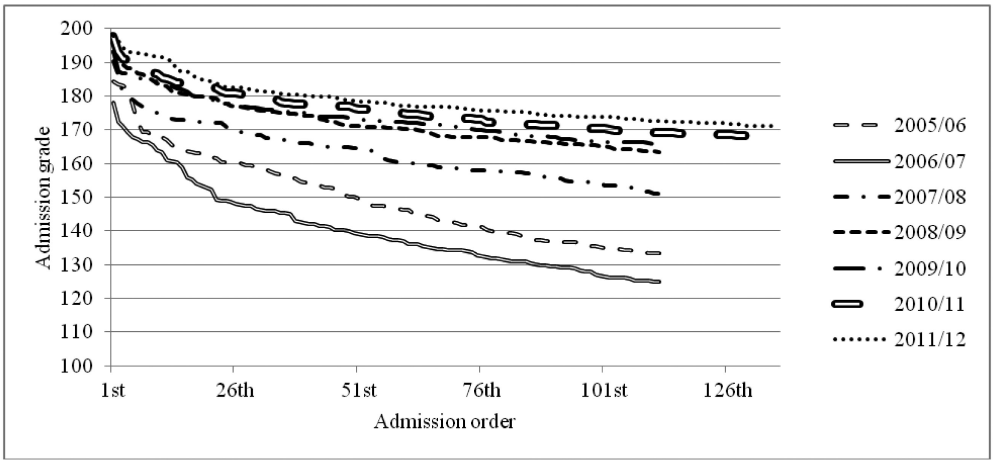

Fig. 2. Evolution of the admission grades in the Mechanical Engineering Master degree: grade versus admission order from 2005/06 to 2011/12.

administration of TIL to 614 Portuguese native speakers, attending the second (n = 170), third (n = 186), fourth (n = 173), and fifth (n = 85) grades for the first time [11]. This test requires accurate and fluent decoding, as well as basic comprehension skills. It consists of reading sentences where the final word is missing. The student has to choose which word, from a set of five alternatives, is a valid completion. Each five-word set includes the target word and four distractors, each of a different type: either no resemblance to the target word, or a visual, phonological or semantic resemblance. Thus a correct answer is likely to implicate a precise decoding of the alternatives. The position of the target and distractor words varies pseudo-randomly across sentences. There are 36 sentences and a time limit of 5 minutes. The normative data is presented in the form of percentiles for children between the 2nd and 5th grade. An answer is considered to be non-correct in two situations: i) if it corresponds to a non-answered question due to time constraints or ii) if it corresponds to an incorrect choice made by the student.

It should be stressed that, as already described, TIL requires only basic comprehension skills, since it was developed for children aged between 8 and 11 years old. In order to illustrate the simplicity of the test, Fig. 3 presents one example of the sentences students have to complete, including its phonetic transcription (Unibet) and English translation. This particular example comprehends two types of distractors: i) words phonologically similar to the target word *quente* [hot]: *mente* [mind], *lento* [slow] and *quente* [hot] share phonological features, as can be confirmed by the phonetic transcription, and ii) words semantically related in the context of the sentence: *bom* [good] and *doce* [sweet] are related, in the sentence, to the words *comer* [eat] and *bolo* [cake]. In order to accurately complete the sentence, the student is required to decode each word and

Não comas já o bolo, porque ainda está [Don't eat the cake yet, as it is still]

Choices (in Portuguese)	*mente*	*lento*	***quente***	*bom*	*doce*
Choices (Unibet phonetic transcription)	[/m2nt /]	[/l2ntu/]	[/k2nt/]	[/b4m/]	[/dos/]
Choices (in English)	[mind]	[slow]	**[hot]**	[good]	[sweet]

Fig. 3. Sentence extracted from TIL, with phonetic transcription (Unibet) and English translation for distractors and target word.

extract its meaning, after which the overall meaning should be inferred, so that the correct choice between the five possibilities is made.

Study [11] allowed the determination of normative results regarding the number of correct answers corresponding to each percentile. In the present study university students will be compared against 4th graders, so their results are shown in Fig. 4. For instance, the filled line of Fig. 4 shows that the percentile 50 for the 4th graders corresponds to ca. 25 correct answers while the percentile 90 corresponds to ca. 33 correct answers (the maximum number of correct answers is 36). Notice that these results may vary according to a child's socioeconomic background, so in order to provide an insight on how reading level measured by TIL is influenced by this factor, Fig. 4 also presents the percentile versus number of correct answers in two extreme situations: the dotted line presents results obtained by high socioeconomic background children (HSE) and the dashed dotted line presents results obtained by deprived socioeconomic background children (DSE).

2.3 Procedure

Eighty-four college students were asked to complete TIL without any time constraints. TIL was administered after a regular class. It was explained to participants that they would be asked to complete sentences with the correct word from a set of five possibilities, underlining the correct option. One example of a training sentence was verbally provided to participants, with corrective feedback, after which they were asked to turn the page and silently and individually complete all the sentences as fast and as accurately as possible. Students were also asked to note the time they spent in the test completion by using a stopwatch displayed in a datashow. This allowed a common time base for all students, since the stopwatch was started after the verbal instruction 'Begin' was given.

3. Results

As previously mentioned, the TIL test is administered to children with a time limit of 5 minutes. This time limit was defined to ensure that only a residual percentage of the 173 children tested would be able to complete all 36 sentences within 5 minutes, thus allowing the discrimination of reading capacities by comparing the number of correct answers, cf. [11] for further details. Given the expected difference between 4th graders and college students' reading capacities and the simplicity of the TIL test, an initial expectation was that the majority of college students would be able to complete the whole test within a time limit of 5 minutes. This meant that a

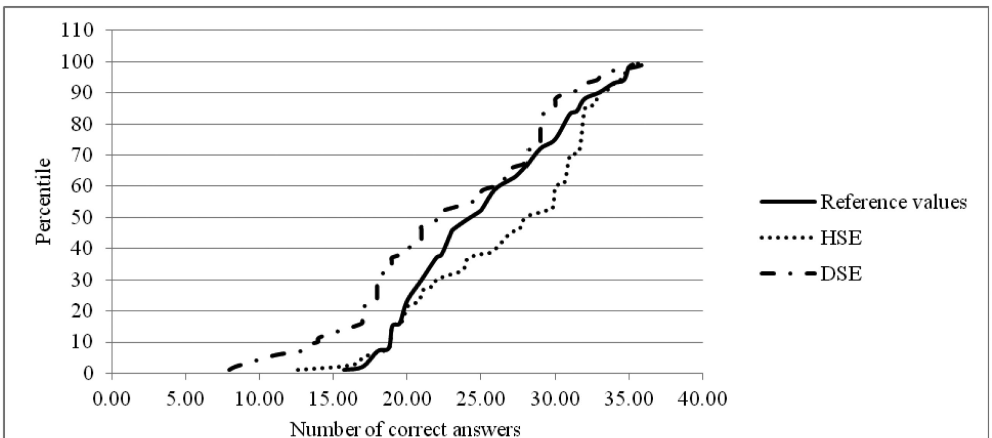

Fig. 4. Fourth graders percentile *versus* number of correct answers: reference values, HSE and DSE (based on [11]).

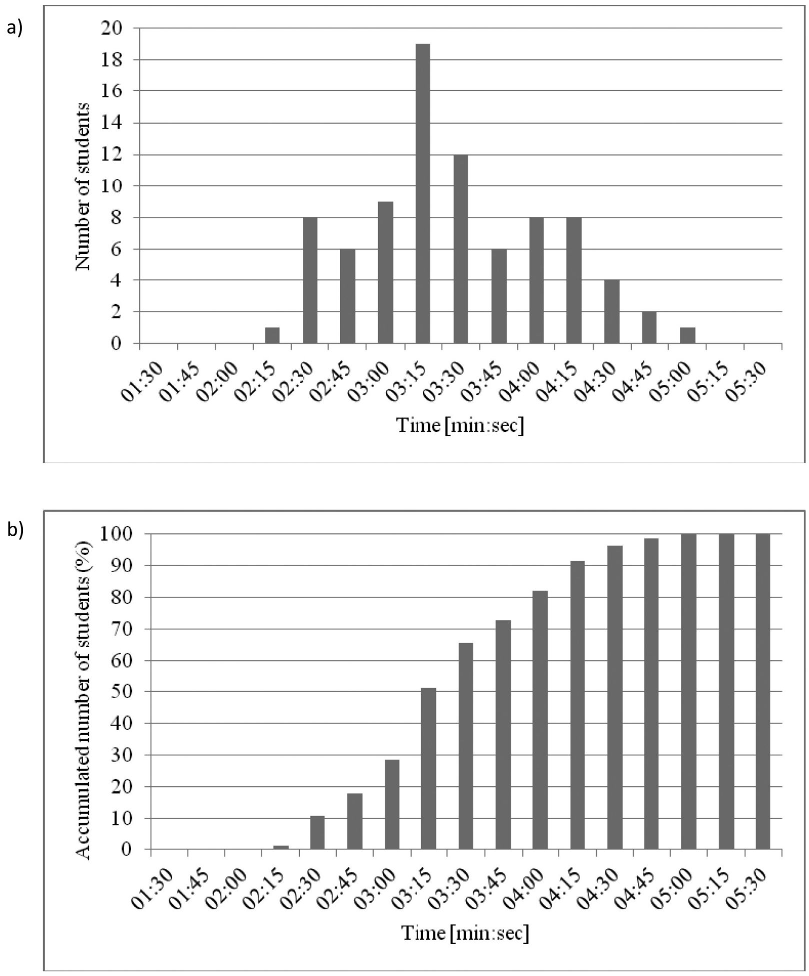

Fig. 5. Histogram results for FEUP students.

new time limit had to be defined in order to allow discrimination. To allow the determination of such a new time limit, TIL was administered without any time limitation at all. Figure 5 presents the results obtained: Fig. 5(a) presents the histogram of the number of students for a given time interval and Fig. 5(b) the accumulated percentage of students for a given completion time.

Figure 5 shows that all college students were able to complete the TIL test within five minutes, thus confirming the initial supposition that a 5 minutes time limit would not allow discrimination. By analysing results from Fig. 5, the adoption of a fixed time range of between two and three minutes seems to provide correct discrimination results, namely regarding low level readers, as it is corresponds to an interval in which approximately 0% up to 30% of students are able to achieve top results. More specifically, in order to maintain the original level of discrimination, enabling only around 7% of the children to attain top results [11], we propose the adoption of 2′ 30″ as the time limit to college students (corresponding to ca. 10% of top results).

It should also be emphasized that, without time constraints, all students were able to complete the TIL test with nearly 100% answers correct; see Fig. 6. It is also interesting to note that from the data shown in Fig. 6 no correlation exists between the percentage of correct answers and the time needed for completion.

4. Discussion

In an unconstrained time limit mode, all college students were capable of attaining ceiling results within 5 minutes—the time limit adopted with children. The mode was 3′ 15″ (19% of the students); the minimum time needed was 2′ 15″ (1%) and the maximum was 5′ (1%). These results are coherent with the idea that as readers acquire more reading experience, both decoding and orthographic lexicon develop and contribute to a stronger fluency. Specifically, in what regards TIL, this test was developed in such a way that all words are frequent. Consequently, when a skilled reader (such as a college student) is asked to complete the 36 sen-

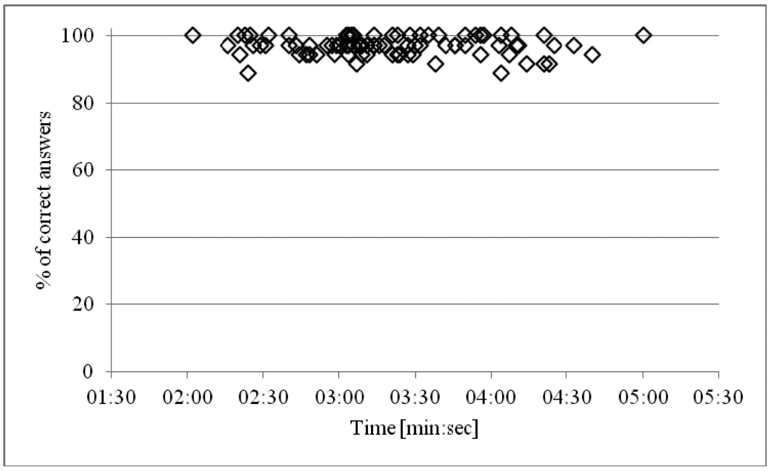

Fig. 6. FEUP results: percentage of correct answers versus completion time.

tences, he or she is expected to do so relying on automatic word recognition, therefore revealing high fluency levels (when compared to less skilled readers, such as 4th graders). In fact, whereas all college students reached ceiling results (more than 32 correct answers, approximately 90% of the sentences) within 5 minutes, only 16% of the 4th graders (of the reference sample) reached the same result (within the same 5 minutes). A less expectable result is the overlap between 4th graders (reference sample) with ceiling results and the slowest college students. As presented in the previous section and summarized in Table 2, 18% of the college students needed more than 4 minutes to attain ceiling results ($\geq$ 90%), i.e., 18% of the college students appear to have a reading fluency comparable to that observed among (the most fluent) 4th graders. Note that the overlap is even larger when we consider the high socioeconomic background of 4th graders (18% of college students versus 30% of HSE 4th graders) and that even when we consider deprived socioeconomic 4th graders, the overlap is still notable (18% of college students versus 10% of DSE 4th graders).

It is important to emphasize that, in what regards reading fluency, someone with a 4th grade education is supposed to be well behind someone with a college education, as may be confirmed by inspecting any of the several standardized reading results available for different education levels, e.g. [22, 23].

It should also be considered that college students are far from being a homogeneous group regarding reading skills. In the USA, for instance, community college students are known to be a disfavoured group compared with bachelor or graduate students. In fact, although half of the total population attending higher schools later enrols in community colleges (cf. [24]), the distribution is quite uneven regarding learning disabilities, with 71 percent of all learning disabilities concentrated within community colleges. Another illustrative result comes from the NAAL study [1], that revealed that the percentage of bachelor and graduate adults with proficient literacy was significantly higher (one and a half to twice) than for adults with a two-year degree—the ones that enrolled in a community college. These results can be easily accommodated by the typical disadvantage of adults with an associate degree, compared with those who have graduated. One should also contextualise these results within the nature of community colleges' two-year associate degree (in contrast with longer graduation cycles) and within the relatively open admission policy adopted by these institutions, which contrasts with highly demanding admission rules adopted by those granting bachelor and graduate degrees.

In regards to the participants assessed in our study, the high admission grades for Mechanical Engineering and the fact that they are enrolling in a Master Degree are strong indicators that these students represent the top college students in Portu-

Table 2. Percentage of students with more than 32 correct answers

	FEUP*	**4th graders (Reference values)**	**4th graders (DSE)**	**4th graders (HSE)**
Students with more than 32 correct answers (%)	17.9	16.2	9.8	29.5

* Results corresponding to completion times of between four and five minutes

gal, for which high reading skills would be naturally expected. However, results obtained in this work show the existence of a non-negligible amount of engineering students with poor reading abilities.

Since this work was not intended to assess dyslexia, its procedures did not include a thorough reading assessment that may determine whether any of the students is dyslexic. These results cannot, however, be analysed without reference to dyslexia. Dyslexia is a specific learning disability characterized by poor reading accuracy and/or fluency and by poor spelling and decoding abilities [25]. Secondary consequences of dyslexia may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge (ibid.). Dyslexia prevalence ranges between 3% and 15%, according to the method adopted and the population under analysis [26–30]. The most consensual hypothesis regarding dyslexia etiology is the phonological deficit hypothesis [31–33] (for a description of the phonological deficit within Portuguese-speaking dyslexics see [34]), i.e., reading difficulties typically result from a deficit in the phonological component of language, which is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Dyslexia is thus a lifetime disability in the sense that there is no spontaneous remission with time. There are, however, different individual trajectories regarding reading acquisition. Whereas some individuals are severely affected by the reading difficulties and continue struggling in spite of remediation intervention [32], other dyslexics reveal significant increments in the rate of reading growth, as the outcome of early remediation intervention [35]. Within this last group, there is a subgroup that eventually becomes capable of sophisticated reading, thus being able to successfully attend and conclude college level studies [36, 37]. Research also documents that these same well successful college students still present some dyslexia symptoms, such as slower non-word reading [36].

In future studies any dyslexic participants should be identified, in order to control for this variable, although it is the authors' conviction that TIL should not to be a challenging task to a dyslexic college student, in the sense that, as already described, it is a basic reading task, both on what regards decoding (focusing exclusively on frequent words) and reading comprehension. Summing up, the (possible and probable) existence of dyslexics within the participants does not constitute a satisfactory explanation as to why ca. 20% of them overlap considerably with 4th graders. These results are therefore a strong indication of poor reading abilities in one of the most educated segments of the Portuguese population, stressing the need for future studies. Another important result of this study is the absence of correlation between the time needed to complete TIL and the number of sentences correctly completed (cf. Fig. 6). Ceiling results were obtained by all participants, with a time span between 2′ 15″ and 5′. This result concurs to the pertinence of the present study, as it allowed the definition of a shorter time limit for college students than that applied to children.

5. Conclusions

This study addressed two main questions: (i) is there evidence of poor reading abilities at a top Engineering school in Portugal? (ii) What is the fixed time limit that allows correct discrimination of college students when using TIL, the reading assessment tool? Regarding the first question, results indicate that there is a non-negligible overlap between the results of the best 4th graders and the worst college students. This is a surprising result as there is a gap of eleven scholar years between these two groups of students. These results are not unique though, as the same general tendency was observed in previous studies in the United States, suggesting that further studies are needed, both in depth and time span. More detailed tests will allow a better distinction of reading abilities, while tests in a wider time span will allow the detection of tendencies that might provide reliable data to better understand the effects of education policies. Regarding the second question, its importance lies in the fact that TIL was originally conceived for much younger students, so the time limit originally adopted had to be reduced. The test was therefore handed to Mechanical Engineering students at a top Mechanical Engineering Master Degree in Portugal without any time constraint. This procedure led to the determination of the time limit that allows a discrimination level between college students similar to the one observed for 4th graders. Consequently, the second goal addressed in this study was successful as it enables the future use of TIL as a simple, quick and time limited test that can be used to screen out low performance readers. Notice that this test may be handed over to students at the beginning or end of a class without almost any perturbation of its normal functioning. This might be of great importance given the indications confirming that the reading level of college students might be reaching red alert levels.

Future works will use the results obtained in this study (namely the 2′ 30″ time limit) to assess college students reading competences. The administration in a time constrained procedure will therefore allow a direct comparison between college students and

4th graders, so that it will be possible to contrast the percentage of poor readers in the two extremes of the teaching system (primary school and university). It is also our intention to find reasons that may justify the apparently alarming results obtained in this study. In order to do so, we will compare engineering students with other university students: (i) with different curricula (e.g., Humanities, Arts); (ii) with equivalent and lower admission grades and (iii) with dyslexia. Goals (i) and (ii) will allow us to determine if there is any relationship between reading levels and curricula or admission grades. Goal (iii) is of great relevance as it will allow us to: (a) understand to what extent the results of the present study were affected by dyslexic students and (b) whether TIL can be a useful screening test to discriminate dyslexic university students. Indeed, an important shortcoming of the present study was the absence of information regarding dyslexia among the participants. This topic will therefore be addressed in future studies, specifically by identifying among the 20% of students with poor reading skills, the ones whose low results are explained by dyslexia, and those whose low results are explained by other factors.

This scenario shows that more research is urgent in what regards the reading competence of Portuguese university students, aiming to investigate if similar results are obtained in other Universities and, if so, contributing to finding its causes, as well as to explore educational measures to prevent the same scenario in future generations.

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