Multilevel Dissemination of Knowledge on Machine Diagnostics

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Abstract. Today, interest in STEM disciplines (Science, Technology, Engineering and Mathematics) is lower than in past decades, as evidenced by the low demand for STEM careers among secondary school leavers. In addition to this, there has been a loss of female interest in STEM careers, although it has always been lower in many STEM fields, has fallen drastically in recent years. With the aim of bringing some interest to this type of studies, in this manuscript the proposal of a knowledge pill related with machinery diagnostics is proposed for all the educational levels. Study about the learning methods for each level is done and applied in order to train and to make STEM disciplines attractive. Familiarizing students with engineering applications is the objective of this proposal and covers the levels of primary, secondary and university education, with special emphasis on lower levels.

Keywords: Stem learning · Learning levels · Isced · Machine diagnostics in education

1 Introduction

Globally, there is a decline in the interest of students leaving secondary school in choosing a STEM career [1]. As a result, each country is taking different measures to attract both female and male talent to these disciplines which, within the paradigm of digitalization and Industry 4.0, are already necessary and will be even more so in the future [2]. Different studies have been carried out which indicate that the lack of vocation towards stem careers is due to different reasons [3,4]. On the one hand, they are considered to be courses with a high level of difficulty where theoretical and practical content is mixed, and, at present, apparently do not guarantee an economically advantageous professional career compared to other studies (although this is not true). On the other hand, due to

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the complexity and dedication of the studies, students feel incapable of tackling the courses successfully. As a result of this search for the causes of the decline in vocations in STEM careers, it has been detected, in addition to the above, the general lack of interest of women in these careers, which has led the scientific community to focus its work on this group. In this case, and in the same way as in the general case, there is a lack of information of the professional development for students pursuing these studies, as well as a lack of female models.

The first policies carried out by countries to attract female talent are based on the protection of female students in STEM degrees, by means of mentoring programs with successful women in their professional careers [5]. This action is not only done to attract female talent, but also for avoid dropping out of university and to prepare women engineers for successful professional careers. On a second level, to attract female talent to these degrees, universities develop workshops and visits for secondary school students with activities that catch the attention of future university students, such as workshops on 3D printing, virtual reality, racing vehicles, etc. Topics that attract students' attention and connect them to engineering studies.

There is a third level to explore, we must know that by the time a student reaches secondary school he/she has already chosen, in the majority of the educational systems, the orientation of his/her studies: humanistic, science or technology. At this stage, the student has already formed in his/her head the different types of studies available, his/her interests and abilities. It is in the first years of life and up to primary school when children have a raw vision of all disciplines, without prejudices or conditioning. In fact, it is in the early years that children show a much greater research skill than they do in the rest of the years. We can see how a child instinctively puts continuously into practice what are considered to be STEM habits of mind [6]: critical thinking, persistence and systematic experimentation. Such habits are important in all areas of STEM research and are essential to how children learn to learn. So it seems logical to incorporate STEM pills at all school levels in order to enhance and advance learning in other disciplines (e.g. mathematics knowledge is known to improve language learning, among others).

In this line, the present work proposes the development of a STEM pill developed for all educational levels so that it can be incorporated into the learning process. It is also proposed the methodology to develop these concepts of any STEM discipline considering the different educational levels and maturity of the students. Specifically, this work will develop the methodology for learning the concept of monitoring and diagnosis of machines, where different interesting concepts for a student are mixed. Concepts of machines and their mechanical elements, data acquisition with the necessary electronics and data processing in the computer to help the decision related with the state of the machine.

2 Educational Levels and the Teaching Process

The International Standard Classification of Education (ISCED) establish the levels of learning, the updated classification is (ISCED-2011, [7,8]):

- ISCED 0 = Early childhood education (pre-school, up to 3 years)
- ISCED 1 = Primary Education (primary education, 5–7 years designed to teach reading, writing, mathematics and elementary skills in other subjects).
- ISCED 2 = Lower Secondary Education (completing basic education)
- ISCED 3 = Upper Secondary Education (specialised 15–16 after compulsory education)
- ISCED 4 = Post-secondary non-Tertiary Education (basic professional practice)
- ISCED 5 = Short-cycle tertiary education (vocational practice)
- ISCED 6 = Bachelors degree or equivalent tertiary education level (graduate, academic qualification)
- ISCED 7 = Masters degree or equivalent tertiary education level (master's degree, advanced academic qualification)
- ISCED 8 = Doctoral degree or equivalent tertiary education level (advanced research qualification)

One of the eight key competences for lifelong learning established on the basis of the European Parliament Recommendation 2006/962/EC [9] is : *Mathematical competence and basic competences in science and technology*, as these competences *induce and strengthen some essential aspects of people's education that are fundamental for life* [10]. In this sense, this competences or skills in first levels are normally covered in the subjects of mathematics and natural sciences: Mathematical competence to apply mathematical reasoning and calculation in problem solving, explaining the natural world from scientific knowledge and understanding of changes caused by human activity and individual responsibility.

In this work, the programme will be developed for levels ISCED-1, ISCED-3 and ISCED-6. covering the intermediate levels with adaptations from the teacher to the student in terms of language and duration of the activity, but not in terms of content.

Thus, for each level the same activity/workshop is prepared, consisting of learning the complete process of diagnosing a machine, from the concept of the machine and its use to the visualisation of its specific state.

Bearing in mind that gender segregation seems to occur between the ages of eight and ten [11], in the ISCED-1 and 2 levels it will be very important to include female referents.

2.1 Primary School

To teach STEM knowledge and according to Arabit et al. [10], in first years levels (ISCED 1–2) teachers should implement active methodologies, develop practical and experimental activities, as well as improve digital competence (in contrast to the traditional teaching applied to the rest of the subjects). At this level, more emphasis and responsibility in terms of language and the transmission of knowledge must be done. On the other hand, given that Duncan et al. in [6] conclude that the skills to be addressed in students in the early school years are attention and behaviour, active methodologies for transmitting STEM knowledge are of great importance, so that fears (not existing at this age) of facing the possible difficulties of scientific learning can be eliminated. This learning should be gradual and based on experimentation, in the same way as learning a language from birth.

2.2 Secondary School

In secondary school, students take technology subjects, they have a broader view of some concepts related to industrialisation and computer applications with visualisation of parameters [12]. They are already familiar with digitalization and IoT concepts at user level with the use of smartwatches, data information in the cloud and software that communicates with sensors. From that point of view, it is more interesting to focus on the use and components of the machine, as well as the measurement chain needed to get the data of the machine behaviour to the computer or to a cloud including digitalization concepts. On the other hand, it is interesting to introduce this profile of students to laboratory practice, as they are able to follow simple procedures and protocols.

2.3 Degree and Master

In the case of the undergraduate students, they are considered autonomous in learning and, although they need some working guidelines, can carry out the training autonomously by using the manuals and practice guides. It is also assumed that they have the basic knowledge to understand the phenomenon under study. On the other hand, lab experiments are very important for engineering students' training in order to acquire the required knowledge to implement and consolidate the theoretical concepts.

3 Study Case

In this work, the adaptation for all educational levels of a classic practice of failure monitoring on rotating machines is going to be developed.

The machine to study is a testbench (see Fig. 1) prepared to include the elements for a classical study of *diagnosing of rotating machine* (rolling bearings, unbalanced shafts, cracked shafts, or different couplings) [13].

The concepts to communicate are:

1. Machine configuration. Description of the elements that make up a machine (transmitting system, support elements and couplings), as well as the driving system and the load system.
2. Description of the sensors and measurement chain for monitoring (the use of accelerometers, acquisition card and PC with application for the visualisation of the sensor measurement).
3. Use of an application to observe the processed data for the assessment of the state of the machine.

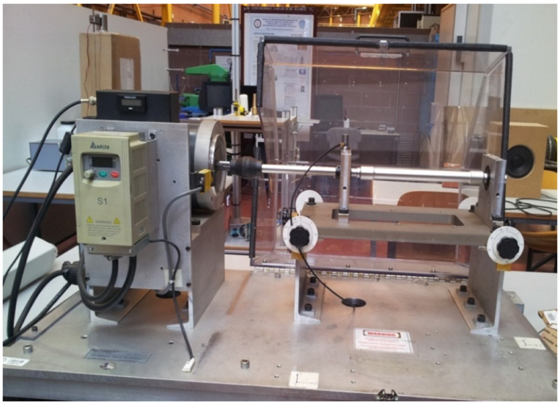

Fig. 1. Testbench used for machine diagnosis lab.

The concepts are clear for a final year mechanical engineering student with extensive knowledge of mechanisms, vibrations and mathematics, but not for primary or secondary school students.

In this work, three knowledge levels will be considered to teach the concepts, each knowledge level correspond with two or three Educational Levels presented in Sect. 2 and considering the skills and knowledge of each age, as commented before. In this sense, Level 1 corresponds to students from primary school (ISCED 1–2), Level 2 to secondary school and vocational practise (ISCED 3–4-5) and Level 3 to degree and master (ISCED 6–7).

3.1 Level 1

When working with elements of the industrial sector (machines), a role playing game methodology is proposed for pupils bringing the concepts of the industrial environment to other situations that are more familiar to them. Thus, it is proposed to humanise the machine and become doctors who auscultate, measure temperature and diagnose the patient's illness.

In this sense, students are able to assimilate engineering studies with an education that is put at the service of society by improving their living conditions.

In this case, the humanised machine is proposed for the first level, as shown in Fig. 2, where students can diagnose and place the associated feelings (ill or happy, in Fig. 2) according to the state of the machine (normal or faulty).

Thus, the proposal for this level is a workshop with two parts:

1. First, a brief presentation of the machine ans its parts and the different equipment to diagnose the possible illness of the machine, we will focus in this level on the detection of rolling bearing failures by presenting the vibration signal measured on the machine (making the equivalence with the response of an electrocardiogram) and the temperature (to check if it has fever).

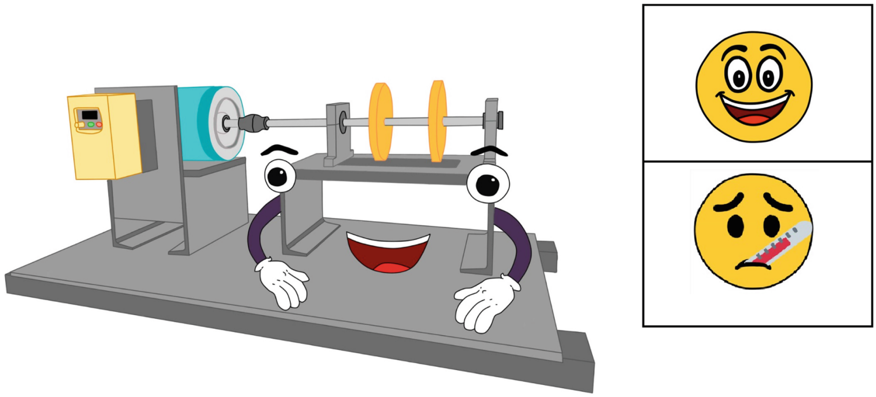

Fig. 2. Rotofriend machine and stickers for good health and illness feeling.

2. After the short presentation, pupils must diagnose the machine state on the basis of the vibration signal obtained. In this case, reference will be made to measurements of the signal amplitude and periodicity (rather than frequency, a less intuitive concept for schoolchildren), so that they can intuitively place stickers on the feeling (state) of the machine, comparing the vibration signal of a healthy machine with a machine with different rolling bearing faults. In Fig. 3 working template for schoolchildren is presented.

3.2 Level 2

For secondary school students, a more practical laboratory workshop is proposed. The workshop allows students to start up the machine, touching some mechanical elements and visualise the graphs of data, giving them some indications of the levels expected for good behaviour and asking them to make decisions in this respect.

The workshop can be held in the laboratory itself, in small groups, where the different elements of a rotating machine can be shown on the test bench (see Fig. 4). They can also learn the different components of the measurement chain and observe the signal representation, through an application, while the machine is in operation.

Students can be introduced to the concept of time and frequency domain signal representation as they have already learned to interpret periodic signals. Vibration data obtained to work is presented in worksheets, as Fig. 5, where students can understand the periodicity of a signal and test with the Power Spectral Density (PSD) of the vibration signal envelope in order to seek the frequencies. Also the concept of filtering the signal for better diagnosis is introduced.

At these two levels, and given the need to include digitalization and technology as learning skills, methodologies related to educational technology such as gaming and even technology applied to education such as augmented reality or

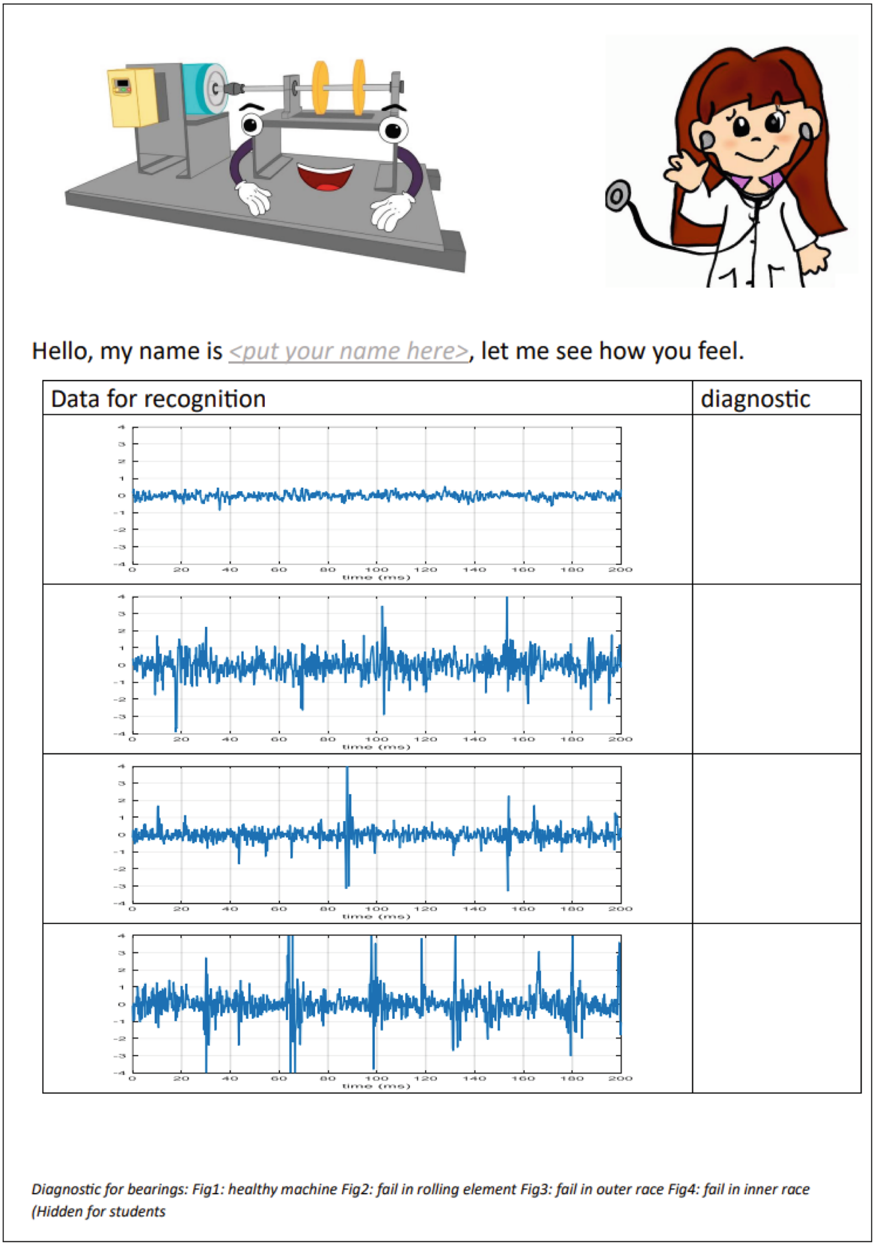

Fig. 3. Template provided to students to work on machine diagnosis

Fig. 4. Working in lab with students from upper secondary school

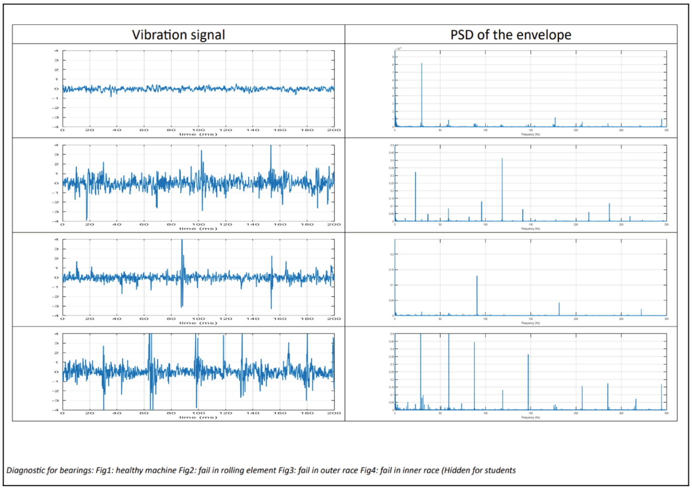

Fig. 5. Worksheet for students, left: the vibratory signal obtained from the testbench, right: the PSD of the signal envelope

virtual reality are proposed. Everything is oriented to visualise machine-related information and to understand the machine diagnosis more intuitively.

3.3 Level 3

For undergraduate students, the workshop is presented as a laboratory practice in itself, as experiments are very important for engineering students' training. The aim of the practice in this case is not an introduction to technology as is that the students learn advanced techniques for mechanical vibration analysis, mainly oriented to machine fault diagnostics. A detailed description of the machine and the measurement chain is described.

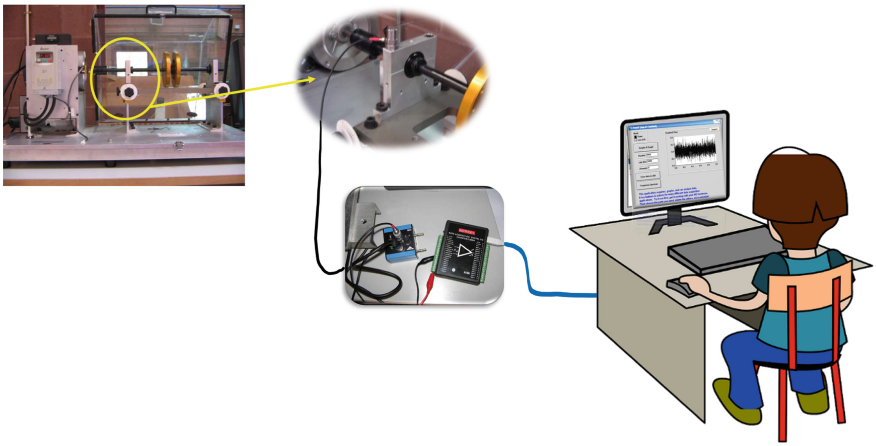

Fig. 6. Detailed description of the measurement chain.

The student is allowed to select components by proceeding to the assembly and disassembly of the machine elements to include different failure elements and they are urged to put the system into operation, by selecting acquisition variables such as sampling frequency, sample size, etc. After working in lab taking the vibration data, students are asked to use the necessary mathematical tools and software to determine the state of the machine [13]. Students are encouraged to calculate and find the theoretical fault frequencies for rolling bearings, as a function of the geometry of the bearings and the speed of the machine, and compare them with the frequency components that appear in the experimental data graphs.

4 Conclussions

In this work, a proposal to disseminate knowledge about the monitoring and diagnosis of machines at different educational levels has been presented. The study of different methodologies for each age and maturity level of the students has been done and applied. The proposal is approached from different points of view and with different motivations. At the lowest educational levels it focuses on the presentation of applications of interest to motivate students towards STEM careers, as well as to reduce gender bias towards these disciplines. At secondary school levels, the focus is for motivation towards industrialisation and digitalization, and, finally, at the grade level for qualified training in specific subjects. These activities are intended to be integrated in different programs proposed by the University Carlos III de Madrid (workshops for high school students) as well as STEM for Girls activities as part of the Association of Women and Technologists (AMIT).

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