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A New Methodology for Teaching the Performance Characteristics of Measurement Systems*

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The traditional approach to teaching the performance characteristics of measurement systems does not differentiate between manufacturer performance characteristics (in-factory calibration, development of data sheets) and end-user characteristics (interpretation of data sheets, performance estimation and in-situ calibration). This paper presents a novel approach to including teaching the performance characteristics of measurement systems from both points of view. We accomplish this by introducing an active-learning approach in which the students first play the role of manufacturers and later the role of end-users, thus being exposed to the different metrics used in each part of the whole design process.

INTRODUCTION

MEASUREMENT SYSTEMS have drastically changed in the last 30 years, mainly due to the new computer-based instrumentation and the development of microelectronic sensors that have given birth to so-called 'intelligent sensors'. However, the fundamentals of measurements have remained almost unaffected. In fact, the majority of changes in instrumentation are related to the implementation of the required measurement functions rather than the measurement methods [1]. Moreover, all the textbooks and handbooks on measuring systems or transducers [2–7] sketch their contents by first introducing the performance characteristics of the systems, leaving the treatment of specific systems and transducers to further sections. Consequently, it seems clear that it is more important to focus the teaching of instrumentation towards the general measuring principles rather than towards the specific implementations. In fact, there is currently a significant tendency toward a systems approach to the measurement problems rather than a list of specific items to be learned [8–9]. This type of approach positively influences the effectiveness of teaching students to become specialists with the spirit of generalists.

Norton [5] has proposed a system to classify transducer characteristics using three parameters: design, performance and reliability. *Design* is focused on how the transducer is built; *reliability* generally refers to rated failure-free performance for a given period of time; and *performance* studies the differences between the ideal and real output, and thereby considers parameters such as accuracy, fidelity, dynamic response, etc.

We believe that, although the measurement principles change less than the techniques and instruments [4], the performance characteristics of the measuring systems change even less, and, therefore, their knowledge should be the essential topic in any instrumentation course. Unfortunately, textbooks for teaching sensors and instrumentation often deal with performance characteristics in a merely descriptive way, sometimes with little emphasis on real applicability, and without relationship between them. As a consequence, a great quantity of concepts, such as offset error, gain error, non-linearity, fidelity, reproducibility, resolution and so on, are described sequentially, but without touching upon their relative importance in the overall system and, especially, without taking into account the difference between the performance characteristics considered from the manufacturer's point of view and the user's point of view. We believe that, although the currently available textbooks are useful in the classroom, they all lack the consideration of these differences between the manufacturer and user's point of view. For this reason, the goal of this paper is to present a new approach to teaching the performance characteristics of measuring systems in an electrical engineering program with a generalist approach.

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In essence, our methodology consists of an interactive and stimulating way of presenting the basic concepts related to the performance characteristics of instrumentation systems. First, the students role play as manufacturing engineers who have to characterize the system's performance and communicate it to potential users by developing a data sheet. Later on, the students adopt the role of design engineer or end user. In this role, they have to be able to understand a data sheet, to infer the performance of the system, and finally to conclude the appropriateness of the system for a given application. Although this paper only focuses on static performance characteristics, the methodology can be used in evaluating the dynamic performance characteristics. Moreover, given the case-study approach, this methodology is not limited to traditional lecture sessions, but will also be extremely successful in student-centered learning opportunities such as laboratory experiences or design projects.

RATIONALE FOR THE NEW METHODOLOGY

The aim of this new methodology is to improve the learning process in a critical aspect of measurement science. In recent years, we have noticed how the majority of pedagogic material in measurement science omits what we believe is a key premise: the clear and significant differences between the performance characteristics considered from the manufacturer's point of view and from the user's point of view.

We believe that graduates should be aware of the following basic principles:

1) the performance characteristics specified on a data sheet are the outcome of different calibration processes carried out by the manufacturer, sometimes obtained from a statistical inference;
2) in order to correctly use the data sheet, users need to have the ability to estimate the performance of any system developed, using the device or subsystem on which they have a data sheet; and
3) any calibration process carried out by the user will enable the users to know the specific performance characteristics of their system.

Figure 1 depicts this process. Initially, at the manufacturer's, the information on the performance of a measuring system is very broad. After the in-factory calibration processes are developed, a unique data sheet is created and offered to potential users. Finally, the end user has two options for learning about the performance of the measuring system: 1) to carry out an error budget analysis using the information provided in the data sheet, or 2) to carry out calibration procedures specifically intended for the designated application.

In addition to focusing on these technical aspects, our approach is also designed with the goal of enhancing the educational experience of the students by using active learning activities that involve them in the whole process. Our approach focuses on: a) extensive involvement of students during the classroom period, b) encouraging interaction between students and c) assessing those

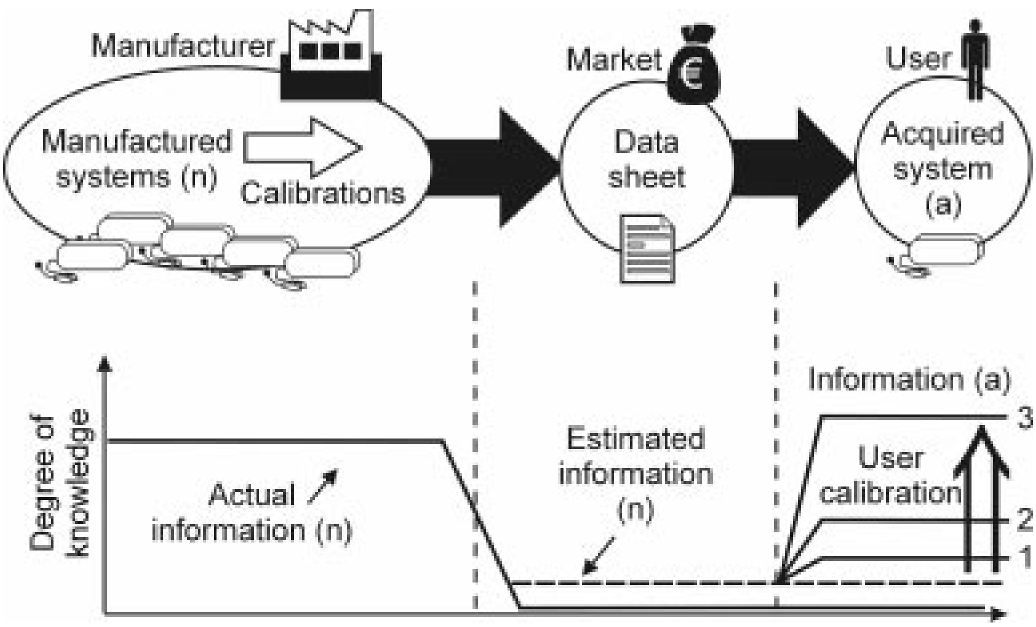

Fig. 1. Schematic diagram on the different degrees of knowledge on the performance of manufactured systems. Initially, the manufacturer is able to know all the information about all the manufactured systems (n). However, the tool to provide technical information on this product is essentially a data sheet, containing some physically measured parameters and some statistically estimated parameters. Once users have acquired a concrete system (a), they may acquire more or less knowledge on its performance by carrying out additional calibrations. Furthermore, the user could eventually learn more about the performance of the system than the manufacturer, especially in cases where the manufacturer did not carry out a calibration procedure on 100% of the manufactured units.

concepts not fully understood by the students. We chose to start the discussions with an open-ended question to the students. Although it is important to give enough time to reflect on and think about the question and its implications [10], a common-sense approach should be used, in order to reduce the amount of time needed for this initial critical thinking.

We see our pedagogical approach as a bidirectional sequential process: a bottom-up approach followed by a top-down approach. The bottom-up approach comes from the large number of measurements carried out and from the acquired data, which has to be categorized and classified in what is normally called 'performance data sheets'. The top-down approach comes from considering the fact that, through a single piece of information contained in the data sheet, users will be able to estimate the entire performance of the measuring system.

SKETCHING OUT THE APPROACH TO THE NEW METHODOLOGY

This approach is based on the students adopting two different role plays during the course. In the first phase the students play the role of the engineers who are involved in designing the measuring system and characterizing its performance by creating a data sheet that contains the critical information needed to predict its performance. In the second phase, the students play the role of the engineers who will be using the system. Therefore, in the first phase, the students are exposed to concepts such as calibration, statistical analyses, sampling of manufactured devices, etc., which all arise in a natural way. In the second phase, after the data sheet has been created, the students work on how to read and understand the information presented in the data sheets.

This teaching approach is strongly based on active learning by the students who, at different points, require information from the instructor to understand a series of basic concepts. Figure 2 shows a road map of how these concepts arise naturally through the student's self-discovery and learning process. Table 1 shows the different classroom activities that yield the outcomes needed in Fig. 2 to cover the basic concepts needed in this learning approach.

Step 1: Case study presentation

We use the case of an imaginary manufacturer of blood pressure transducers, as it is a simple example of a measuring system. Initially, the marketing department provides the role-playing students with some 'general' characteristics of the requested sensor, such as being disposable and of low cost, low weight and volume. Nevertheless, the most important characteristics in this first step are: the range of measurement (0 to 300 mmHg), the output range (0 to 50 mV), and a lineal relationship

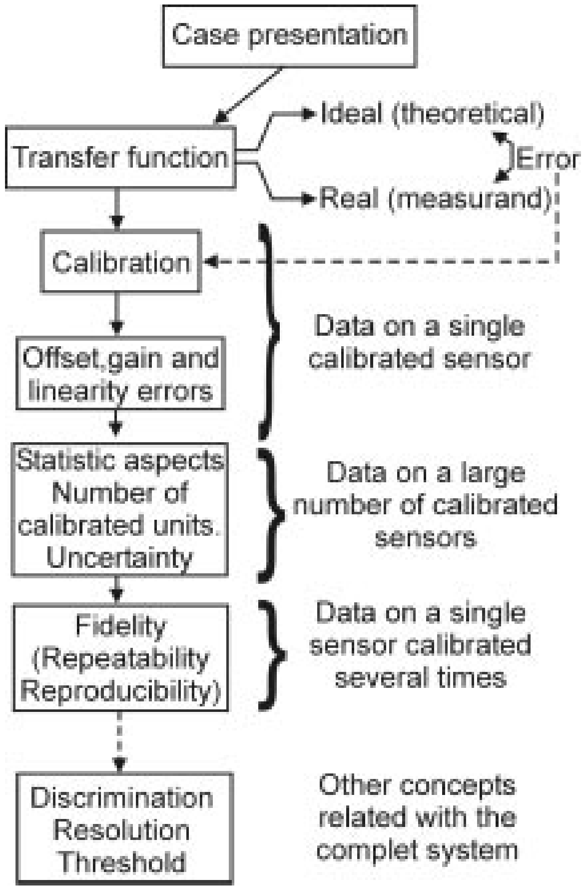

Fig. 2. Flowchart showing the pathway of concepts related to the performance characteristics of a measurement system.

between input and output (theoretical transfer function). These characteristics are not considered as performance characteristics [5] but as design and measurement characteristics. This first step is used to introduce and define the basic theoretical concepts to the students.

Step 2: Real versus ideal behaviour (performance)

Using the previous specifications and assuming a 'good manufacturing success', the student-engineers have developed a batch of 1000 blood pressure transducers. At this point, the instructor proposes a question to the students: 'Should they sell the sensors, assuming that they comply with the original specifications, or should they perform a complete analysis of their performance?' After some discussion, the students tend to choose the second option. At this point, it is possible to introduce some non-technical factors such as economic cost, reliability, marketing strategies and ethical issues [11].

During this step, the instructor will be able to introduce and discuss the concepts of ideal (theoretical) and real (measured) transfer functions. Consequently, a new concept, the generic error that is defined as the maximum difference between the two transfer functions, appears and needs to be studied and quantified.

Table 1. Steps of the methodological proposal and kinds of classroom activities

STEP	Description	Classroom activity
1	– Definition of the measurand characteristics [5]	BTC
2	– Is the real performance of the measuring system always as the function transfer says?	QS
	– New definitions: ideal vs. real transfer function	RD
	– The difference between these functions is the error	BTC
	– Ways of quantifying the error (absolute, relative, %FS, %measurand; reference-to-input vs. reference-to-output)	MDD
3	– How can we know the error in our system (real transfer function)?	QS
	– Definition of the calibration process	RD and BTC
	– What is the matter with the 'quality' of the input measurand quantity and the output measurement instrument?	QS
	– Definition of the patron (reference)	RD and BTC
4	– Partitioning the generic error	QS
	– Definition of offset, gain and linearity errors	RD and BTC
	– Use of different lines to define the linearity error	TE
5	– Inferring the performance of the rest of the manufactured systems	QS
	– Definition of uncertainty	BTC and TE
	– Criteria to characterize the performance of all these systems	RD and BTC
6	– Studying the repeatability of each system	QS
	– Concept of fidelity (reproducibility, repeatability)	RD and BTC
	– How can fidelity be increased?	QS
7	– Defining the discrimination of a measurement system	BTC
	– Examples of discrimination in digital and analog readout measurement systems	TE
8	– Use of a data sheet to perform an error budget analysis	TE
9	– Minimizing errors by calibration and adjusting	TE

Nomenclature
BTC: Basic theoretical concept (definition given by the teacher)
MDD: Minor definitions derived from the BTC
QS: Question for the students
RD: Result of a discussion with the students
TE: Theoretical exercises and problems proposed to students

Step 3: Quantifying the generic error

The concept of calibration can be tricky: some students will have heard it previously while other students may confuse it with the adjusting process in a measurement system. For this reason, we prefer to start with students brainstorming about possible alternatives to quantify the discrepancy between the theoretical (ideal) transfer function of the measurement system and the real outcome, with the instructor facilitating the discussion and introducing questions such as how many experiments to carry out, the number of units to be tested, the cost, complexity and appropriateness of the procedure, etc. From the multiple solutions that are proposed, we choose to begin with the test of a single sensor randomly chosen. We use the concept of 'test' due to its generic meaning, instead of the concept of 'calibration', which has not yet been introduced. This simple test is carried out by evaluating the response of the transducer to a range of different inputs. During this step the students are also faced with presenting their results in the most meaningful way. As we have found that in general they tend to use a two-column table, the instructor could point out the advantages of using a graphic approach [12].

In this methodology approach, the calibration concept is only used as a tool to obtain information on the system performance: its static and dynamic response. A deeper study on calibration procedures is closely related to measurements standards [13] and the concept of traceability [3], which are more appropriate for advanced courses. However, even with our approach it is necessary to discuss with the students the usefulness of some of the tools employed in the calibration process. In fact, Doebelin [3] makes a proper distinction between 'measurement method' and 'measurement process', defining the latter as the (imperfect) physical realization of the first. A couple of critical questions to be introduced and discussed in the classroom are 'How can we know the actual value of the measurement quantity set in the input of the measurement system?', and 'How can we know that the output voltage measured during the calibration process is the actual output voltage of the sensor?' These two questions lead to the introduction of the concept of patron (reference) in a calibration process. Finally, it is necessary to continuously stress to the students that the static calibration process does not refer to the adjusting process to minimize the errors in a measurement system, but the process for which the input–output relations are experimentally obtained [3].

Step 4: Partitioning the generic error

At the end of step 3, the students have a calibration curve for the transducer. This curve can be different for each student or group of students if the instructor chooses to provide a different data set for each. The next step is to introduce the concept of partitioning the generic error instead of lumping it together as a single datum error (generic error). There are several reasons for partitioning the generic error. First, as manufacturers of transducers and devices specify different types of errors for their products, the students should follow this practice too, especially as they play the role of manufacturers and users of these devices. However, and perhaps more importantly, we believe that students should arrive at the same conclusions after careful deliberation and focused class discussions. Figure 3 shows an example of how to conduct these discussions: it depicts the performance of three pressure transducers manufactured by three different companies. These figures provoke the students to talk about concepts such as offset and linearity, for example, even before these concepts have been formally introduced in class.

The concept of accuracy is often referred to in the literature as a 'total' (generic) error, but it has limited practical utility, and therefore it is necessary to introduce concepts with a more practical utility, such as offset, gain and linearity error [5].

Step 5: Inferring the performance of all the manufactured sensors

Once a unique sensor has been characterized using the concepts of offset, gain and non-linearity error, we ask the students to critically think about the following questions: 'How can we infer the performance of the rest of the 999 manufactured pressure sensors?'; 'Would we find significant differences among all the 1000 sensors?'

At this point, the students may propose different solutions; however, it is critical that they reflect on the advantages and drawbacks of each proposed solution. Because manufacturers rarely indicate that all their sensors have been fully calibrated nor do they provide a statistic analysis of their characteristics, this is a good time to explore with the students a possible way of characterizing all, or a fraction of, the sensors, taking into account factors such as cost and time.

At the end of this step, the students have partitioned the generic error (accuracy) into three different error values: gain, linearity and offset. Moreover, depending on the number of tested units and the inferring method employed, the students will have different statistical values for these error values: mean value, range, standard deviation, confidence intervals. The most pedagogical value comes from the student understanding that each one of these errors will have an associated uncertainty value. Students then learn to see the uncertainty value as the probability that the error for any randomly chosen sensor will be within the range specified in the data sheet. By using several numerical examples, the students then learn the relationship between uncertainty as described earlier and the number of units tested.

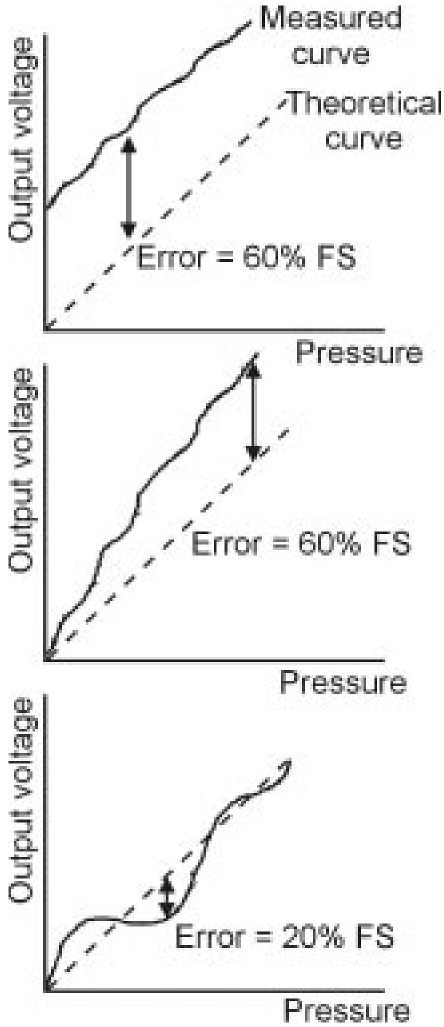

Fig. 3. Example of three calibration curves (measured curves) obtained for three different pressure sensors in order to provoke a discussion with students about 'the best' performance.

Step 6: Studying the repeatability of each sensor

After calculating the offset, gain, and linearity errors, the students may think that they have completed the study of their performance characteristics. However, this is the time to remind students that the data used to study the performance of the sensors has been collected only once and to pose the following question: 'Would each sensor offer the same value of generic error if it had been measured at a different time?' Although the students agree that these values will be different, they are unlikely to be able to point out reasons for these differences.

This allows the instructor to introduce the concepts of reproducibility and repeatability. In fact, these concepts are related to the more general concept of fidelity (precision is an equivalent word). In this area, we disagree with some authors [14] who assert that these words do not describe a quality of the measurement and are incorrectly used as such. In fact, although the definitions of reproducibility and repeatability are very clear, the concept of fidelity is not only fundamental in the science of measurement but also allows the classical discussion on accuracy versus fidelity (e.g. using the comparison with darts shot into a bull's eye [14] reproduced in Fig. 4), which is always appropriate and motivating for the students. In fact, during this discussion, students often use concepts studied previously, such as offset error and how it can be reduced, especially when explaining how a measuring system with poor accuracy and good fidelity (such as the one depicted in Fig. 4a) 'measures better' than the opposite system depicted in Fig. 4b. Interestingly, some students point out the possibility of reducing the fidelity error using averaging. Once again, a new concept materializes as a result of a discussion with the students; different statistical techniques can now be commented on in order to reduce the reproducibility and repeatability errors. Moreover, it is important to stress that sometimes these techniques are easier to implement than those techniques used to reduce systematic errors (offset or gain). In this step, the instructor could provide hypothetical data on results of different calibrations in order for each student to calculate the reproducibility and repeatability errors. With these errors and those previously estimated, the students would be almost ready to create a complete data sheet regarding the 1000 manufactured sensors.

Step 7. The concept of discrimination

The preceding steps have allowed us to introduce the concepts of accuracy and fidelity. However, these two concepts are not enough to entirely characterize the performance of the sensors; we also need to introduce the concept of discrimination (resolution is an equivalent word). The concept of discrimination is strongly dependent on the kind of sensor (analog versus digital readout), therefore we believe that the best approach is first to provide a general definition, and later to offer practical examples. Moreover, the concept of discrimination is related to the concept of dynamic range [15]. We have found that the best approach for getting students to use the concept of discrimination after it has been defined is to start by asking them to calculate the discrimination of systems with digital readouts, as they are easier to handle, and later to move on to a whole analog system.

We believe it is very beneficial to introduce practical exercises in which the students have to calculate the dynamic range of very different types of measurement systems, from a simple encoder to complex measurement equipment.

Step 8. Using a datasheet

Once all the performance of the system has been characterized by using the different concepts described previously, it is time for the students to work on the inverse problem. At this point, they switch to playing the role of being the users of the system, thereby needing to estimate the performance of a system by using the data sheet created by its manufacturer. The use of budget analysis is useful to help the students understand how to analyze the errors through a data sheet [16–17]. This part of the proposal can be based on practical exercises. The target of these exercises should be the theoretical estimation of the total error in a concrete measuring system under some environmental conditions (pressure, temperature, aging,

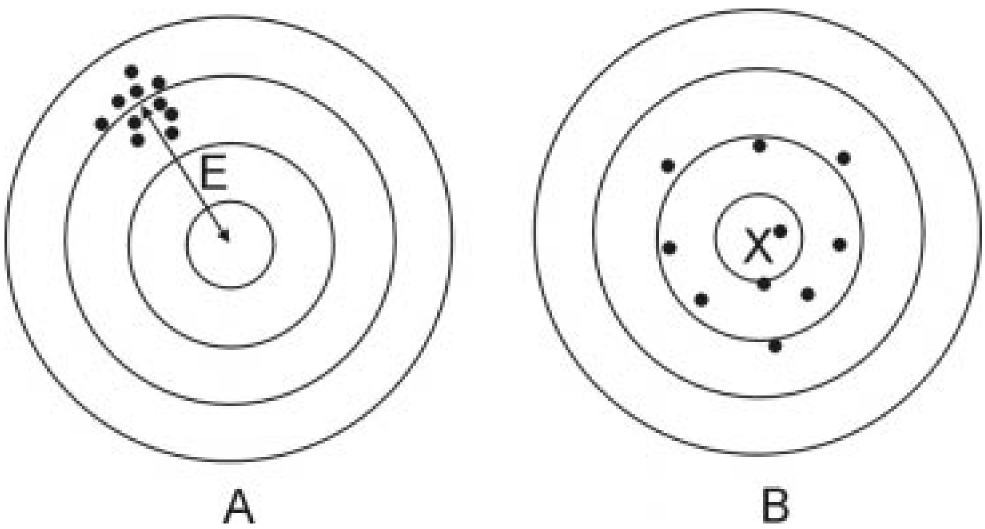

Fig. 4. Classic model of darts shot into a bull's eye, to explain the differences between the concepts of accuracy (uncertainty) and fidelity (precision), and to discuss what characteristic is more significant in a measuring system. A: results of a system with bad accuracy and good fidelity. The value 'E' would represent the distance between the target (true value) and the mean of the obtained values. The students identify this value as an offset error. B: results of a system with bad fidelity and good accuracy. The symbol 'X' represents the mean value, which is very close to the true value. The students have a tendency to consider the dispersion of results as a negative and uncontrolled characteristic, and therefore they consider the first system to be 'better'.

etc.). It is also very useful to perform this theoretical analysis by partitioning the total error into three types: absolute, temperature-dependent, and resolution error. The first one (including offset, gain, fidelity) could be minimized by calibration and adjusting. The second could be minimized by measuring the temperature and then by adjusting, or by maintaining, a constant temperature. Finally, the resolution error (including non-linearity and internal noise) cannot be reduced and consequently involves a limit in the design of an error-free system.

Step 9. Minimizing errors by calibrating in-situ and adjusting

Although the general performance of a measurement system is defined by its data sheet, any calibration process carried out by the user will allow the user to know the performance characteristics of that particular system. A one-point calibration usually allows knowing and consequently correcting the offset error of a specific system, while a two-point calibration allows additional treating of the gain error, and so on. A good descriptive example of these procedures can be found in [18] for a temperature sensor AD590 (Analog Devices, Norwood, MA, USA). In the example of a pressure sensor, its data sheet could offer us values of ± 10 mmHg, $\pm 2\%$, and ± 1.5 mmHg for the offset, gain and non-linearity errors respectively. Then, non-complex electrical circuits and procedures of adjusting to reduce the offset and gain errors could be proposed by the instructor and analyzed by the students. Moreover, data on the thermal dependence of offset and gain error could also be included in the analyses, as well as some linearization techniques.

Until this point, we think that the proposed methodology shows, easily and quantitatively, the relationship between the performance characteristics of a sensor, the topology and the characteristics of the connected conditioning circuits.

COURSE ASSESSMENT, POSITIVE OUTCOMES AND LIMITATIONS

Over the last three years, this approach has been used in a senior-level elective course on Industrial Sensors within an 'Industrial Electronics Technical Engineering' program at the Polytechnic University of Valencia (Spain), which is equivalent to a US baccalaureate degree in engineering. From the topics shown in Table 2, it can be seen that the course contains three main sections: fundamentals of sensors, main types of sensors and signal conditioning for sensors. The first one includes the performance characteristics of the measurement systems, which are the focus of this new methodology.

The traditional approach for teaching the performance characteristics of measurement systems does not allow the lecturer to clearly communicate to the students the difference between the performance characteristics considered from the manufacturer's point of view and the user's point of view. By contrast, using our approach, we have noticed that, at the end of the course, the students were able to clearly understand not only the concepts related to performance characteristics but, more importantly, the implications of these concepts in the practical process of design.

Furthermore, we believe that this method has allowed us to increase interaction with students, moving away from traditional lectures and incorporating a large number of student-centered activities [19]. This allowed us to develop an active-learning approach to the course, including problem-solving, hands-on laboratory experience, discussion groups, role-play techniques, self-directed study, cooperative learning, tutorials, oral and written communication, posters session, and other learning resources. In fact, this approach is in agreement with the guidelines of the European convergence on higher education, as the European Credits Transfer System (ECTS) strongly emphasizes active and student-centered learning (http://www.esib.org.) Similarly, this teaching approach is also in agreement with the criteria of the Accreditation Board for Engineering and Technology in the US [20].

We have identified the following as the main benefits and innovations of this teaching approach:

1. With this approach it is possible to present and discuss techniques for presenting engineering results, such as the (preferable) use of graphics instead of data tables [12, 21].
2. The concepts on calibration mean that the students need to design experiments in order to obtain results or demonstrate a hypothesis [20].
3. Because of the specificity of some industrial measurement techniques, it seems natural to expect that graduates will receive the appropriate training in the industry. However, Pallás-Areny [13] indicates that good habits or a good sense for measurement should be learned while in school.

Table 2. Some topics included in the course on industrial sensors

Section	Topic	% time
I. Fundamentals of sensors	Basic definitions, classification, performance characteristics, other characteristics	≈ 45
II. Main types of sensors	Displacement, strain, acceleration, pressure, temperature, flow, liquid level, light	≈ 35
III. Signal conditioning for sensors	Differential vs. non-differential signals, common mode and CMRR, amplification, isolation, linearization, sampling and data conversion	≈ 20

4. Developing a personal ethical framework is becoming increasingly important in academia [22] with a growing trend of incorporating ethics into technical courses [22, 23]. This teaching approach incorporates these concepts; they are taught by a practicing engineer and can be supported by other professionals.
5. There is currently a healthy debate in process focusing on teaching methodologies using either the top-down or bottom-up approach [8]. We believe that, because our approach begins by using a bottom-up approach, students are able to appreciate the importance of low-level information next to the practical world (calibration results). Then when we move on to the top-down approach, students can organize the details and develop more general ideas (information in a data sheet). In this sense, our proposal has a tendency to minimize the drawbacks of each approach.
6. Most of the criticism that instrumentation textbooks receive comes from the fact that they are often written to serve the educational needs in a given situation and focus on certain types of students [23]. Moreover, some new topics, such as virtual instrumentation (personal computer based) or smart and miniaturized sensors, are becoming increasingly important in instrumentation, producing a fragmented and 'personal' way of teaching. Instrumentation and measurement courses should not be standardized but instead should be developed to make them interesting and attractive to students, using, for example, some of the active-learning techniques that we use in our approach.
7. Some authors have suggested that enjoyment is the most essential ingredient of learning and teaching [13]. Although we believe that it is only one of the key factors, our experience using this approach has produced a high degree of enjoyment and motivation from the students. In addition, students are becoming increasingly used to instrumentation based on easy-to-handle digital instruments [9] and, consequently, concepts such as 'virtual instrumentation' and 'smart sensors' become more attractive to them than the traditional names of 'calibration process' and 'error classification'. We believe that the work that we have done might correct this tendency and bring motivation and interest into the instrumentation and measurement classroom.

Conversely, we have also been able to identify some limitations of this approach:

1. Although this approach focuses on a very important part of an instrumentation and measurement course, it only covers a small portion of the course. Therefore, some other general issues, such as types of sensors, signal conditioning, etc., are still being taught in the traditional way.
2. Pallás-Areny [13] has pointed out that academic institutions should provide basic skills enabling students to understand technical documents, including standards. Since our approach does not cover this topic in depth, other complementary courses should cover it [23].
3. Our approach does not address the experimental work to be done by the students but is merely focused on developing new strategies for teaching the performance characteristics of sensors and instrumentation systems. However, we understand the critical importance of experimental learning and plan to develop parallel laboratory sessions that will become the centerpiece of engineering education [12].
4. Several authors [3, 17] have stressed the importance of learning the mathematical aspects of measurement systems. However, we believe that the best pedagogical approach is to start with the basic concepts related to practical applications and leave the formal treatment of these systems after we have captured the students' interest and attention.
5. Morawski [24] has suggested that measurement and instrumentation science should be taught at engineering schools according to the same principles by which other fundamental subjects are taught. Morawski mentions not only the uncertainty of the results of measurement, but also the relationship between mathematical modeling and measurement, and the inverse modeling as a basis for reconstruction and calibration of measurement channels. Further work in the approach described in this paper will incorporate a more in-depth analysis of these topics.

CONCLUSION

This paper describes an educational methodology for teaching the performance characteristics of measurement systems that could be used in any instrumentation course, and not just courses on electrical or electronic instrumentation. The approach emphasizes the difference between the performance characteristics considered from the manufacturer's point of view and the user's point of view as the critical steps to guide the student's learning process. Moreover, this approach considers the use of different active-learning techniques to develop a student-centered learning environment that increases the students' self-confidence in their technical skills and abilities.

We are aware that this paper only deals with a small portion of a typical instrumentation and measurement course. However, because the topics treated in this approach are critical to understanding further concepts, we decided to focus our efforts on these specific topics. We hope, as part of our future work, to develop similar strategies to cover the remaining topics in an instrumentation and measurement course.

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