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A new didactic approach to statistical analysis of measurement data for the evaluation of measurement uncertainty – "SAM–EMU"

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ABSTRACT

This paper describes assumptions, aims, methodology, content and consortium make up of a European project (SAM–EMU) founded under the Erasmus Lifelong Learning Programme. The project has developed learning materials in the field of evaluation of measurement uncertainty. It is available in the form of a multimedia web based course, which has many advantages. This format is commonly accepted as a good way to prepare an EU wide vocational training vehicle. The course is available in English.

1. Introduction

The evaluation of measurement uncertainty is very important since a measurement result quoted without stated uncertainty is of no real use. Quality management systems require knowledge of the uncertainty to ensure the proper ratio of uncertainty and tolerance. In the case of complex measurands and/or advanced measuring systems it is increasingly difficult to assess and to document high measurement accuracy. There are many factors that influence measurement uncertainty. The correct estimation of uncertainty is not an easy task and an interdisciplinary knowledge is required from the measurement experts: a good knowledge of basic statistics, quality and metrology. The curricula of universities do not normally cover the subject of uncertainty evaluation in a comprehensive way. There are many documents dealing with uncertainty available, but to use them effectively one needs a good level of training and understanding.

Progress in advanced measuring processes is a core element in the development of manufacturing technology, and hence in the progress of industrial quality management. A critically important element of quality management is a knowledge of uncertainty of measurement. Experts in measurement uncertainty estimation are needed in industry and the need will grow in the coming years due to increasing quality management requirements. The lack of experts is caused by the fact that evaluation of measurement uncertainty needs interdisciplinary competence. Industry traditionally focuses on the technical possibilities of manufacturing, measurements, inspection and research. Industry trusts (naively) the suppliers of measuring equipment that the devices provided are adequate to the measurement needs with respect to the measurement task.

2. Consortium

The project partnership [1] developed and implemented an advanced e-learning system that integrates contributions from quite different disciplines into a user-centred approach that respects the necessary scientific precision and problem-solving approach of the field of engineering studies. Competences will be presented in a way that is methodologically and didactically optimised for employees with a mostly work-based vocational qualification as well as for engineering students and should, at the same time, be appealing and motivating to both groups.

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The project partners were:

- University of Bielsko-Biała, Laboratory of Metrology (formerly part of Department of Manufacturing Technology and Automation) and Academic Centre of Informatics (Poland).
- Friedrich-Alexander-University Erlangen-Nuremberg, Chair Quality Management and Manufacturing Metrology (Germany).
- University of Huddersfield, Centre for Precision Technologies (UK).
- Technical University of Cluj-Napoca, Department of Machine Tools and Industrial Robots (Romania).
- University of Padova, Department of Innovation in Mechanics and Management (Italy).
- Physikalisch-Technische Bundesanstalt, Division 3: Chemical Physics and Explosion Protection (Germany).
- "ANGA" Mechanical Seals Ltd. (Poland).
- International Foundation for World Class Manufacturing (IFWCM) (Poland).

The consortium members have good knowledge on uncertainty in measurement thanks to the long established research record and close cooperation with industry.

3. Aims and methodology

The project encompasses the development and implementation of a coherent learning system which can be a supplement for existing curricula of engineering studies and higher-level vocational training concerning the uncertainty of measurement. The courses are delivered by means of basic and specialised continuing e-training system offering on-demand e-learning modules, as well as an assistance system that incorporate permanent participation in a ubiquitous e-learning community of experts. Being developed especially for the needs of distance learning, simulation software will facilitate virtual experiments necessary to gain the skills to carry out estimation of uncertainty. The didactic materials provide a possibility to gain/refresh the necessary knowledge from probability and statistics, measuring equipment and measurement errors. The contents enable self-learning at a high level in the area of uncertainty. Many real-life examples explaining the methodology of evaluation of the uncertainty are included. The sources of necessary data for uncertainty evaluation are highlighted. The required experiments for calculation of the uncertainty are described. Much attention is paid to the uncertainty of coordinate measurements which are the key-technique in mechanical manufacturing industry. Additionally simulation software is available to explain the mechanism of source and propagation of errors. The developed learning system can significantly ease the mastering of the philosophy and significance of the uncertainty evaluation problem. Significant numbers of examples are integrated in the system to make users of the system aware that particular measuring situations are unique.

The working approach of a project has been to enable an efficient procedure to achieve results of high quality. For projects with an educational topic, several methods are offered via the models of Instructional Systems Design (ISD). For the project SAM–EMU, the model ADDIE which consists of the five phases – Analysis, Design, Development, Implementation and Evaluation – was chosen [2]. It efficiently facilitates the development of user-oriented learning by focusing on the needs of the learner together with the intended learning aims [3]. To enhance a smooth work flow and avoid iterations, elements of evaluation are not only used for a summative assessment of gathered results at the end of the project, but additionally measures of summative evaluation are included. The specific results of each phase is checked and if necessary improved before passing on as base for the next step, thus implementing a concept of quality gates.

4. Approach of user needs analysis

For the implementation of a training course, it is indispensable to know the needs and wishes of the intended learners. Consequently the design and implementation of training concept and realised learning materials has to be adjusted to the wishes of the learner to enable the definition of the learning aims.

As a base for this, it is necessary to describe the intended target groups of the course to identify their specific needs and requirements as well as other properties to be expected. For the course SAM–EMU, two kinds of participants have to be considered:

Primarily, the course is meant for students of technical subjects. Currently, there are few formal lectures courses concerning measurement uncertainty provided in university education across Europe. This results in a gap of knowledge and understanding in this area, which is likely to cause severe problems, when the young engineers start their career in industry and have to handle or interpret measurement results – a task that is part of nearly all working areas in engineering.

Secondly, the course is intended to be offered to employees already in industry as a possibility for advanced vocational training. Due to the aforementioned lack of information about the topic of measurement uncertainty in university education, there is a big need for advanced courses on the subjects. Yet, a market analysis showed, that there are very few offerings [4,5]. Those that do exist are mainly targeted at the expert level and thus are not suitable for most employees.

To identify the needs of the intended target groups, results of former development projects were used, where comprehensive analyses have been performed [6,7].

Additionally, experience of the members of the project consortium concerning the implementation of e-learning based courses in universities were used as well as national studies performed to assess the ability and interest of students in universities to use e-learning, e.g. [8–10].

Out of these sources, general information about the target groups was gained, covering manufacturing metrology as well as constraints on learning forms.

Regarding students of technical subjects as the primary target group, feedback for the use of new learning tools was very positive. Nearly all students have access to computers and internet and are also skilled in using this media.