New Innovative eWay of Vocational Training in the Field of Mechatronics

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Abstract: - This paper is focused on introduction of best practices in the field of vocational training of mechatronics further supported with the state-of-the-art information-communication technology, as well as with established methodological and didactical approaches, with the view of improving the quality and efficiency of vocational training. The presented methodology introduces a completely new way of vocational training of this profile because both, theoretical and practical training will be entirely conducted on-line. Practical work will be done through an innovative remote laboratory for practical work, based on web technology which allows the performance of the real mechanical-electrical and programming related experiments in the physical laboratory, what is in the training of mechatronics crucial. This should result in a greater recognition and attractiveness of the profession and will positive influence on the reduction of existing disparities between supply and demand of qualified mechatronic staff on the market.

Key-Words: Enhanced E-learning, Learning Management System, Mechatronics, Real On-line Experiments, Remote Laboratory.

1 Introduction

The profession of a mechatronic is believed to be a profession of the future, as many EU studies [9,11] have indicated it, placing it among the top three most perspective professions. The mechatronic area offers modern job opportunities, combining three main fields of interest: mechanical engineering, electrical engineering, and information technologies; this is why the mechatronics is considered an interdisciplinary technical filed. These professions have just recently been born in the industrially developed states, due to an ever-greater automation of the production processes. The mechatronics is a new way of thinking, a new way of planning products and systems that enable the integration of precision mechanics, electronics, automatic management, and informatics into the basic processes of planning, instead of searching for engineering solutions for every task individually. Mechatronics is therefore an interdisciplinary technical field, founded on the grounds of classical technical science of mechanical engineering, electrical engineering, and computer science. Instead of electromechanically (with bits of electronics) based systems, more and more complex mechatronic systems are entering the market.

In Slovenia and other EU member states formal training programs in mechatronics are already offered at the level of secondary school, as a programme of higher education and at university level [10]. However, market demand is much greater than supply. For the time being, the market is short of adequately trained staff; for that reason jobs that would call for experts in mechatronics are done, as a rule, by experts in mechanical or electrical engineering, who, due to their narrow orientations and focus on just one area, do not provide the possibility of a comprehensive insight into the installations and processes that require knowledge of mechatronics. Company research has shown that there is a great interest on the side of economy in additional vocational training for the staff, who have already completed their formal studies in mechanical or electrical engineering, to train them for work in the production processes, where mechanical machine installations are controlled by electronic control systems. In this way, the companies could at least partially diminish the currently existing gap on the market, which lacks qualified staff. Companies also voiced a demand for vocational training to be efficient substance-, time-, and cost-wise, and implemented at an independent location, with the purpose of minimizing the effects on the company operations [12].

2 Objectives

The main purpose of this paper is to introduce good practices into the areas of vocational training in mechatronics supported with the state-of-the-art ICT and computer based learning, as well as with the established methodological and didactic approaches, all with the view of improving the quality and efficiency of education. The purpose and the goals of the project MeRLab - Innovative Remote Laboratory in the E-training of Mechatronics (www.merlab.eu), founded by Leonardo da Vinci Lifelong Learning Programme 2007-2013, are directly focused on resolving the issue of the current market imbalances of supply and demand of qualified staff, trained in the field of mechatronics.

3 Methodology

If we wish to present the mechatronic studies in an attractive and innovative way, if we want to facilitate training access to a wide spectrum of potential users, and be at the same time and cost-effective, then implementing e-training is an optimal solution. Therefore the focus of the project is in the preparation of the innovative e-course. E-learning alone, as a teaching method, is no news to the world today, the only thing that can be innovative is the e-learning contents [13]. Besides the preparation of the interactive-multimedia e-materials for the chosen study modules [5], produced in the accordance with the SCORM (Shareable Content Object Reference Model) standard [1] which guarantees their interoperability and enable them to be further used in all e-learning management systems which support this standard, and implementation of a remote laboratory for practical work is another innovative dimension of our project (Fig. 1).

The companies demand on more and more practical knowledge and skills from their employees, merely theoretical knowledge is no longer enough. Practical skills can only be developed by working in laboratories. Preparing a practical training course in a classical laboratory is normally very expensive and limited in space, time and number of participants. For this reason, within the E-Learning Distance Interactive Practical Education (EDIPE) project a product called Remote Laboratory for Practical Lessons was developed, which resolves the above-mentioned problems and limitations [4]. A remote laboratory does not present web-based simulations. It truly makes it possible for students to perform actual experiments in the area of mechanical and electrical engineering, as well as programming, which take place in a physical laboratory. A user accesses the laboratory from a dislocated place using web tools (internet and browser), where (s)he can start to perform an experiment. The remote laboratory enables the user to have a full control over the implementation, measuring and monitoring of the experiment. The greatest advantage of the remote laboratory is that the users can perform their tasks anytime, anywhere, and can do so safely, without a laboratory assistant. The remote laboratory experiments are not only analysis-oriented (measurements and result observation); they can be synthesis-oriented, including also the planning aspect.

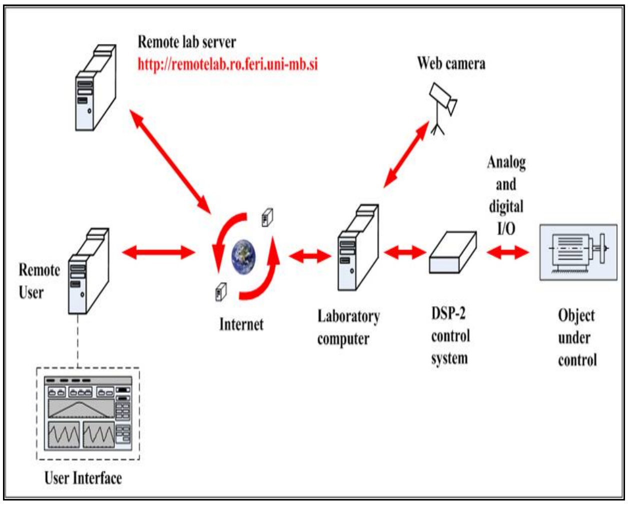

Fig. 1 Architecture of the Remote Laboratory

4 Six necessary steps to create the effective mechatronic e-course

To achieve the objectives from the above described methodology we needed to accomplish six main concrete goals: *Needs analysis, establishment of the innovative remote lab, adoption of the Learning Management System (LMS), production of interactive multimedia e-learning contents, usability evaluation of the LMS, remote lab and e-contents, pilot training.*

4.1 Needs analysis

Determining the actual company needs for mechatronic staff, based on company research, and determining its skill requirements for the employees. According to the performed needs analysis the mechatronic skills are much on demand, and we have noted a strong support with the Slovenian employers to develop these types of professions. People with combined work tasks and knowledge in the field of electronics, mechanical engineering, and informatics are needed in automatic production and other processes (eg. for modern purification plants) at three levels of difficulty: as operators, processing installation administrators, and processing technology experts. The first ones – mechatronic operators – manage processing installations, supervise their operation, carry out simple maintenance works and serve them. Processing installation administrators – mechatronics administer the operations of the processing systems, diagnose mistakes, repair processing lines, maintain installations, maintain and archive software and documentation for the maintenance of the processing system. A mechatronic of processing technologies predominantly deals with the line and machine assembly, with production optimisation and adjustments of the processing lines and installations to suit the needs of an individual company. Our e-course is adjusted to serve as an additional vocational training course for the needs of the first two described professional profiles.

4.2 Establishment of the innovative remote lab

The goal of the establishment of the remote laboratory and its adaptation is to enable inclusion of mechatronics remote experiments, to establish user-friendly booking process for remote experiments and to simplify the procedure for creating user accounts at the remote lab.

Experimental devices must enable execution of remote experiments from all major mechatronic's subfields. This includes: *modelling*, *control* and *regulation* of electrical devices and electrical drives, modelling, control and regulation of mechanical systems with linear and nonlinear dynamics with or without gear-boxes. Devices should also enable study of the problems as noises in measured signals, design of mechanical components, selection of suitable drives, gears, sensors and other industrial components common in mechatronic devices.

Experimental device must be designed so that its functioning is reliable, safe and that it does not demand special supervision. Proper design should also guarantee that the experimental device cannot be broken by the experiments performed by the remote user. For mechanical subsystem this means that its motion should be limited to the safe area with inclusion of the hardware or software end switches. For electrical subsystems limitation of electrical current and voltage must be applied.

Experimental setup must be designed to enable to the remote user access to all measured mechanical and electrical signals. User must also have possibility to tune all important controller and regulator parameters, as well to change the motion trajectory of the mechanical part of the mechatronics device. Therefore open controller for each mechatronic device that will be included in remote laboratory is necessary [2,3].

According to this conditions following was ascertain: Today there are no commercially available controllers and mechatronic devices for reasonable price that would fulfil all above stated conditions. According to this we have decided to implement as a controller a DSP2 control system. This system was developed at project partner Faculty of Electrical Engineering and Computer Science (University of Maribor), Institute for robotics. Its hardware can be to certain extend adapted and it can be also programmed to support mechatronics devices as an open controller, that is enable online parameter tuning and measurements of electrical signals and motion trajectory.

Mechatronic devices will be also designed at the Institute for robotics. Building blocks for mechatronic devices will be industrial components as drives, gears, sensors and other (Fig. 2).

At least three mechatronic devices will be necessary to enable the user an insight in all major mechatronics problems. A mechatronic device with simple mechanical part would be suitable for study of the basic problems of electro-mechanical systems. More complex device, if possible with mechanical subsystem with more degrees of freedom and more drives, would be suitable for study of advanced problems and problems that are partially from the field of robotics. Third device should be adjusted specially for study of electrical subsystems of mechatronic devices.

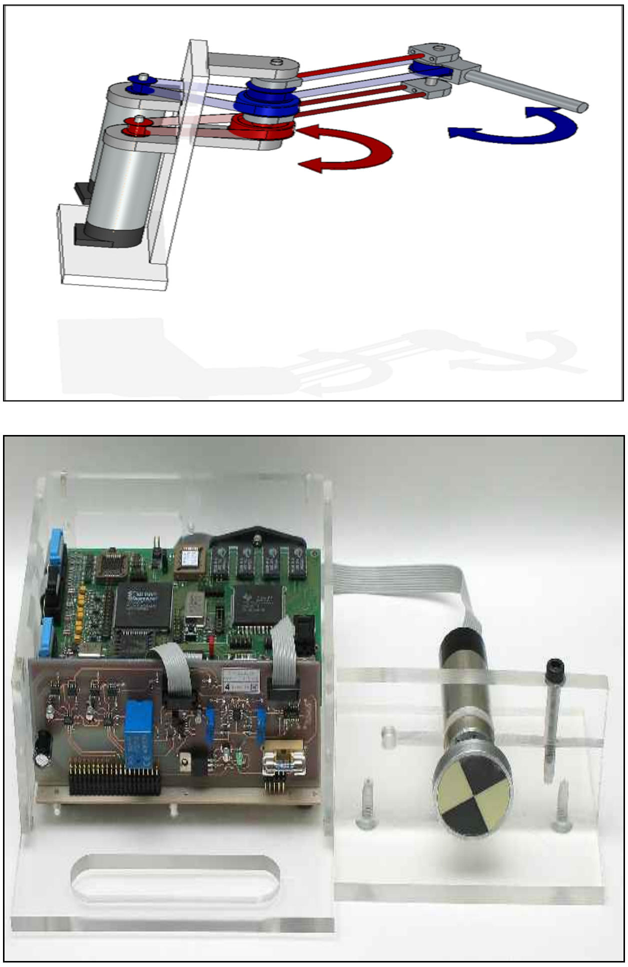

Fig. 2 Complex mechatronic devices

4.3 Adoption of the Learning Management System (LMS)

The very nature of the e-learning implementation dictates the use of modern information technology. For this purpose we shall put to use an already tested, reliable and stable learning environment eCampus®. This LMS system is based on a robust architecture, which facilitates adjustability to specific needs, such as multilayer connectivity with the remote laboratory (at the presentational level, at the data exchange level and user interaction between the two systems, as well as memorisation of past activities according to the identity of an individual user). Given the fact that communication is also an indispensable part of e-learning, it is supported with multiple Web 2.0 options (*forum, private message exchange, internal and/or external mailing list system communication, chat room, blogs, RSS, etc.*), which offer both the learners and the mentors/tutors a wide spectrum of possibilities for communication. The portal will be publicly accessible through a special URL web address. For the purposes of dissemination we will use the login portal site as an informative web page offering number of articles, news and best practices related to mechatronics [7].

4.4 Production of interactive-multimedia e-learning contents

On the basis of the corporate needs analysis we chose relevant mechatronic topics and organised them into learning modules; enhanced with know-how in creating and implementing multimedia and interaction elements, ensured with SCORM compatibility and partially redesigned XML templates in LMS platform. All e-contents will be available in two languages: *Slovene* and *English* [1,7].

4.5 Usability evaluation of the LMS, remote lab and e-contents

Usability is most often defined as the ease of use and acceptability of a system for a particular class of users carrying out specific tasks in a specific environment. Ease of use affects the users' performance and their satisfaction, while acceptability affects whether the system or product is used [22].

Testing with end users is one of the most fundamental usability methods and one which provides direct information about how people use the observed system and e-content, what their exact problems are with the concrete interface and it verifies its expected usefulness for the system user [24].

In usability testing it is very important to pay attention to the issues of reliability and validity [23]. Reliability is the question of whether one would get the same results if the test were to be repeated, and validity is the question of whether the result actually reflects the usability issues one wants to test. To ensure reliability and validity of the usability evaluation outcome, several points need to be considered: representativeness of test participants for real users of the system, realness of testing tasks as compared to actual tasks performed by real users, accuracy of observations of test participants behaviors, and sensitivity of measuring tools.

There are several unique methods and techniques for testing usability as well as many possible ways of combining various usability methods. A combination of methods and techniques used for usability assessment of LMSs and e-contents usually contains: task scenarios, think aloud protocol, field observations, questionnaires and participant debriefing [14, 15].

The most important thing that we need to do before any testing is conducted is writing down a test plan and addressing the following issues [16]:

- **Usability Evaluation Goals**

The usability testing of the system and e-contents evaluates the potentials for errors and difficulties involved in using the system and e-content for human resource activities. Some of the areas that will be tested through the usability evaluation process are identified from the observed system functionalities (i.e. Can users successfully navigate through the system? Can they easily locate the information they are looking for? Can the application be used with only the on-line help? etc.). Specific usability goals are determined from the above concerns. These goals allow the creation of evaluation scenarios and tasks that let us know if the observed system is: ***effective, efficient*** and ***satisfactory***. During the task creation and selection we need to be very attentive because one of the essential requirements of every usability test is that the test participants attempt tasks that real users of the system will want to perform with it and also probe potential usability problems [17].

- **Target Audience**

The selection of participants whose background and abilities are representative of the e-course intended end user is a crucial element of the evaluation process. Valid results will be obtained only if the selected participants are typical end users, or are matched as close to a selected set of characteristics as possible.

- **Preparing the Testing Environment**

Before you are ready to conduct the pilot test, which is the last step before conducting the usability evaluation, you have to prepare the physical test environment. The evaluation team needs to prepare the test room and observation room, procure required equipment (hardware, software), network connections and establish communications between the participant and the helpdesk [18].

- **Experimental Design**

Each participant receives a short, scripted verbal introduction and orientation to the evaluation. This material explains the purpose and objective of the evaluation, and additional information about what is expected of them. They are assured that the LMS and e-content are the center of the evaluation and not themselves, and that they should perform the test in whatever manner is typical and comfortable for them. The participants will be informed that they are being observed and videotaped and asked to fill out a short background pre-test questionnaire. The scenario is as follows:

- After the orientation, the participants are asked to sit down at the computer. The evaluation administrator gives the participants the task scenario booklet and instructs them on the use of the help desk.
- After the participants begin working through the evaluation scenario, they are encouraged to work without guidance except for the provided material and the product itself. The evaluation administrator may ask the participant to verbalize his or her thoughts if the participant becomes stuck or hopelessly confused. These occurrences will be noted by the evaluation administrator, and will help to pinpoint the cause of the problem.
- All test participants are required to think aloud when performing the task scenarios. It enables administrators to identify where participants are in a series of tasks, follow their thought processes, and identify points in the task flow where users deviate from the ideal path. As participants are providing feedback while completing a task, this method vividly reveals users' conceptions and misconceptions regarding the observed LMS and e-contents [19].
- To gather additional insights from the participants about performed scenarios, participants are asked to fill out a post-scenario questionnaire: the After-Scenario Questionnaire (ASQ). The ASQ is a 3-item questionnaire which assesses participant satisfaction after the completion of each scenario [20]. The items address three important aspects of user satisfaction with system usability: ease of task completion, time to complete a task, and adequacy of support information (on-line help, messages, and documentation).

- **Data Collection Methodology**

Usability evaluation data is usually a combination of two types of measurements: *performance measures* and *subjective measures*. Performance measures are obtained primarily through observations. These measures concern counts of actions and behaviors observed and consist of several aspects [21], e.g.: *timing* (time to finish a scenario), *errors* (number of wrong menu choices, selections and other errors), *seeking help* (number of screens of on-line help and number of times help is solicited from the evaluation administrator) and *emotional expression* (observations of frustration). Subjective measures are obtained mainly through participants' self-reporting. These measures concern people's perceptions, options and judgments and consist of two aspects: *quantitative aspect* (Computer System Usability Questionnaire - CSUQ - and After-Scenario Questionnaire - ASQ) and *qualitative aspect* (participants think aloud all the time when carrying out the task scenarios and participants debriefing).

- **Participant Debriefing**

After all tasks are completed or the time expires, each participant is debriefed by the evaluation administrator. The debriefing is recorded and usually includes the following:

- Participant's overall comments about his or her experience,
- Participant's responses to probes from the evaluation monitor about specific errors or problems encountered during the evaluation.

The debriefing session serves several functions. It allows the participants to say whatever they like, which is important if tasks are frustrating. It provides important information about each participant's rationale for performing specific actions, and it allows the collection of subjective preference data about the application and its supporting documentation. After the debriefing session, the participants will be thanked for their efforts, and released.

4.6 Pilot training

Pilot training with the prepared e-topics and the implemented remote laboratory for practical work, we prepared a 40-hour e-course, which will be entirely conducted via Internet. In the beginning of next year we will organise a pilot training of at least 30 course participants, chosen from the main target group where are workers who have already completed formal education in the field of machine or electrical engineering, and are currently employed by SMEs or large enterprises, more precisely working within the production processes, which include mechanical machine devices for electronic control systems. Due to an increased complexity of devices, which require mechatronic know-how, their knowledge in either mechanical or electrical engineering only proves often to be insufficient; resulting as a substantial need for further training of such staff. The pilot training will be performed for the purposes of validation and evaluation of the e-course. Their competences shall be tested at the end of the e-course. The examination will include both theoretical questions and practical tasks. Every course participant who will pass the final exam will receive a training certificate.

5 Expected impact of the innovative e-training on the field of mechatronics

In Slovenia, we currently do not have a model and even less an enviable level of cooperation between economy and the systems of education or their institutions, due to some known specific circumstances. Thus, this project should serve as a linking element and an example of how such connections can be improved and cooperation between the two parties enhanced. It shall ensure the establishment of connections between economy and education at the national level and further on EU level, since its main purpose is to meet the demands of economy. The economy, which for the time being is well undernourished with the above mentioned profile of labour force, shall at least partial mitigate the needs. The individuals will acquire an additional professional qualification and upgrade their skills, thus improving their employability potential on the labour market, which fits the spirit of lifelong learning. Through activities such as presentations, dissemination, etc. the project will have a direct impact on the public awareness regarding the new field of mechatronics, regarding the companies' needs of workers with such a profile and regarding the ways and possibilities for education and training in the field of mechatronics. In this way, young people will be encouraged to undergo formal processes of education in this area of expertise, and adults will be encouraged to either participate in the training process as provided by this project or through the system of National Vocational Qualification (NVQ) or in some other way. Potential mechatronic e-course participants, besides the main target group, are also the employed or the unemployed, who have completed their formal education in other fields (eg. textile sciences, chemistry, pharmacy, etc.), but have some experience in managing electronically controlled mechanic machine installation systems. This training will provide such staff with the necessary theoretical and practical knowledge (requalification), which is a necessity for the management of mechatronic installations. Requalification of people with very low and low employment prospects will improve their competitive position on the labour market, and will consequently have an additional impact on diminishing the gap between supply of and demand for qualified mechatronic staff, indicating a high potential for the future use of the results to be achieved by this project. More direct impact of the project result are fore mostly the course participants, because the training will provide them with the necessary new knowledge and skills, which will make them more competent at work and will provide them with better career development opportunities. Furthermore the project results – e-course – will also be used by the companies, since on the basis of adequately qualified staff they can increase their production efficiency and diminish the number of mistakes, which consequently leads to a higher cost-efficiency and higher profits. The project results may also be used by the institutions of education, who are implementing various professional and vocational training programmes. They will have a possibility of integrating the e-mechatronic course prepared in the framework of this project into their study programmes.

Expected impacts of the project results:

- **Target group(s)**

Short term impact: Predominantly already educated and trained staff with secondary vocational, specialized or post-secondary education in the field of technical and natural sciences will undergo further training or retraining for the current field of interest – where there is a great demand.

Long term impact: Diminishing unemployment levels of those, who might have no employment prospects for the time being. Expand employment possibilities for persons with mechatronical skills.

- **Target sector(s)**

Short term impact: Most of all, the employees (or those who intend to become such) in companies with technological processes shall contribute to improved company results and efficiency.

Long term impact: Diminishing the gap and lack of staff trained in the field of mechatronics.

- **Potential user(s)**

Short term impact: Production and service companies shall increase their efficiency, while it shall facilitate employees' work and increase job satisfaction.

Long term impact: It will be easier for the companies to carry out and support undisturbed technological or production process.

- **Vocational education training systems & practice**

Short term impact: National Institution for Vocational Education and Training, which carry out programmes in the field of mechatronics, they will access new, innovative and, most of all, efficient mechatronics teaching and learning tools.

Long term impact: School will be able to implement the mechatronics programmes in a more attractive and innovative manner, offering better, more sustainable and, most of all, more innovative know-how to students and future employees.

6 Conclusion

Given the fact that according to the European Commission's Joint Report on Social Protection and Social Inclusion the number of elderly employees will rise from 41% in 2005 to the foreseen 50% in 2010, and given the fact that mechatronics, or computer technology connecting, foddering and mechanical elements are the third fastest growing sector in Europe [5,9], we have to make sure that the method used in educational process (formal and informal) is effective and re-conciliated with the market demands. One step to meet these requirements is also our innovative and efficient teaching method, which is fully e-learning based, and mechatronic training puts significant emphasis on practical work, the decision to transpose and implement the remote laboratory innovation into this e-course is absolutely necessary. This method offers the possibility for additional vocational training (further training or retraining) of employees and unemployed, who had already completed their formal studies, and whose knowledge has become insufficient due to great technological changes. Since our teaching method provides for time and space independency, it minimizes the company work process disturbances and fulfils the requirements of the companies, as expressed in the research previously carried out.

The added value of the MeRLab project, if compared to the EDIPE project, is that the remote laboratory, which was the end-product of that project, will be adopted and upgraded with some additional interactive-multimedia e-contents, connecting them with an established methodological and didactical approach into a modern, attractive and innovative course of mechatronics for a specific user target group. This should result in greater recognition and appeal of the profession and will positively influence the gap between supply and demand of mechatronic staff on the Slovenian as well as on the EU market.

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