Int. J. Engng Ed. Vol. 26, No. 1, pp. 2–8, 2010
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Development and Implementation of Didactic Sets in Mechatronics and Industrial Engineering Courses*

GORDANA OSTOJIC, STEVAN STANKOVSKI, LASLO TARJAN AND IVANA SENK
Faculty of Technical Sciences, Novi Sad, Republic of Serbia. E-mail: goca@uns.ac.rs

VUKICA JOVANOVIC
Purdue University, West Lafayette, Indiana, USA

The collaborative design process supports the development of successful systems and products with a many participating engineers from a variety of disciplines. This kind of working environment lays stress on obtaining such multidisciplinary knowledge. Such efforts became an important element of capstone projects for students from different departments. This paper describes research related to the use of didactic sets in a problem based classroom setting. These sets are designed and implemented by teams comprising students from the Mechatronics and Industrial Engineering departments. They are installed in the mechatronics lab at the Faculty of Technical Sciences in Novi Sad, Serbia. The sets are used by students who are enrolled on a number of courses as part of their lab practice in the Mechatronics and Industrial Engineering departments. These didactic sets enable the integration of knowledge gained from various courses. They help the students to understand the connections between different engineering fields. Some of the lab topics that can be delivered with this kind of equipment are: electric motors, frequency controllers, Programmable Logic Controllers (PLC), fieldbus systems, and Supervisory Control and Data Acquisition (SCADA) systems. The students are involved in problem-based learning during hands-on activities such as making mechanical connections or wiring. Each didactic set consists of: an asynchronous three-phase electric motor, a frequency controller, a PLC, different relays, pushbuttons, indicators, and wiring. Some of the most important learning benefits are obtained through scenarios that simulate real industrial tasks and conditions.

Keywords: mechatronics; laboratory; didactic set

1. INTRODUCTION

MECHATRONICS is an interdisciplinary engineering field [1–5] that combines various areas such as: mechanical systems, electrical systems, control systems, computer sciences, etc. Many industrial applications such as automated manufacturing require mechatronics knowledge and skills, and therefore it is necessary to educate experts in this area.

Mechatronics and Industrial Engineering study programs at the University of Novi Sad, Faculty of Technical Sciences, Serbia, provide various courses for Bachelor and Master Degrees. Students are enrolled on the standardized curriculum, which is tested and certified to meet industry standards and quality compliance. Those courses also include internships and outreach activities, designed to provide real-world experiences for the students.
There is an ongoing debate about the way in which information should be transmitted to students [6–8]. The theory of experiential learning [11] propagates learning through experience and by experience in which learning is a process whereby knowledge is created through the transformation of experiences. Mechatronics education requires a full understanding of real time applications and problems. Therefore, adequate equipment is needed by the students for solving different multidisciplinary tasks to support such a curricula.

At the Faculty of Technical Sciences, there are various kinds of apparatus in the mechatronics lab. There are sets for pneumatics, sets for electro-pneumatics, programmable logic controllers (PLC), didactic manipulators, etc. This equipment provides an insight into industrial conditions, systems, processes, and problems. As such, the students gain practical knowledge that helps them in their future work. Various studies have given evidence that the increasing telematic-based work environment is important in the context of geographically distributed commissioning, installation, maintenance and repair of plant and machinery [9, 10].

This paper describes the development and implementation of new didactic sets in the mechatronics laboratory to integrate knowledge that has been previously acquired by the students in their courses. Students meet all the processes that are encountered in an industrial environment whilst designing, implementing, commissioning, maintaining, and repairing the didactic sets in the lab.

* Accepted 3 September 2009.

It is also important to point out that the development and implementation of the didactic set was delegated to specific teams of students. In this way the problem of design and implementation helped the students to develop the necessary socio-technical skills related to teamwork and communication. Those soft skills are identified as being important for the evaluation of the social impact of technology, as highlighted by the ABET general engineering criteria [12–14]. Design teams had various challenges to overcome during the course of the project. Most of them were related to their multifaceted characteristics, all acting to produce complex relationships and social processes from which a design eventually emerges. The professors and teaching assistants have insight into the process through shared documents and observations of the team dynamics during classes.

2. DIDACTIC SETS FOR ASYNCHRONOUS THREE-PHASE MOTOR CONTROL DS3MC-*x*

Didactic sets for asynchronous three-phase motor control DS3MC-*x* were developed and used by the students in the Implementation of Automated Systems course, which is part of the master's course at the Departments of Mechatronics, Robotics and Automation, and Industrial Engineering—Process Automation at the Faculty of Technical Sciences, Novi Sad. After developing these didactic sets, they were also used in the Systems for Supervision and Process Visualization (SCADA systems) and Programming and Implementation of Programmable Logical Controllers (PLC) courses in Master and Bachelor courses, respectively. Prior to taking these courses, the students have already completed the following courses: Machine Elements, Principles of Product Development, Components of Technological Systems, Factory Automation, Computer Integration of Manufacturing Systems, and have gained adequate knowledge in these areas. The objective of these three courses (Implementation of Automated Systems, Systems for Supervision and Process Visualization and Programming and Implementation of Programmable Logical Controllers) is to integrate previous theoretical and practical knowledge, and to qualify the students for solving real tasks in their future engineering careers.

2.1 Didactic set development

In 2006, students from the Mechatronics department who had enrolled in the graduate Implementation of Automated Systems course were given a project to design and realize four different didactic sets for speed and direction control for a three-phase asynchronous electric motor driven by:

- time relays and contactors, by switching $Y \rightarrow \Delta$;
- the use of a frequency controller, controlled by a programmable logic controller (PLC).

The assignment included electrical circuits design for control methods, CAD model development for the didactic panel and, finally, the physically realization of the system.

The final decision for the best concept was made when the design had fulfilled all the given constraints. Every set had to include the following components (see Fig. 1): a frequency controller (1), a three-phase asynchronous motor (2), a main switch (3), an emergency stop button (4), pushbuttons and switches for set handling (5), light indicators (6), and parts for the control box (7) i.e. an electronic control board. Parts of the electronic control board consisted of (see Fig. 2) a programmable logic controller (PLC) (1), a power supply (2), terminals (3), relays (4), fuses (5), a cable trunking system (6), H-rails (7), and cables (8)). Every didactic set has to comply with the task set.

While solving the task, each team had to complete the following phases:

1. Development of concept for the task solution
2. Presentation of chosen concept for the task solution
3. Didactic panel design—CAD model and drawings
4. Electric circuit design
5. Selection of available equipment
6. Didactic panel set-up—assembly of mechanical parts and electrical equipment
7. Wiring, according to the electric circuits
8. Programming the programmable logical controller
9. Commissioning
10. Testing, faultfinding and verification
11. Writing the project documentation.

Since the didactic set development is a complex task, teams of eight students were organized to solve this problem. Responsibilities within the team were divided in the following way: students worked in pairs; the first pair did the 3D modeling; the second designed the electrical circuits and wired the control board; the third programmed the PLC and the last pair commissioned and tested, and did the faultfinding and verification.

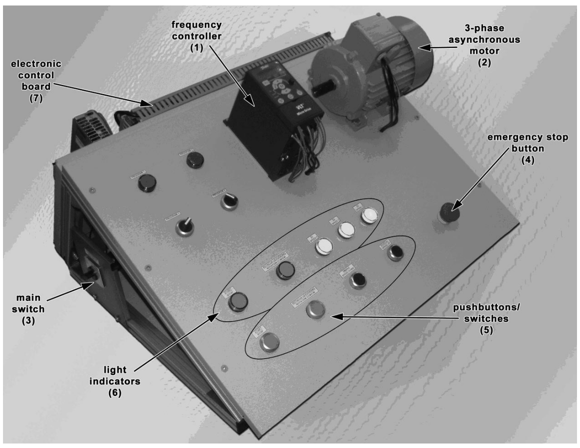

Fig. 1. Didactic set.

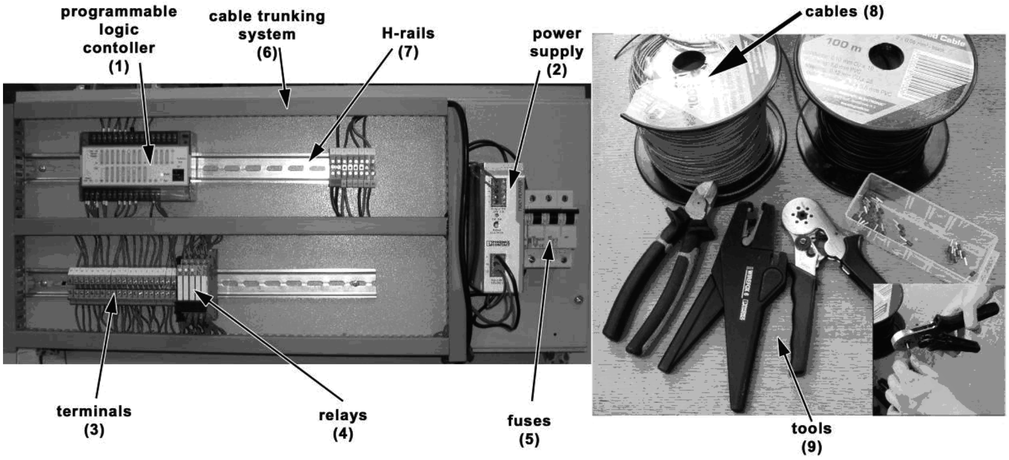

Fig. 2. Electronic control board and tools for wiring.

All the students were involved in the initial generation of ideas phase. They came up with the given concept for the problem solution, presenting the concept and writing the project documentation.

One special requirement was to realize the control cabinet as an electronic control board that could be easily assembled and disassembled. This control board represents a tool for laboratory classes where the students can learn how to use electronic circuits and I/O connection lists for wiring the control closet. In this way, all the components were assembled on the board, and could be easily seen and analyzed. The application of such a board in the class is easier than using a standardized cabinet.

The students uses specialized set of tools, wires and wire endings, commonly used in wiring control closets for wiring a control board in real product automation processes. This was an opportunity for all the students to become familiar with tools used in industry. The students learned how to wire components in an electronic closet, as well as how to distinguish standard wire colors.

With minimal advice and help from the professor and assistant, the students successfully realized the sets over a period of 15 weeks. The sets were made in five phases:

1. Concept, 3D model and electrical circuits design—5 weeks
2. Didactic panel set-up, connecting the equipment and wiring—4 weeks
3. Frequency controller adjustment and PLC programming—1 week
4. Commissioning, testing, faultfinding and verification—2 weeks
5. Development of project documentation—3 weeks.

Each of the four realized sets DS3MC-*x* (where *x* is the number of a particular set 1–4, as there are 4 sets) includes the same type of equipment, but with different characteristics (motors, regulators and didactic tables). Every set can be used for solving the same tasks, so the students can get acquainted with a variety of equipment and problems, although they are using the same types of components. Even though the sets were projected as being independent, they can be connected with other laboratory sets, such as didactic manipulators, pneumatics sets, etc. In this way various tasks and problems can be solved, and the students have the opportunity to see the integration of different engineering areas.

3. APPLICATION OF THE DS3MC-*x* DIDACTIC SETS IN LECTURES

The didactic sets for introducing and applying electric motors as well as their control in automation are used for lectures (laboratory classes) in three courses: Implementation of Automated Systems, Systems for Supervision and Process Visualization (SCADA systems) and Programming and Implementation of Programmable Logical Controllers (PLC).

In the Implementation of Automated Systems course these didactic sets are used in laboratory classes where the students develop and realize the solution for a given task. In the first part of the semester, the students are given the task of developing a didactic set to the level of 3D models and electrical circuits. After that, they get documentation for a didactic set, written by a previous generation of students. The students are supposed to read and analyze the documentation, and then create control board I/O connection lists according to the electrical circuits. The control board of the existing set is then disassembled and the students have to do the wiring again according to the I/O connection lists. By performing these tasks, they can become familiar with the technique of reading the I/O connection lists, and the ways of connecting (wiring) the control board. The students then adjust the frequency controller and program the PLC. Finally they write the project documentation, which includes technical documentation (3D models, electrical circuits, etc.) and documentation

Table 1. Number of tasks solved by using didactic sets with or without other laboratory sets

Course	Number of tasks solved by using didactic sets	Number of tasks solved by using didactic sets in combination with other laboratory sets	Percentage of the average use of didactic sets in the particular course
PLC	6	7	20%
SCADA	10	12	40%

that includes suggestions for improvements in the didactic sets, and a comparison between the designed and implemented sets, as well as suggestions for expanding the sets by adding more components (sensors, actuators, etc.). At the end of the semester, the students have to present their project in a half-hour presentation.

These didactic sets allow every student (in every generation) to pass through all of the phases of prototype/product development, starting with designing, through implementation to commissioning and systematic fault (error) finding.

In the 2009/2010 class there is a plan to use the didactic set in the Disassembly and Recycling Systems course that is part of the Industrial Engineering course. Instead of the present disassembly process, accomplished by students in the Implementation of Automated Systems course, students in the Disassembly and Recycling Systems course would first be asked to write the disassembly didactic set documentation, and then disassemble the didactic set to the lowest level of disassembly, thus enabling the next generation of students to assemble it from the start.

In the Systems for Supervision and Process Visualization (SCADA systems) course these didactic sets are used in laboratory classes, where the students are supposed to solve different tasks in supervision, remote control and visualization. These didactic sets allow tasks such as the remote adjustment of frequency controller parameters and its supervision to be performed, as well as supervision and control of every part of the systems by communicating with the PLC —displaying indicator states, activating pushbuttons and switches, and displaying the speed and direction of the motor rotation. By constant supervision, it is possible to make reports and graphs of motor activity, electrical energy consumption, etc. While performing the tasks, the students can use available software solutions for making a SCADA system, or develop their own solutions in standard programming languages. In addition, the students learn how to establish communication between a SCADA system and a PLC, a PLC and a frequency controller, and SCADA and a frequency controller, by using different interfaces and communication protocols. By accomplishing these tasks, the students gain an understanding of the practical problems involved in establishing communication between a computer and a PLC, and writing programs that collect data from the PLC and display them to the user. They also understand the possibilities of practical applications of SCADA systems in real industrial conditions. The students also understand the problems related to specific customer demands, and the program adjustments required for meeting these demands (e.g. parameter tracking and their analysis, realizing manual and automatic mode switch according to the current state of the system, etc).

The Programming and Implementation of Programmable Logical Controllers (PLC) course is a Bachelor's course, and is basic for the two above-mentioned courses. When the sets were realized for the first time, they were also introduced in the laboratory classes in this course, where the students solve various programming problems— different ways of controlling a three-phase motor, communication with a frequency controller, etc., in two PLC programming languages: Statement List and Ladder Diagram (according to the standard IEC 61131- 3). In addition, in this course the sets are connected to other didactic sets in the laboratory, such as didactic manipulators, pneumatic sets, etc., and the students complete a number of tasks with such combinations. In this way the students become acquainted with the control of various actuators and connect different controllers in unique control systems by using different communication protocols and different interfaces.

Table 1 lists the courses in which the didactic sets are used as well as the number of tasks that can be solved using didactic sets, and the number of tasks that can be solved using didactic sets combined with other laboratory sets. It can be concluded there are number of tasks that can be solved using either integral didactic sets, or using them in combination with other laboratory sets.

4. ASSESSMENT RESULTS

The mechatronics laboratory described in this paper was set up in 2002. Since then, different courses have been taught in the laboratory. Those courses are Programming and Implementation of Programmable Logic Controllers, Material Handling Technologies, Systems for Supervision and Process Visualization, Components of Technological Systems, Factory Automation, Computer Integration of Manufacturing Systems, and Implementation of Automated Systems. In the first phase, the lab equipment comprised only electropneumatics sets (cylinders, valves, and sensors). Later, the laboratory was upgraded with a three degree-of-freedom didactic manipulator (MRA-

M01) in 2006 and DS3MC-*x* didactic sets in 2007. The problems used during the courses were formulated with the purpose of stimulating the development of the students' team skills as the lab is used for the first time.

In addition to this common objective, every course has its defined objectives, as follows. The Programming and Implementation of Programmable Logic Controllers course's objective is to teach students to be 'proficient in PLC coding in standard IEC 61131-3 programming languages, networking, applications, and PLC usage in system design'. The Supervision and Process Visualization Systems course's objective is for students to gain proficiency in 'data acquisitions of industrial and nonindustrial processes, chronology and analysis of events, and process visualization'. The Implementation of Automated Systems course's objective is for 'proficiency in industrial requirements specifications, requirements analysis, criteria for equipment, project management, project model, design project, installation/commissioning, maintenance, and fault-finding'. For these three courses, the common objective is to 'encourage teamwork', which is also achieved by solving tasks related to the didactic sets.

The assessment of learning in the mechatronics laboratory involved students of Mechatronics and Industrial Engineering who took courses in the laboratory between 2002 and 2009. The maximum number of full-time students in the Mechatronics department was 56 and 36, respectively, for Industrial Engineering. At the end of each course, a questionnaire was completed, which evaluated the quality of lectures, course material, and available laboratory equipment, as well as their influence on achieving course objectives. This questionnaire had a standard form, developed for this purpose, and it was completed for every course in the Faculty of Technical Sciences in Novi Sad, including the three already mentioned. In this assessment, only two of the questions that were related to the laboratory equipment, were looked at. The first question was: 'Rate your ability to individually solve different tasks in the laboratory'. The following answers were available: totally individually; with the help of literature (textbook, technical documentation, etc.); with the help of a team colleague; with the help of a professor/assistant. The student is required to pick the answer with which he or she agrees most. The second question was 'Rate how the laboratory supports better achievement of the course objective on a scale of 10–100%?'

In addition to this questionnaire, students completed an additional form where the following question was asked: 'Rate how the laboratory with didactic sets DS3MC-*x* supports better achievement of the course objective on a scale of 10–100%'.

The questionnaire answers were analyzed and average values for the school years 2002/2003 to 2006/2007 (Before), and 2007/2008 to 2008/2009 (After), are presented in Table 2. This period was selected as the mechatronics laboratory was founded in 2002.

The results were analyzed and the conclusion reached that the students who have used the laboratory since the time when the didactic sets were introduced became much more team oriented than did the students who did not use it (see Table 2). The values differ by about 7%. In addition, students who used the didactic sets DS3MC-*x* evaluated laboratory equipment better then the students who did not use it. The difference in the students' estimation of different courses comes from the fact that the number of tasks that are solved in the laboratory varies with the course.

Evidence that didactic sets DS3MC-*x* add value to courses is found in the average student's grade in the class, which involved hands on experiences. Tables 3 and 4 show results for the Programming and Implementation of Programmable Logic Controllers (PLC's) and Systems for Supervision and Process Visualization courses, respectively.

Based on the analysis of results given in Tables 3 and 4, it was observed that the percentage of students passing the exam who had experience with didactic sets DS3MC-*x* (in school years 2007/2008 and 2008/2009) and passed the exam at the first scheduled date, which is just after the semester, is greater than that for the students who did not work with didactic sets DS3MC-*x*. For each class of students the first exam period for the Programming and Implementation of Programmable Logic Controllers course is in June, the second is in September, and the third in January. The terms for the exam for the Systems for Supervision and Process Visualization courses are January, June and September. In both cases, the increase in the number of students who passed the exam at the first available time is about 15%.

Table 2. Average values of students' responses

Course	Before* (average)	After* (average)	Before** (average)	After** (average)	After*** (average)
PLC programming and implementation	25%	31%	86%	88%	90%
Supervision and process visualization systems	26%	33%	89%	91%	92%
Automated Systems Implementation	78%	85%	90%	93%	95%

* Question: Rate your ability to individually solve different tasks in the laboratory. Answer: With the help of a team colleague
** Question: Rate how the laboratory supports better achievement of the course objective?'
*** Question: Rate how the laboratory with didactic sets DS3MC-*x* supports better achievement of the course objective?

Table 3. Percentage of students who passed the exam in the Programming and Implementation of Programmable Logic Controllers (PLC's) course for different exam periods***

	2003		2004		2005		2006		2007		2008		2009	
Exam period	**MEH***	**IE****	**MEH**	**IE**	**MEH**	**IE**	**MEH**	**IE**	**MEH**	**IE**	**MEH**	**IE**	**MEH**	**IE**
January	45%	38%	46%	44%	31%	36%	47%	27%	40%	39%	50%	31%	70%	59%
June	65%	61%	58%	56%	61%	49%	63%	52%	66%	57%	81%	69%	78%	67%
September	19%	17%	27%	20%	14%	22%	23%	13%	16%	26%	11%	10%	–	–

* MEH—the course in the Department of Mechatronics
** IE—the course in the Department of Industrial Engineering
*** January, June, September—in Serbia, students can take exams at different exam times, not just at the end of the semester, in the final week.

Table 4. Percentage of students who passed the Systems for Supervision and Process Visualization course for different exam periods***

	2003		2004		2005		2006		2007		2008		2009	
Exam period	**MEH***	**IE****	**MEH**	**IE**	**MEH**	**IE**	**MEH**	**IE**	**MEH**	**IE**	**MEH**	**IE**	**MEH**	**IE**
January	71%	69%	68%	64%	73%	66%	70%	67%	75%	70%	84%	81%	85%	80%
June	19%	16%	16%	22%	13%	21%	18%	17%	12%	13%	10%	11%	8%	11%
September	10%	15%	16%	14%	14%	13%	12%	16%	13%	17%	6%	8%	–	–

* MEH—Mechatronics course
** IE—Industrial Engineering course

The results retrieved from the Implementation of Automated Systems course are not represented in this paper. This was because the students are obligated to pass the exam in the first given exam term so the results are within the limits of about 2%.

All this leads to the conclusion that the didactic sets DS3MC-*x* have increased the students' ability to solve different problems in various automation fields and have led to better achievement of the different course' objectives.

5. CONCLUSIONS

The didactic sets DS3MC-*x* have been developed with the aim of providing Mechatronics and Industrial Engineering students with the chance of getting higher quality training through examples from areas where multidisciplinary knowledge is needed. While working with didactic sets, students have introduced themselves to problems of three-phase motor controls. With minimal intervention from the professor/assistant, students substantively were immersed in the problems of design, implementation, commission, faultfinding and other processes that they will actually meet in factory automation after their graduation. These kinds of projects will establish a deep foundation for their future work since they are being acquainted with various types of equipment and problems, though they are using the same type of components.

In summing up the results of the students' assessment, it can be concluded that they are satisfied with the project. The second result that came to prominence is that this project not only helped the students who developed the didactic sets during the Implementation of Automated Systems course, but also the students who used the sets in labs for the Programming and Implementation of PLC and Systems for Supervision and Process Visualization courses.

The main weakness in using these didactic sets is the limited collection of sensors and actuators and in the number of possible variants. Although the students can propose different designs and characteristics for sets in the Implementation of Automated Systems course, they do not have the opportunity to verify them practically. The only possibility for demonstrating the advantages or disadvantages of the proposed solutions versus the available sets is in the creation of simulation models. However, this may be a benefit since the students can also realize the importance developing simulation models in estimating the justifiability of the proposed solutions. Therefore, it would also be interesting to use digital manufacturing applications for computer integrated manufacturing processes to develop new systems based on the skills gained through those labs.

REFERENCES

1. A. Brown, Who owns mechatronics? *Mechanical Engineering magazine*, 2008, pp. 23–31.
2. D. Bradley, What is Mechatronics and Why Teach It? *International Journal of Electrical Engineering Education,* **41**, 2004, pp. 275–291.

3. D. Elata and I. Garaway, A creative introduction to mechanical engineering, *International Journal of Engineering Education,* **18**, 2002, pp. 566–575.
4. M. Grimheden and M. Hanson, Mechatronics—The Evolution of an Academic Discipline in Engineering Education, *Mechatronics*, **15**, 2005, pp. 179–192.
5. D. Tomkinson, and J. Horne, *Mechatronics Engineering*, McGraw-Hill, New York, 1995.
6. M. Grimheden and M. Hanson, Teaching fast prototype design of mechatronic system—From idea to prototype in 24 hours, *REM 2005 Conference*, France, 2005.
7. M. Grimheden and M. Hanson, What is mechatronics? Proposing a didactical approach to mechatronics, *First Baltic Sea Workshop on Education in Mechatronics*, Kiel Germany, 2001.
8. V. Giurgiutiu, J. Lyons, D. Rocheleau and W. Liu, Mechatronics/microcontroller education for mechanical engineering students at the University of South Carolina, *Mechatronics*, **15**, 2005, pp. 1025–1036.
9. J. Lee, H. Qiu, J. Ni and D. Djurdjanovi, Infotronics technologies and predictive tools for next-generation maintenance systems, *11th IFAC Symposium on Information Control Problems in Manufacturing*, Salvador, Brazil, 2004.
10. T. D. Graupner and E. Westkämper, E-maintenance web-based services for production systems, *Proceedings of International Conference on Intelligent Maintenance Systems*, Xi'an, China. Changsha, China: National University of Defence Technology Press, 2003, pp. 637–645.
11. H. H. Erbe and F. W. Bruns, Didactical aspects of mechatronics education, *5th IFAC International Symposium on Intelligent Components and Instruments for Control Applications (SISACA)*, Aveiro, Portugal, 2003.
12. C. L. Dym, J. W. Wesner and L. Winner, Social dimensions of engineering design: observations from Mudd Design Workshop III, *Journal of Engineering Education*, **92**, 2003, pp. 105–107.
13. C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey and L. J. Leifer, engineering design thinking, teaching and learning, *Journal of Engineering Education*, **94**, 2005.
14. W. A. Wulf, Some thoughts on engineering as a humanistic discipline, *International Journal of Engineering Education,* **20**, 2004, pp. 313–314.

Gordana Ostojic graduated from the University of Novi Sad, Faculty of Technical Sciences, Mechanical Engineering in Novi Sad in 1999 with a dipl.ing-master degree, received her Magistar (Ph.D. candidate) in the area of automation in 2003 and doctorate in the area of mechatronics in 2008. Her research is focused on automation. She works in the Department of Mechatronics in the University of Novi Sad as an Assistant Professor.

Stevan Stankovski earned his dipl.ing.-master in Electrical Engineering at the Faculty of Technical Sciences, University of Novi Sad in 1987, from which he also received his Magistar (Ph.D. candidate) degree in the area of Computer Science and Automation in 1991, and his doctorate in the area of Intelligent Automated Systems in 1994. He is a full Professor in the Mechatronics Department of the University of Novi Sad.

Laslo Tarjan is a teaching assistant at the Department of Industrial Engineering, Faculty of Technical Sciences, Novi Sad, from which he received his dipl.ing-master degree in the area of Mechatronics in 2008. His research interests are in industrial engineering, robotics, mechatronics and automation systems. He works as a graduate teaching and research assistant Professor Assistant in the Mechatronics Department of the University of Novi Sad.

Ivana Senk is a teaching assistant in the Department of Industrial Engineering, Faculty of Technical Sciences, Novi Sad, from which she received her dipl.ing-master degree in the area of mechatronics in 2008. Her research interests are robotics, mechatronics, software engineering and automated identification technologies. She works as a graduate teaching and research assistant Professor Assistant at the Mechatronics Department of the University of Novi Sad.

Vukica Jovanovic is a graduate research assistant at Product Lifecycle Management Center of Excellence, Purdue University, West Lafayette, Indiana. She is currently working on her doctorate in the area of Design for Environment of Mechatronic Products. She received her Magistar (Ph.D. candidate) in 2006 and dipl.ing-master's degree in 2001 from the University of Novi Sad, Industrial Engineering and Management department: Robotics, Mechatronics and Automation, where she worked as teaching and research assistant. She worked as a student intern for Technigraphics, Inc. during the summer of 2009, and for Gamesa Aeronautica, Moasa Montajes in the summer of 2002.