Effective knowledge exchange with modern didactic concepts

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Abstract - Production sciences and manufacturing technologies are worldwide a central element for societies which take profit and welfare by their producing industries. Especially in the highly industrialized countries it has to be considered that these production plants can only be operated with highly qualified staff.

In this contribution we demonstrate a structure and scheme for knowledge transfer from the tertiary to the secondary educational level with examples in the field of Robotics and Flexible Automation.

Thanks to the initiative Leonardo Lifelong Learning – Transfer of Innovation of the EU it is shown that a successful cooperation of Austrian, Croatian, Slovenian and Turkish partners is realized in terms of education and engineering. The essential elements of the project will be presented in this paper.

I. INTRODUCTION

Modern production sciences and manufacturing technologies processes need both flexibility and a high level of automation [1]. Of similar importance is especially in highly industrialized countries that these production processes can only be operated by highly an excellent qualified staff. This is even more important, if these processes have to be optimized.

The practical relevance and the corresponding complexity is the main reason for choosing the topics “Flexible Automation” and “Robotics” as an example for developing a structure and concept for knowledge transfer to different educational levels as well as to SMEs and their staff.

A. Associated Project

The LLL-project of “Flexcell” makes a contribution to keep high standard production plants at the industrial location of Europe by offering a modular teaching concept for the educational demands to start operation of a flexible production cell with success. This modular teaching concept considers the levels of demands of the different target groups, e.g. academic staff, students, pupils and workers. Regional close partnership is necessary and supported by skills and technological equipment of cooperating countries and partners in the project [4].

The present paper is therefore based on a collection (summary) of experiences and knowledge of experts who all work in the field of Flexible Automation and robotics. These people work for example as consultants in industry, teachers in technical schools of higher education and lecturers in universities of applied sciences. It is important to mention that they are in close relationship to the needs of industrial applications.

B. Educational concept

The main scope of the considered concept is to establish training modules of VET teachers, trainers of practical lessons in schools as well as employees in companies. Furthermore in order to show the effectivity of the concept training sessions have been successfully undertaken. The basic direction of innovation transfer is from Austria and Slovenia to other countries – for example Turkey. Also a good cooperation to the “Industrial and craftsmen school Pula” was established.

Figure 1. Flexcell Project devices of different partners

It is well known that a profound knowledge leads to higher quality, reduced costs, better company reputation and competitiveness.
The developed scheme is a working guideline for finding the needs of industry in the field of education and how to establish a new education system that is based on those needs. Therefore one of the results of this project is for example the preparation of questionnaires, which identify the needs of industry, their expectations for the future, weaknesses, possible potentials for optimization and how they would like to cooperate with schools and universities. Beside the target group further results are adapted training modules for a specific topic, a special dictionary, knowledge transfer in the field of flexible automation, a better cooperation between industry and schools and evaluation sheets for continuous improvement.

Additionally solutions found in a previous project [9] are prepared to be transferred.

The quality of this process is monitored and continuously improved by the Deming circle, which is a four-step method consisting of plan / do / check / act (fig. 3). The last point is essential to assure that the needs of the target groups are met. The combination of theoretical knowledge and practical exercises is also very important for the overall teaching process.

It is worth to mention that an overview of the corresponding school and education system of the partner country is helpful. Fig. 4 gives an example of the Turkish education system from pre-school up to doctoral studies.

Our didactical concept was matched with the current preeducation/knowledge of the students in Turkey. In order to ensure an implementation in the corresponding curriculum it is necessary to understand the overall education structure in Turkey. Finally it could be shown that a smooth integration of the course was successfully performed.

In fig. 1 different flexible cells, which have been developed by project partners and used machines are presented in order to understand the application behind the concept. Basically this can also be seen as a contribution to the implementation of industry 4.0 concept.

II. TRANSFER CONCEPT

The didactical concept of the project is based on two pillars.

A) Training of trainers in Austria and Slovenia with flexible production cells (see fig. 1).

B) Training of trainers and pupils in partner countries (Turkey and Croatia).

A. Training the trainers

The first part of the training uses the results of the previously reported SIAT project “Koop Flexible Automation” [8], which combines various disciplines of process automation, e.g. robotics, process control for CNC-based manufacturing, image processing and analysis on a high education level (see fig. 2). Due to differently designed cells with various education focus, specific
training modules had been developed earlier and could now be employed in practice (see fig. 1). All prepared courses can be seen in the following fig. 5. Additionally the estimated duration for each part is documented.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Module</th>
<th>Hour</th>
<th>Days</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CNC Manual Programming (milling + turning)</td>
<td>8</td>
<td>6</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>CNC Cam Programming (milling + turning)</td>
<td>8</td>
<td>5,5</td>
<td>44</td>
</tr>
<tr>
<td>3</td>
<td>Robotics basic</td>
<td>8</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Robotics advanced</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>Quality management</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Optical measurement systems</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Process control</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Machine control and embedded systems</td>
<td>6</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>Machine control and embedded systems</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>Safety basic</td>
<td>5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>Safety advanced</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Design I</td>
<td>6</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>13</td>
<td>Design II</td>
<td>6</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>14</td>
<td>Economics and organization</td>
<td>8</td>
<td>2</td>
<td>16</td>
</tr>
</tbody>
</table>

Figure 5. Training module setup

The modular design has proved to be very advantageous, because it was possible to adapt the training program to the trainees in the short term. Another benefit arises from the fact that the above mentioned modules were presented by the different project partners, which considers their specific skills. This enhances the quality of teaching and offers a wider range of industrial applications. Especially in the field of computer-aided design and material processing our project partners could provide complementary knowhow. Additionally a parallel training of the groups is feasible.

Further details can be found in [9].

B. Training in partner countries

A particular challenge was the training in our partner countries. For this purpose it was essential to perform a local inspection of the sites with special focus on the available infrastructure (see fig. 6).

Figure 6. Local inspection of partner sites

It was immediately recognized that the financial resources of our friends in Turkey and also in Croatia were very limited. Therefore a low-budget concept was absolutely necessary.

An appropriate solution was the implementation of the Open-source learning platform Moodle. It is a learning platform designed to provide educators, administrators and learners with a single robust, secure and integrated system to create personalized learning environments. Moodle is provided freely as Open Source software, under the GNU General Public License. Anyone can adapt, extend or modify Moodle for both commercial and non-commercial projects without any licensing fees and benefit from the cost-efficiencies, flexibility and other advantages of using Moodle. The system is web-based and so can be accessed from anywhere in the world. With a default mobile-compatible interface and cross-browser compatibility, content on the Moodle platform is easily accessible and consistent across different web browsers and devices [10].

Fig. 7 shows the overall structure of the Moodle course which is divided into different courses. These courses exist for Robotics Basic, Robotics Safety, Quality management, Optical measurements, Cam Programming Turning, Machine Control and Embedded Systems, CNC Manual Programming.

Figure 7. Moodle Training at CUAS

Furthermore a technical dictionary English – Croatian, English – German, English – Slovenian and English – Turkish was added.

C. Software - Tool (Matlab)

Finding solutions for technical problems need first of all physical knowledge of the proposed task and a lot of mathematical relationships. Therefore a successful knowledge (transfer) concept has to cover these topics. Furthermore a modern pedagogical method requires
computational help in solving mathematical problems. It turns out that mathematics is a challenging topic for many pupils and students. On the other hand nowadays there are different pleasant ways to improve mathematical skills. There are for example applications running on a tablet or smartphone, which help to teach and learn mathematical content in a playful way for pupils. For engineers Matlab is a valuable tool - some people would say a “toy” for technicians - for solving mathematical oriented tasks. Matlab and its simulation environment Simulink combine the evaluation of mathematical formulas or complex tasks with the elements of a simple programming language. It is seen as an easy-to-learn tool for solving and understanding mathematical related tasks. Therefore we decided to include an introduction to Matlab in the training module. We are convinced that Matlab is a suitable programming language also for pupils and beginners in a technical field [2].

Due to the fact that our proposed topic is related to robotics the introduction to Matlab is based on the needs of basic robotic calculations.

Furthermore we used the introduced Moodle platform to prepare an interactive “Matlab for robotics” training module [5], [7].

It is clear that users (e.g. pupils involved in the training) need Matlab access when elaborating on the units. We added citrix receiver functionality to the Moodle course, so that the user has access to our Matlab configuration. Thus the student only needs an internet connection but no additional software to perform the training units.

Due to the fact that our proposed topic is related to robotics the introduction to Matlab is based on the needs of basic robotic calculations.

<table>
<thead>
<tr>
<th>Useful vector manipulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of a vector (</td>
</tr>
<tr>
<td>For the scalar product of two vectors use: ( \mathbf{v} \cdot \mathbf{w} = \mathbf{v}_x \mathbf{w}_x + \mathbf{v}_y \mathbf{w}_y )</td>
</tr>
<tr>
<td>For the cross product of two vectors use: ( \mathbf{v} \times \mathbf{w} = \mathbf{v}_x \mathbf{w}_y - \mathbf{v}_y \mathbf{w}_x )</td>
</tr>
<tr>
<td>Example</td>
</tr>
<tr>
<td>( \mathbf{p} = \begin{pmatrix} p_x \ p_y \end{pmatrix} )</td>
</tr>
<tr>
<td>If we want to rotate the vector this can be done by multiplying the vector by a specific matrix. ( R_\theta = \begin{pmatrix} \cos(\theta) &amp; -\sin(\theta) \ \sin(\theta) &amp; \cos(\theta) \end{pmatrix} ) ( \mathbf{p}<em>\text{rot} = R</em>\theta \mathbf{p} )</td>
</tr>
<tr>
<td>Now rotate the vector</td>
</tr>
<tr>
<td>( \mathbf{p} = \begin{pmatrix} 1 \ 0 \end{pmatrix} ) through ( \phi = 30^\circ )</td>
</tr>
</tbody>
</table>

In order to give an impression of the unit the content is summarized. The main task of the module consists of

- Doing simple calculations (scientific calculator)
- Using variables
- Making plots
- Working with vectors and matrices
- Using m-file functionality
- Applying control flow (loops, etc.)
- Trajectory planning

The corresponding pedagogical approach uses three elements. First the considered mathematical background is explained. Then selected examples are presented and solved both by “manual calculation” and Matlab. In addition exercises are included which have to be solved by the user immediately. Of course related solutions can be found in the tutorial so that students are getting direct feedback to their learning progress. A vector/matrix example is presented in fig. 8.

It is clear that there are many printed books and a lot of online material available for Matlab training and Robotics education. Our approach involves comfortable theoretical internet based training, while at the same time Matlab usage is directly integrated in the course.

Moreover it is possible to use the same environment (Moodle-Matlab) for complex robotic tasks. In the case of available budget robust ready-to-use real world components can be integrated. In our labs for example we deal with Quanser elements (e.g. DC-drives) and the Simulink related software “Quarc” to setup robotic experiments. We used this configuration also in the training session for the mentioned project [9], which is integrated in the Moodle course. An additional advantage is that most of the presented Matlab exercises can also be directly solved by free software like octave [11], [12].

D. Low-Cost solution

The training concept that guarantees a successful knowledge transfer and corresponds to the given framework conditions (e.g. long distance training) needs on one hand a web based training platform.

On the other hand practical experiments are still an indispensable pedagogical element in teaching technical subjects. As mentioned above, there are a lot of educational lab products available on the market. Unfortunately this equipment is very expensive.

Figure 8. Example of Moodle course

In order to give an impression of the unit the content is summarized. The main task of the module consists of

- Doing simple calculations (scientific calculator)

Figure 9. Line follower LEGO
So a setup is needed that takes the particular financial situation of the partners into account. A feasible low-cost hardware solution, which offers especially beginners the possibility to perform robot experiments, is provided by LEGO. The corresponding controller – the LEGO Brick EV3 – and a lot of actuators (DC-Motors) and sensors are used to build a simple robot lab experiment [3]. The specific training module included thereby the following parts:

- Explaining the components of a robot
- Creating a line follower (fig. 9)
- Understanding feedback control [6]

Again a Moodle section was made to provide the theoretical knowledge of the considered hardware. For example the functionality of used sensors is explained at an undergraduate level.

During the local training a line follower was established together with a student group (see fig. 10). It turned out that this was very motivating for both pupils and teachers to get results in a very short time. It has to be mentioned that in this particular session the freely software of LEGO MINDSTORMS was used to create and implement the needed software task. It is a welcome development that the latest controller is now supported by many software producers. Therefore the presented task can basically also be solved by means of Matlab/Simulink.

During the local training basic concept of feedback control was given. The usefulness and mechanism of feedback was explained based on LEGO components. Within one hour pupils without prior knowledge in automated control designed a P-controller for a DC-Motor and performed their first positioning task.

IV. DISCUSSION AND OUTLOOK

This paper is a contribution to a modern didactical knowledge transfer concept. It could be shown that a combination of onsite training and web-based learning together with state of the art simulation tools and traditional elements is an excellent method also for long distance education. The feedback of the students and teachers was very positive and a follow-up training was requested.

Beside the technical solution also friendly relationships are established, which leads to an intention of a further collaboration of all partners (fig. 11).

ACKNOWLEDGMENT

The authors would like to thank the project team for the great collaboration. Without the commitment and good will of all parties, this project could not be realized. Special thanks is given to Mr. Mario Wehr who supported us at any time in case of problems with Moodle.

REFERENCES