Course of automation in industrial processes based on the blended learning approach

Eduard Brindfeldt  
Tallinn Center of Industrial Education  
eduard@tthk.ee  
Aleksandr Grinko  
Tallinn Center of Industrial Education  
abgrinko@hot.ee  
Margus Müür  
Tallinn University of Technology  
margus.muur@ttu.ee

Abstract

This article describes modernization of automation courses for vocational education on the basis of blended learning. The authors review methodological approaches to the blended technology design of practical training in the vocational education.

Training is composed of several courses implemented in the education of regular and extramural automation students and also industry professionals. Training courses include the following: sensors and actuators in industrial automation, application of PLC in industrial automation.

Keywords

Course, Practical training, Automation, Teaching, Blended learning

Introduction

The main aim of Estonian education is to prepare human resources for innovation and to develop creative abilities of the individual. To achieve this goal it is necessary to apply the innovative educational technologies.

According to the requirements the professional qualifications system [1] the Vocational Education Standard [2] was designed that clearly defines the following:

1. Requirements for professional skills arise from the professional standards approved by professional councils.
2. The content of studies is determined by the requirements for professional skills set forth by the professional standards. In the absence of a professional standard, the content of study shall be coordinated with the relevant professional associations.

The content of the national and school curricula in the Vocational Education Standard is defined as follows:

1. The national curriculum is a document which determines the purposes and functions of vocational training, the requirements for starting and graduating from the studies, the modules of curricula and the volumes thereof together with short descriptions, the possibilities of and conditions for electing modules and possibilities of specialization.
2. The national curriculum shall be reviewed and if necessary, a new version shall be approved if the professional standard which constitutes the basis for the national curriculum is repealed, a new professional standard is established, or the name of the professional standard or the requirements for professional skills provided in the standard are amended.
3. The school curriculum is the source document of vocational training. Schools shall prepare a curriculum for each profession being taught and for every type of vocational training, basing such curricula on the Vocational Education Standard and the national curriculum, and taking into account different forms of study.

In the transition to the new school curriculum it is in line and in strict compliance with the national curriculum. The school curriculum may include elective (of your choice) study modules.

This approach to vocational education has a clear focus on the constant interaction with the labor market. All changes in the standards of the professional qualifications system are the reason for the adjustment of the national and the school curriculum that provides flexibility for vocational education.
Today there is a social order for such professionals who are able to innovate for all spheres of activity. New technologies in the educational system aimed at fulfilling the important tasks are:

1. development of cognitive activity of students;
2. teaching of innovators;
3. improving communication skills, etc.;
4. contents and structure of the course.

The basis for drawing up of the course was a state curriculum approved by the Ministry of Education and Research [3].

Course Title: Automation of industrial processes

Duration: 120 hours, composed of 35 hrs of theoretical training, 70 hrs of practical exercises and 15hrs of independent work.

The aim of the course is:

- to provide a student knowledge and orientation in the character and features of different manufacturing processes;
- to provide the skills to reading various schemes of control systems and knowledge of the graphical notation;
- to develop abilities to correctly reproduce the manufacturing process according to the description, knowledge of the components and equipment for control systems and languages for programming.

Before starting the course, students should have acquired knowledge of electrical engineering, automatic control, pneumatics, digital technology, programmable logic controllers (PLCs).

Contents of the course:

1. Technological processes
   Topics: the concept of the process, the basic definitions and terminology, classification, continuous and discrete processes, the process as an object of automatic control; levels of automation of technological processes: partial, complex and full; features of flexible manufacturing; automatic control systems, protection systems, data transmission in automated systems.

2. Technical documentation
   Topics: basic requirements for content and design; the main types of schemes: block diagrams, functional, electric, pneumatics diagrams; standard graphical notation used in diagrams; software for projects and schemes of automatic control.

3. Technical documentation of control systems.
   Topics: analysis of control processes, composing a block diagram of the control system; analysis of the control object and determination of the values of main parameters; ability to identify control points and set their parameters; inventory of equipment of a control system with an indication of the main technical parameters and specifications; description of the features of process, control charting and diagrams; programming for automatic control system.

4. The control system project realization
   Topics: choice of equipment, installation and testing of control circuits.

Setting up a control system - a connection with a programming module, checking, debugging and downloading of the control program; checking the control program, detecting and eliminating errors and installation of the program; proper use of skills of safe performance of work in the assembly and installation of control systems.

A list of specific control objects is specified depending on the specialization, example:

- electrical, pneumatic and hydraulic systems;
- devices for moving: transport lines, lifting platforms, cranes;
- lighting control: light boards, internal and external lighting, traffic lights, emergency lighting.
- automatic control of life-support systems of buildings;
- control of the single or cascade pumps depending on the level, pressure and time.
- management of safety and control parking lots, warehouses, gates and checkpoints.
- automation of doors and gates of garages and warehouses;
- automatic control of fire safety and security systems.

As the teachers of Tallinn Center of Industrial Education (THK) have sufficient experience with curricula and teaching materials, preparation of the theoretical part went smoothly. The novelty of this phase was adaptation of electronic materials for students of correspondence students whose ratio of time between independent work and training in classroom highly varied. Training materials were prepared by the project VANKER using Moodle software. During creating practical exercises and tests the authors monitored previous projects and teaching materials.

During the development of the course the following factors interfering with successful results were taken into account:

1. lack of transparent and clear objectives of the course;
2. lack of a common concept of the course;
3. poor feedback or its absence;
4. boring exercises (repetitive testing tasks);

Among the major problems that were solved during the creation of the course are the following:

1. development of prototype-based e-learning management software Moodle as a component of the information space of the school;
2. working out and developing the functional facilities of the modules in the course; 
3. development of methods and educational methodical materials that support the process of blended learning. 

Project result is a web-orientated learning theoretical course and after the participation in practical training in the classroom. The general structure of an integrated educational environment is shown in Fig. 2.1.

**Fig.2.1. General structure of a blended learning course**

**Practical training in laboratory**

The scope and subject matter of practical training is quite varied, so all the practical tasks were grouped into three separated cycles:

1. Automation of continuous processes in the chemical and food industries and the energy sector; 
2. Automation of life support systems of buildings; 

The first of these cycles is based on the methodical and technical equipment from a well-known firm Festo Didactic [4]. Therefore, we give only a brief summary of a single module (6 units have been installed in the THK laboratory (Fi 3.1.)).

The four control systems in the Compact Workstation can be operated individually. The level and flow rate control systems can be structured as a cascade control system through the addition of an appropriate controller.

The layout of the sensors and servo drives permits experimentation with both continuous (e.g. P, I, PI, PID) and discontinuous action controller types (e.g. 2-point controllers).

![Fig.3.1. Compact Workstations in TTHK laboratory (level, flow rate, pressure and temperature closed-loop control systems)](image)

The pump can either be controlled directly or operated in a controlled speed mode. The manipulated variable of the controller in the flow rate and pressure control systems can alternatively act upon a proportional directional control valve. A ball valve with a pneumatic drive is built into the return between the high-level container and the lower reservoir. The pneumatic drive can be used to simulate a “load” for switching on a disturbance in the level control system or as an on-off valve for emergency switch-off.

The second cycle takes place in the laboratory of automation life support systems of the buildings. The TTHK course on "Buildings Automation" was adopted with the concept of group Siemens "HVAC (heating, ventilation and air conditioning) building automation" [5], which focused on needs that greatly depend on factors such as building size, life cycle, operating times, and comfort needs.

Adopted HVAC that can create an optimal room climate covers the following applications:

- control of individual rooms with radiators; 
- control of heating boilers to generate hot water; 
- domestic hot water regulation; 
- ventilation control: for a ventilation system with up to two or three floors; control of kitchen exhaust hood; 
- automatic control for lights and blinds. 

With simple safety and security components we can realise:

- smoke detection; 
- windows and doors monitoring.
In the topic "Buildings Automation" we use the following control systems:

- Micro PLC SIMATIC S7-200 that can be used as either a stand-alone Micro PLC solution or in conjunction with other controllers;
- Logic module LOGO! for micro automation that suits perfectly for small-scale automation projects and makes life much easier by replacing switches, relays, counters and protective relays.

Simple installation, minimum wiring, easy programming are typical of both control devices.

There are 4 mandatory parts in the content of the course:

1. Ventilation
2. Heating
3. Lighting
4. Alarm and security

In addition, trainees must choose two parts of the 6 exercises:

1. Exterior lighting
2. Car parking subject to the availability of free places
3. Automatic gates
4. Automatic control of a pool
5. Automatic control of a lifting platform
6. Exterior alarm system

All of these exercises are tightly bound with any construction plan of rooms or buildings. The student has the following opportunities to acquire such plans:

- to do measurements of apartments or building independently;
- to draw construction plan of an apartment or a house;
- select a construction plan from the Internet.

Practical exercise includes following stages:

- principles of automatic control
- control programs
- device selection
- device locations on the plan
- electrical diagrams

At the final stage of the course students will demonstrate a working model that is installed and operated on a laboratory bench shown in Fig.3.2.

During the course following training forms will be used:

1. lectures;
2. practical works in the laboratory;
3. processes programming with software LOGO! Soft Comfort for module LOGO! and Step 7 MicroWin for PLC SIMATIC S7-200;
4. equipment search from catalogs of manufacturers;
5. seminars and debates for discussing the final and intermediate results of the work.
6. final result of their work is present as a Word or PowerPoint file;

For practical work in “Small automation of process”, a stand was designed to allow use of modular control units and executive devices and actuators. This stand will allow students to fully use all the features of the Modular Production System from the company Festo [6]. Its major advantage is the use of different control systems based on different PLC: Programmable Logic module LOGO!; PLC SIMATIC S7-300; PLC SIMATIC S7-1200 [7]. If necessary, thanks to a dedicated universal bus it is possible to integrate PLC from other manufacturers such as Omron, Mitsubishi, etc.

A study material was prepared for students who learn the PLCs and actuators in an automation course (MFS structure chart shown Fig. 3.3.). The multifunctional production automation stand MFS (Fig. 3.4.) is one part of a blended learning system. It consists of two parts: the control module and the actuator modules. The control module itself is divided to different integrated control units: relay unit and Simatic S7-300 controller unit (Fig. 3.5.). The actuator module consists of a pneumatically controllable input module, a placing module and an electrically controllable rotary stage module. Following actions take place in this module: workpiece feeding, repositioning and placing it to the rotary stage. To carry out practical work at various levels of execution units can have different completeness that enable all the processes that are available by The Modular Production System to be performed and expanded.
Control module enables the learner to get to know logic modules: logic modules, installation of modules (construction and finding faults); programming (learning to use the software and programming instructions within it; doing programming exercises; debugging programs).

The following knowledge is acquired about the programmable controllers:
1. finding the build and installation errors;
2. learning to setup hardware and software settings in the development tools;
3. solving simple programming tasks (writing simple program instructions);
4. program debugging, diagnostics and testing.

Actuator module (Fig. 3.6.) enables learners to get to know the pneumatic control components, the actuators, the production automation systems and the installation of the automation system components.

The control- and the actuator module together provide an excellent opportunity to get to know the automation systems: installation and troubleshooting; programming and tuning of flexible manufacturing modules; experimenting with flexible manufacturing.

Installation of automation system components includes the following: installation of electrical, magnetic, optical, inductive and capacitive sensors; connecting them with measuring transducers, PLCs or computers measuring interface; processing the measurement data with computers; software needed for processing of measurement data.

**Example exercise for practical training**

Control of an application with two pneumatic cylinders

In this example a double-acting cylinder ejects the workpieces one at a time and the rotary actuator drives a swivel arm which picks the workpieces up with a suction gripper. After picking up the workpiece, the workpiece is moved to the other side. The program works only one cycle at the time because there is nothing that would remove a workpieces away from the last position.
In addition to the above, each task may contain:

- Pneumatic diagram
- Electric diagram
- Program description based on GRAFCET
- In program used variables (symbol) table
- PLC Program
  - STL (Statement List)
  - LDR (Ladder Diagram)
  - FBD (Function Block Diagram)

**Conclusions**

Blended learning is an effective training ground for research and testing of various new pedagogical solutions. The complex of activities done during the creation of blended learning has the following results:

- development of prototype-based e-learning management system Moodle as a component of the information space;
- development of methods and teaching materials that support the process of blended learning;
- strengthening of the role of independent cognitive activity of students;
- a stand designed for practical work in which it is possible to use modular units of control and executive devices and actuators.

The final version of blended learning will be developed during the project VANKER (started on 01.12.2010 and to be finished on 30.04.2011).

**References**