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Production and programming of industrial automation training set with project based learning curriculum

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Highlights

- Production and programming of an experiment set for online and classroom training in the field of industrial automation technology.
- Case studies for training courses on the development of free SCADA software.
- Practical examples for technical training in schools through project-based learning

Abstract

The purpose of this study is to provide students with a 21st century training that can be easily applied to industrial automation training, both online and in person, and that goes beyond traditional learning methods. It involves creating and programming a training package that is compatible with the Ministry of National Education (MEB) curriculum, using the project-based learning (PBL) method and a curriculum that focuses on skills acquisition. Two different brands of programmable logic controllers (PLC) have been integrated into the manufactured training set so that the set can be used to conduct various PLC trainings. In the training set, product separation can be carried out using the electro-pneumatic system with a turntable and two conveyor belts. Motor controls, sensor applications, electro-pneumatics, touch panel and various PLC controls can also be carried out with the training set. The set focuses on the grafcet diagram method and can show how to program the same scenarios in different PLC models. By using PLC software components in the training set, students also get the opportunity to develop and experience their own unique SCADA (supervisory control and Data Acquisition) software with visual programming. This study also includes a sample curriculum prepared for PBL. In this way, all on-set training can be done using the PBL method and students get a 21st century experience. They also get the opportunity to improve their skills. PBL is an innovative and process-oriented learning method and is supported by the Ministry of Education (MoE). The prepared curriculum also includes the learning plan and measurement and assessment scales (rubrics). We anticipate that this package will be effective and useful in providing students with 21st century job skills and abilities in the field of industrial automation engineering, both online and face-to-face.

Article Info: Research Article

Keywords: *Industrial Automation, Project-Based Learning, Vocational Training, PLC, Hybrid Education*

1. Introduction

Industry and industrial processes are constantly evolving. The need for competitive advantage in production and manufacturing has led to the development of advanced and new cost-efficient mechanisms. To this end, revolutionary technological leaps have been made in the various eras of industrial history. The first industrial revolution was mechanization and the steam engine, the second industrial revolution was the use

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of electrical energy and mass production, and the third industrial revolution was established by information technology (IT) and the spread of digitalization, as shown in Figure 1 (Sapre and Tomar, 2016).

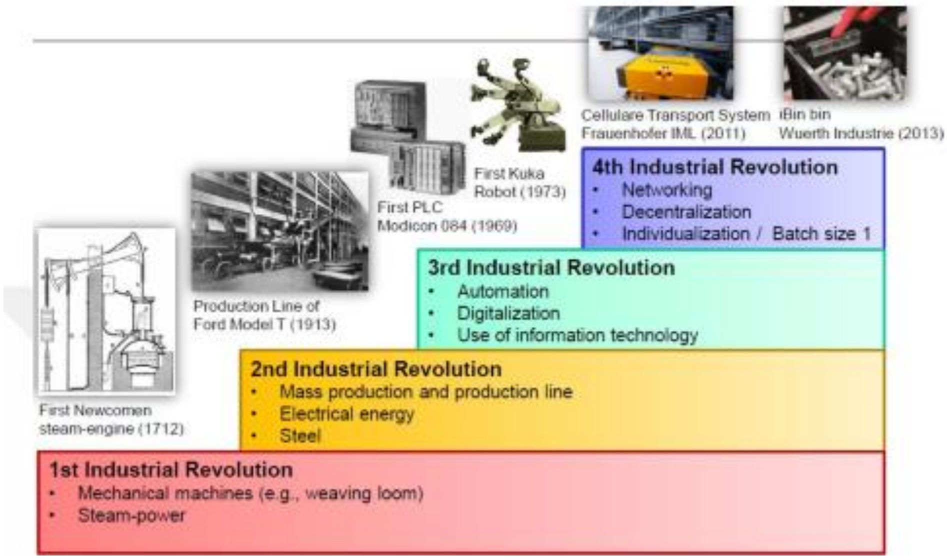


Figure -1. Steps of the industrial revolution

Current industrial activity is rigorous and difficult to replace; innovation is hard to come by, falling raw material prices often lead to a drop in quality and can increase process costs, so profit margins are constantly falling. There is also a great dependence on the existing knowledge base. If this decreases, more improvisation is required, and development times increase. Although production systems are highly automated, they do not have a conscious core to learn and act without constant human intervention [Dopico vd., 2016).

Figure 2 is a basic demonstration of the main networked implementations through Industry 4.0, where monitoring tools and sensors can be used to collect data and track systems. IoT solutions, network structures and industrial apps play an important role in data analysis. Automations for running processes, secure and cost-effective monitoring environments are important features alongside other components of Industry 4.0 and associated smart systems.

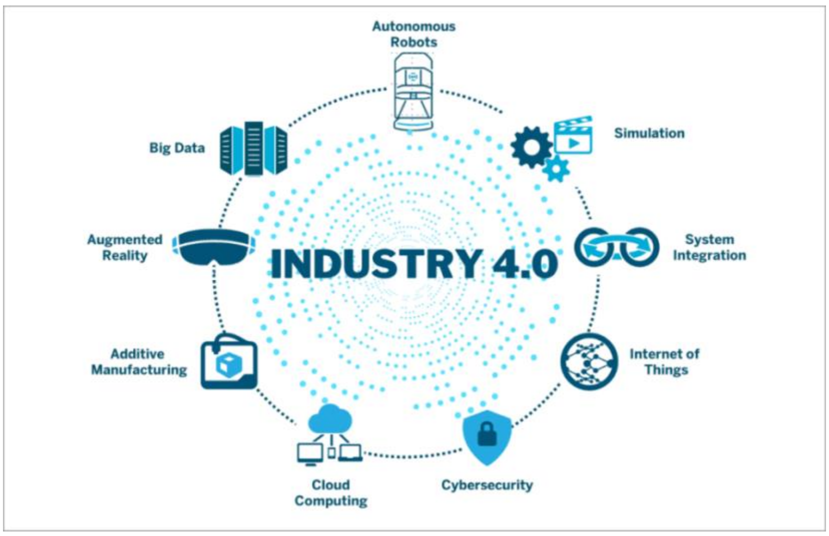


Figure - 2. Implementation Components of Industry 4.0 (Source: http://www.endustri40.com)

Education in the field of industrial automation technologies is of great importance when it comes to realizing the era of Industry 4.0 and the vision of a national industrial movement. Many experimental kits are used for this training in vocational schools and universities. Most of these kits are expensive products from Europe and the Far East. This study focused on an original, useful and economical industrial automation training kit.

Looking at the growth rates, the increase in production observed since the early 2000s, according to the industrial production index data in Figure 3, can be explained by the fact that our manufacturing industry attaches the necessary importance to automation.

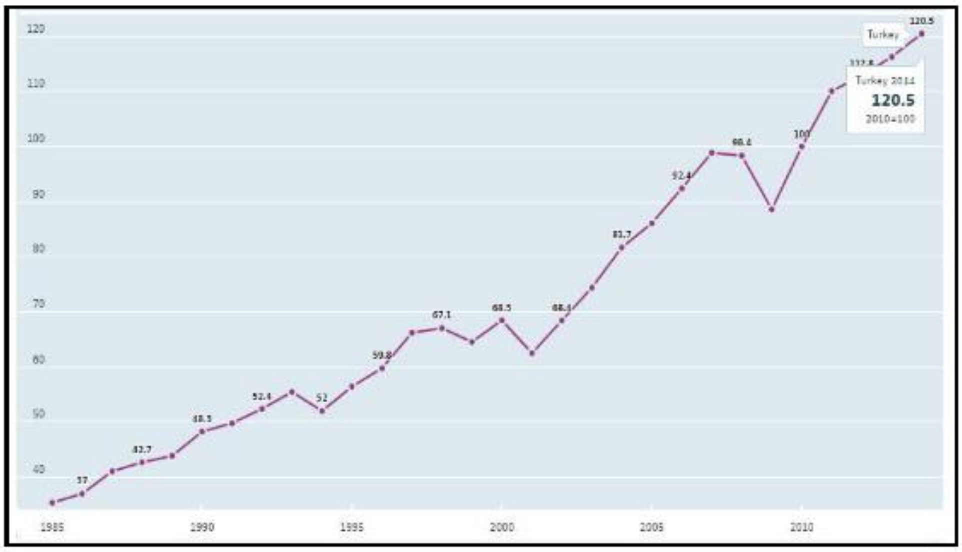


Figure - 3. Industrial production index (1985-2014) (Source: http://www.data.oecd.org/industry /industrial-reduction)

The field of industrial automation is a multidisciplinary field that includes electronics, machinery, software and electrical areas. In this study, an experimental setup that includes a programmable logic controller (PLC), a conveyor belt, a turntable, a pneumatic system, a touch panel, inductive, capacitive and infrared sensors, a touch panel, an industrial Ethernet and Supervisory Control and Data Acquisition (SCADA) software based on visual programming, which are the basic components of industrial automation, was investigated. In addition, the project-based learning (PBL) model was used as the basis for the curriculum, planning and assessment of the training.

In this experimental set, which was manufactured and programmed as part of the study, unlike similar sets, not one but two different PLCs were used, so that the same applications can be executed on the same set with different PLC processors. In this respect, the set is innovative. With the set, which uses two conveyor belts and a turntable, the separation of short and long plastic and metal products can be done with the help of a pneumatic system using Grafcet diagrams in different scenarios. Thanks to the possibility of running different Grafcet algorithms on the set, programming can easily be switched to two different PLC processors. In this way, the training of different PLC software can easily be carried out on a single set. It is important to gain the ability to work with different PLC models. This is because nowadays not only one model/brand of PLC is used. There is a need to work with many PLC models. Cost planning requires this.

Local and original SCADA software can be created on the set using object-oriented programming (e.g. C#, C++, Visual Basic.NET) and libraries for PLC software components. The SCADA software can be developed on the set according to the desired scenario. Visual designs can be created on the touch panel of the set and industrial IoT (Internet of Things) applications can be realized with industrial Ethernet technology.

On-set training is conducted within a model curriculum with the student-centered PBL method, beyond the teacher-centered traditional teaching method. The measurement and assessment scales (rubrics) created with the PBL method can also be used after the training. The curriculum has been developed based on a sample scenario. If desired, PBL-based curricula and plans can be created for different scenarios by using the sample curriculum as a reference.

2. Literature

With the advancement of technology, different approaches in education are emerging, i.e. technologies that can influence the learning and teaching process and process, display and share information instantly (Allen and Seaman, 2014). In this context, online learning has become more functional in our age (Palvia vd., 2018), it has "pushed the boundaries of time and space in the dissemination of information" (Gunawardena vd., 2004) (Ma vd., 2021) and it has been noted that this situation creates many opportunities in education for all (Heinchi vd., 1995) (Wilson and Marsh, 1995)

The term project generally means that student's complete homework or assignments given to them individually or in groups; it is the undertaking of studies to solve a problem (Vatansever and Bayraktar, 2015) A project means imagining, thinking and constructing (Erdem and Akkoyunlu, 2002).

Let us consider these definitions in general: a learning approach based on the development of designs, imagination, planning and construction (Demirel, 2019) and a student center that focuses on reality-based issues and practices, an interdisciplinary learning approach where activities are distributed among several processes or focus on solving everyday problems, as expressed in (Korkmaz and Kaptan, 2001). According to Moursund, PBL is an activity that takes place through individual or group interaction and leads to a demonstration, a performance or generally a product over a period (Moursund, 2003) PBL is also defined as a teaching method that provides students in a course with the knowledge and skills to plan, create and then demonstrate a product or performance (Simkins, 1999). In PBL, it is of great importance to evaluate not only the activities, but also the resulting product and the process of creating this product, that is, process and result evaluation (Korkmaz, 2002) (Yurtluk, 2003). As explained in (Williams, 1998), assessment measures (rubrics) can be self-assessments, peer assessments, checklists, observations, diaries, performances and presentations, interviews, recorded student work and written assignments.

3. Methodology

This section contains basic information about the structure, materials used, SCADA programming, PBL curriculum, plan, and assessment measures of the set.

The following steps were used to compile the training set as shown in Figure 4:

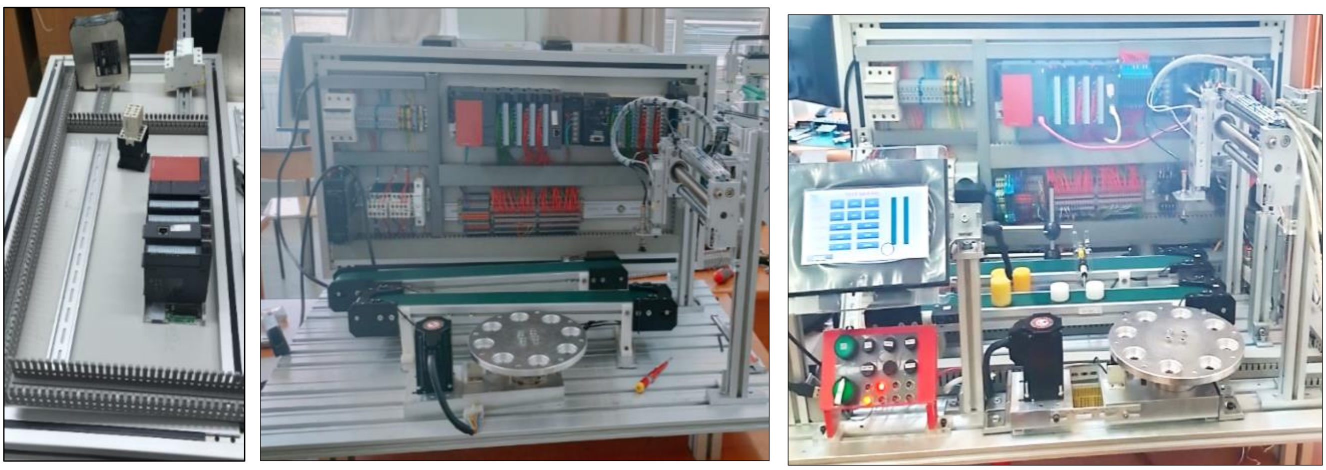
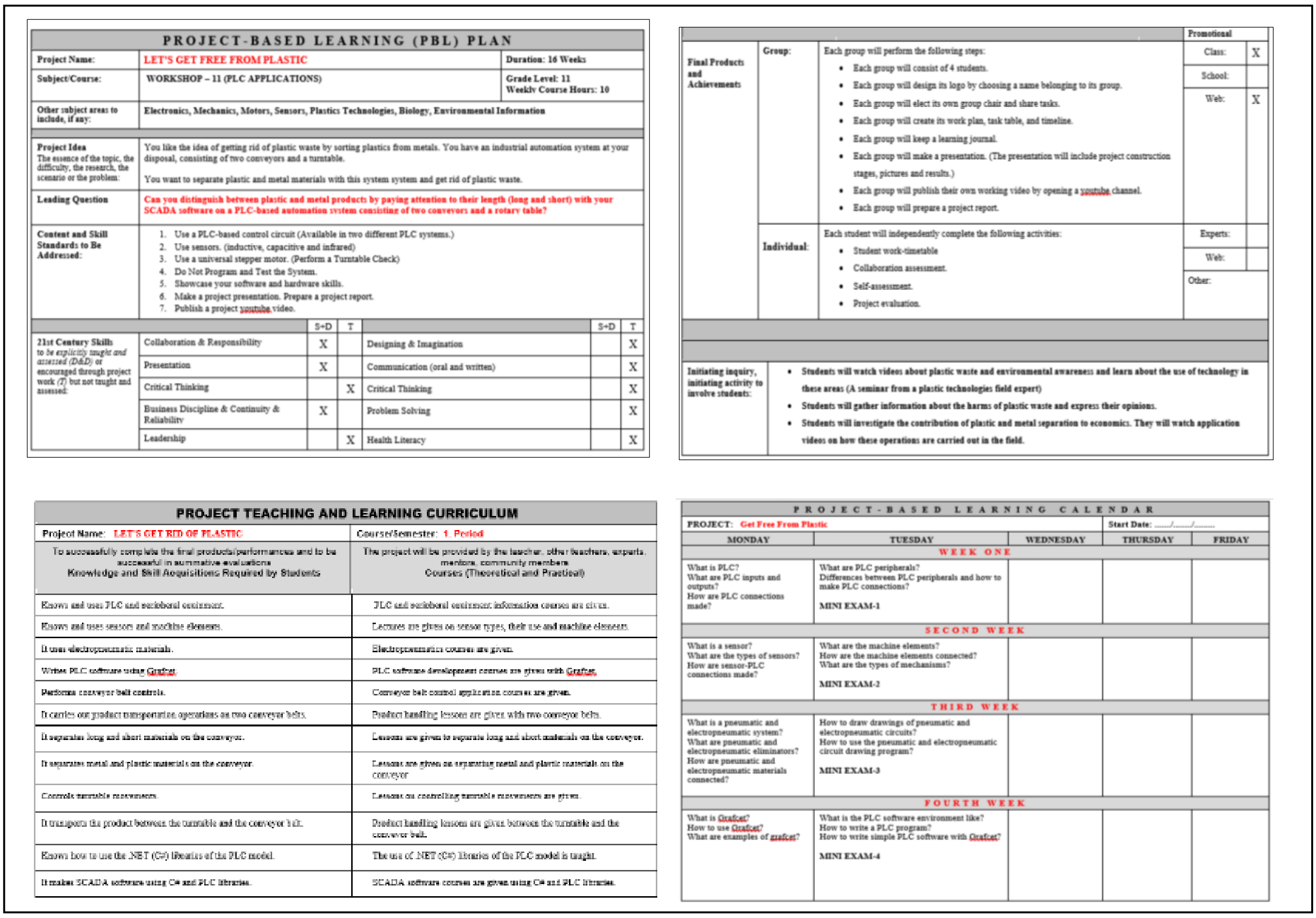


Figure - 4. Steps in the production of the set

1. The profile parts of the set were put together in an L-shape.
2. The cable ducts were placed. The vertical axis was divided into 4 sections
3. The fuse connections for the power floor were installed.
4. Fuses, contactors and power supply connections were made for the PLC selection.
5. Two different PLCs, stepper motor drivers and Ethernet switch with two inputs and two output modules for each PLC were installed on the vertical axis.
6. The input and output connections for each PLC were connected to terminal blocks.
7. The motor drives for the conveyor belts were installed in the connection area.
8. Conveyor belts, electro-pneumatic valves and pistons were installed on the set.
9. The air hoses and cables of the electro-pneumatic system were connected.
10. Plexiglas material was used for the button sets. The buttons were attached.
11. The sensors were installed in the correct and necessary places.
12. The turntable and stepper motor were added to the set.
13. The cable connections for all materials were made.
14. All inputs and outputs were tested.
15. Problems have been fixed.

In this study, the Buck Institute for Education myPBLWorks website (https://my.pblworks.org/) and the Buck Institute's PBL form templates were used in the creation of PBL plans and curricula. The PBL process and everything that is necessary in the process is clearly outlined in the forms. In this paper, as seen in Figure 5, a 16-week PBL plan was created for the Workshop 11 course taught in the 11th grade Industrial Automation Technology Department over 10 class periods per week for 12 weeks. Students receive the necessary theoretical and practical lessons about the set, and then they are expected to carry out PBL work in a 4-week period.



PROJECT-BASED LEARNING (PBL) PLAN

Project Name:	LET'S GET FREE FROM PLASTIC			Duration: 16 Weeks	
Subject/Course:	WORKSHOP – 11 (PLC APPLICATIONS)			Grade Level: 11 Weekly Course Hours: 10	
Other subject areas to include, if any:	Electronics, Mechanics, Motors, Sensors, Plastics Technologies, Biology, Environmental Information				
Project Idea The essence of the topic, the difficulty, the research, the scenario or the problem:	You like the idea of getting rid of plastic waste by sorting plastics from metals. You have an industrial automation system at your disposal, consisting of two conveyors and a turntable. You want to separate plastic and metal materials with this system system and get rid of plastic waste.				
Leading Question	Can you distinguish between plastic and metal products by paying attention to their length (long and short) with your SCADA software on a PLC-based automation system consisting of two conveyors and a rotary table?				
Content and Skill Standards to Be Addressed:	1. Use a PLC-based control circuit (Available in two different PLC systems.) 2. Use sensors. (inductive, capacitive and infrared) 3. Use a universal stepper motor. (Perform a Turntable Check) 4. Do Not Program and Test the System. 5. Showcase your software and hardware skills. 6. Make a project presentation. Prepare a project report. 7. Publish a project youtube video.				
		S+D	T		S+D	T
21st Century Skills to be explicitly taught and assessed (D&D) or encouraged through project work (T) but not taught and assessed:	Collaboration & Responsibility	X		Designing & Imagination		X
	Presentation	X		Communication (oral and written)		X
	Critical Thinking		X	Critical Thinking		X
	Business Discipline & Continuity & Reliability	X		Problem Solving		X
	Leadership		X	Health Literacy		X

			Promotional	
Final Products and Achievements	Group:	Each group will perform the following steps: • Each group will consist of 4 students. • Each group will design its logo by choosing a name belonging to its group. • Each group will elect its own group chair and share tasks. • Each group will create its work plan, task table, and timeline. • Each group will keep a learning journal. • Each group will make a presentation. (The presentation will include project construction stages, pictures and results.) • Each group will publish their own working video by opening a youtube channel. • Each group will prepare a project report.	Class: School: Web:	X X
	Individual:	Each student will independently complete the following activities: • Student work-timetable • Collaboration assessment. • Self-assessment. • Project evaluation.	Experts: Web: Other:	
Initiating inquiry, initiating activity to involve students:	• Students will watch videos about plastic waste and environmental awareness and learn about the use of technology in these areas (A seminar from a plastic technologies field expert) • Students will gather information about the harms of plastic waste and express their opinions. • Students will investigate the contribution of plastic and metal separation to economics. They will watch application videos on how these operations are carried out in the field.			

PROJECT TEACHING AND LEARNING CURRICULUM

Project Name: LET'S GET RID OF PLASTIC	Course/Semester: 1. Period
To successfully complete the final products/performances and to be successful in summative evaluations Knowledge and Skill Acquisitions Required by Students	The project will be provided by the teacher, other teachers, experts, mentors, community members Courses (Theoretical and Practical)
Knows and uses PLC and peripheral equipment.	PLC and peripheral equipment information courses are given.
Knows and uses sensors and machine elements.	Lectures are given on sensor types, their use and machine elements.
It uses electropneumatic materials.	Electropneumatics courses are given.
Writes PLC software using Grafcet.	PLC software development courses are given with Grafcet.
Performs conveyor belt controls.	Conveyor belt control application courses are given.
It carries out product transportation operations on two conveyor belts.	Product handling lessons are given with two conveyor belts.
It separates long and short materials on the conveyor.	Lessons are given to separate long and short materials on the conveyor.
It separates metal and plastic materials on the conveyor.	Lessons are given on separating metal and plastic materials on the conveyor
Controls turntable movements.	Lessons on controlling turntable movements are given.
It transports the product between the turntable and the conveyor belt.	Product handling lessons are given between the turntable and the conveyor belt.
Knows how to use the .NET (C#) libraries of the PLC model.	The use of .NET (C#) libraries of the PLC model is taught.
It makes SCADA software using C# and PLC libraries.	SCADA software courses are given using C# and PLC libraries.

PROJECT-BASED LEARNING CALENDAR

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
PROJECT: Get Free From Plastic			Start Date: ....../....../......	
WEEK ONE				
What is PLC? What are PLC inputs and outputs? How are PLC connections made?	What are PLC peripherals? Differences between PLC peripherals and how to make PLC connections? MINI EXAM-1			
SECOND WEEK				
What is a sensor? What are the types of sensors? How are sensor-PLC connections made?	What are the machine elements? How are the machine elements connected? What are the types of mechanisms? MINI EXAM-2			
THIRD WEEK				
What is a pneumatic and electropneumatic system? What are pneumatic and electropneumatic eliminators? How are pneumatic and electropneumatic materials connected?	How to draw drawings of pneumatic and electropneumatic circuits? How to use the pneumatic and electropneumatic circuit drawing program? MINI EXAM-3			
FOURTH WEEK				
What is Grafcet? How to use Grafcet? What are examples of grafcet?	What is the PLC software environment like? How to write a PLC program? How to write simple PLC software with Grafcet? MINI EXAM-4			

Figure - 5. PBL Plan

The 7 PBL assessment forms (rubrics) created as part of this work, one of which is shown in Figure 6, are listed below:

1. FORM-1 Student Agreement
2. FORM-2 Teacher Observation Form
3. FORM-3 Student self-assessment form
4. FORM-4 Collaborative Learning Form
5. FORM-5 Project Evaluation Form
6. FORM-6 Presentation Evaluation Form
7. FORM-6 Report Evaluation Form

FORM-6: Presentation Evaluation Form

PROJECT PRESENTATION EVALUATION

The presentation should include information discovered by the team, plans, drafts, combined final status of the product and project, conclusions and recommendations.

CATEGORY	4	3	2	1
Oral presentation: Be prepared	The team was fully prepared and rehearsed in advance.	The team looked ready, but needed a few more rehearsals.	The team seemed a little ready, but it still had to be rehearsed.	The team wasn't ready to present at all.
Oral presentation: Willingness	The gestures and facial expressions of the team and their body language clearly showed that they were very interested and willing to do the subject.	The gestures and facial expressions of the team, as well as their body language, often indicated that they were interested and enthusiastic about the subject.	The gestures and facial expressions and body language of the team tried to appear very interested and enthusiastic about the subject, but it was not very successful.	Very few gestures, facial expressions and body language were used. The team was clearly uninterested in the matter.
Integrity	The presentation had all the material that could be needed on the subject and that would provide comfort.	In the presentation, there were most of the materials that could be needed and provided comfort on the subject, there were one or two missing.	There was a lack of multiple key elements in the presentation.	There were many shortcomings and inconsistencies in the presentation.
Background information	The presentation contains 10 slides summarizing the information discovered. Sketches, drawings, images, etc. are available.	The presentation contains 7 slides summarizing the information discovered. Sketches, drawings, images, etc., were available.	The presentation contains 5 slides summarizing the information discovered. Sketches, drawings, images, etc., were available.	The presentation contains 1-4 slides summarizing the information discovered. There were no drafts, drawings, images, etc. in our presentation

Figure - 6. Presentation Evaluation Form

In the series of experiments, 4 types of materials were selected to be used for product separation:

1. Long plastic
2. Short plastic
3. Long metal
4. Short metal

The following operations are carried out as an example application when programming the set:

1. Moving the turntable and the set to the starting position
2. Selecting the product to be transported onto the turntable
3. Identifying the product
4. If the incoming product is the desired product, it should be moved to the table, if not, it should be moved to the other belt.
5. Movement and occupancy control of the turntable

For the visual software of the Set (SCADA). NET platform, the software language C# is preferred. The PLC libraries for the software of the set were added to the project. The design phase was carried out first and then the coding phase was started. The software was finalized according to the SCADA logic. Snapshots are written to the database in conjunction with the SQL server. The data recorded in the database is not only displayed on the form but can also be saved in an Excel file. The product information is displayed graphically on the form. As there should be a simulation in SCADA, the operation of the system is simulated immediately. PLC inputs and outputs (I/O) are read simultaneously and displayed on the form as a test page. The AForge.Net library was also used to monitor the system with a camera.

In the PBL-based training, after the Grafcet design, PLC ladder program, and SCADA software in Figures 7, 8, and 9 were explained to the students and applied to the first PLC, they were asked to create a similar SCADA design and software using the same Grafcet algorithm on the same device. For the students to reach this level, the PBL curriculum and the method explained in this study were used. Four groups of three students each participated in the PBL activity for one month. Assessments were made using PBL assessment forms (rubrics), which are explained in the relevant section. The students successfully completed the PBL process, filled in the relevant forms and expressed their satisfaction in their presentations.

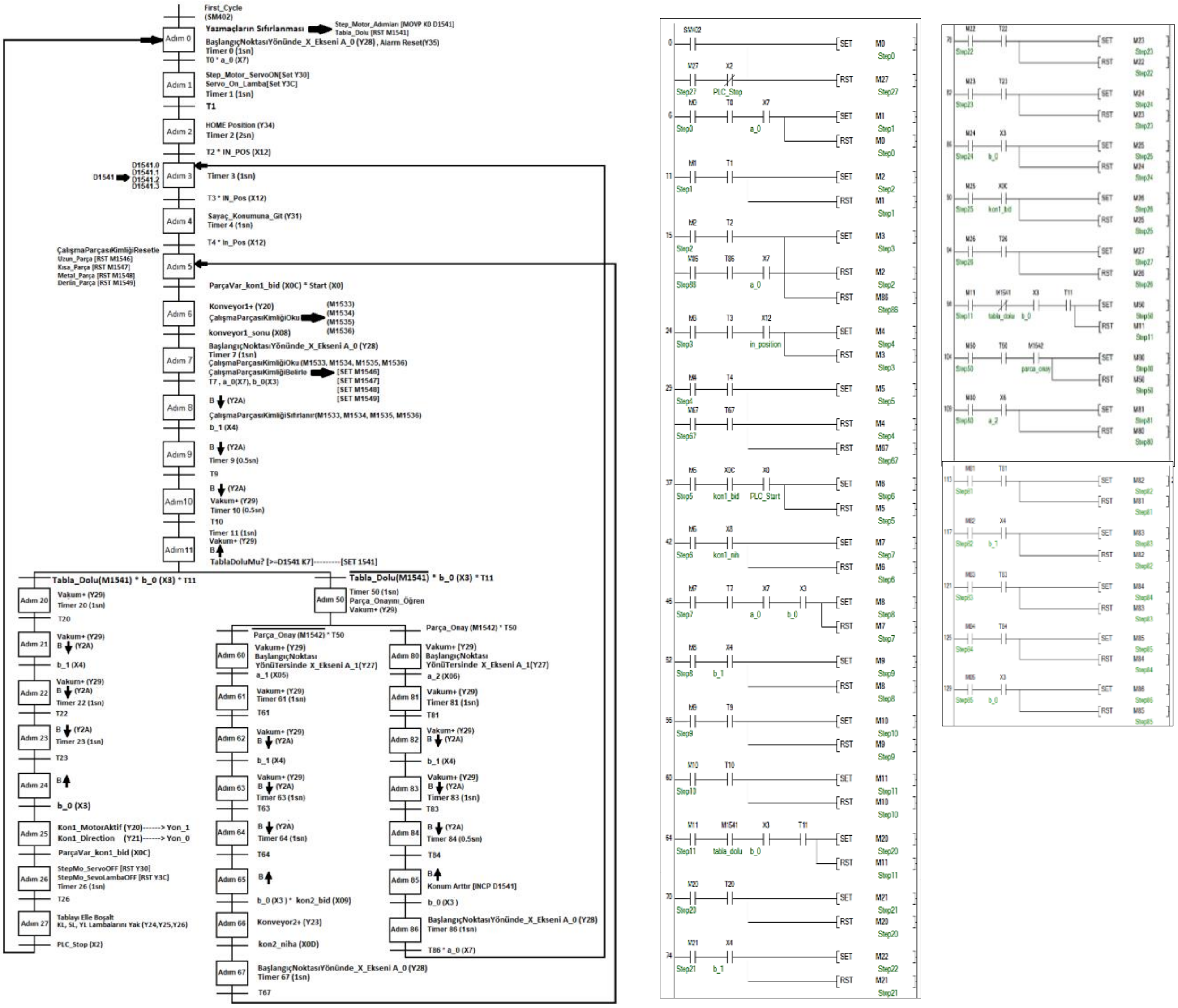


Figure - 7. Grafcet diagram of the set and PLC ladder programming example

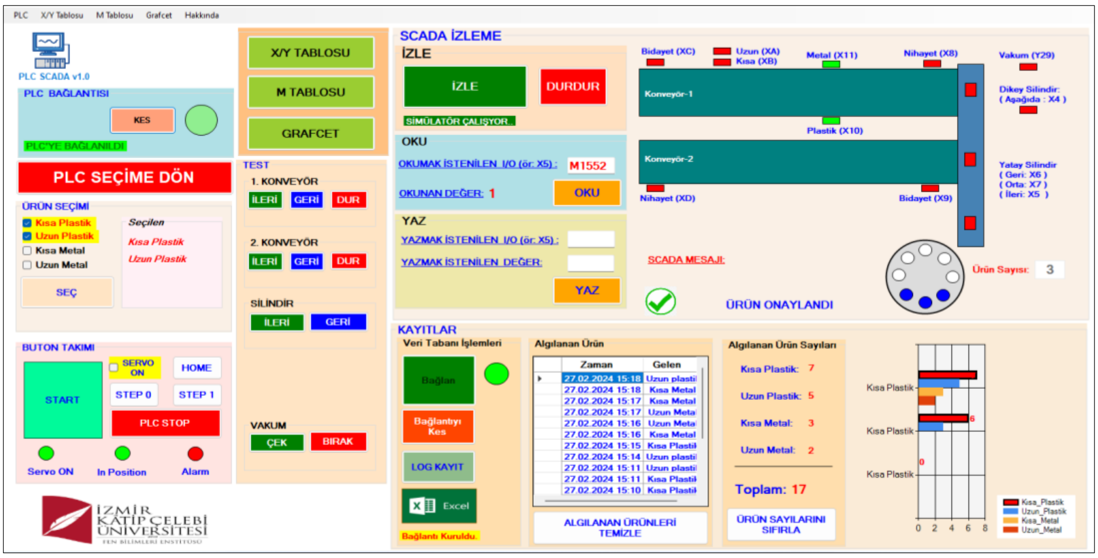
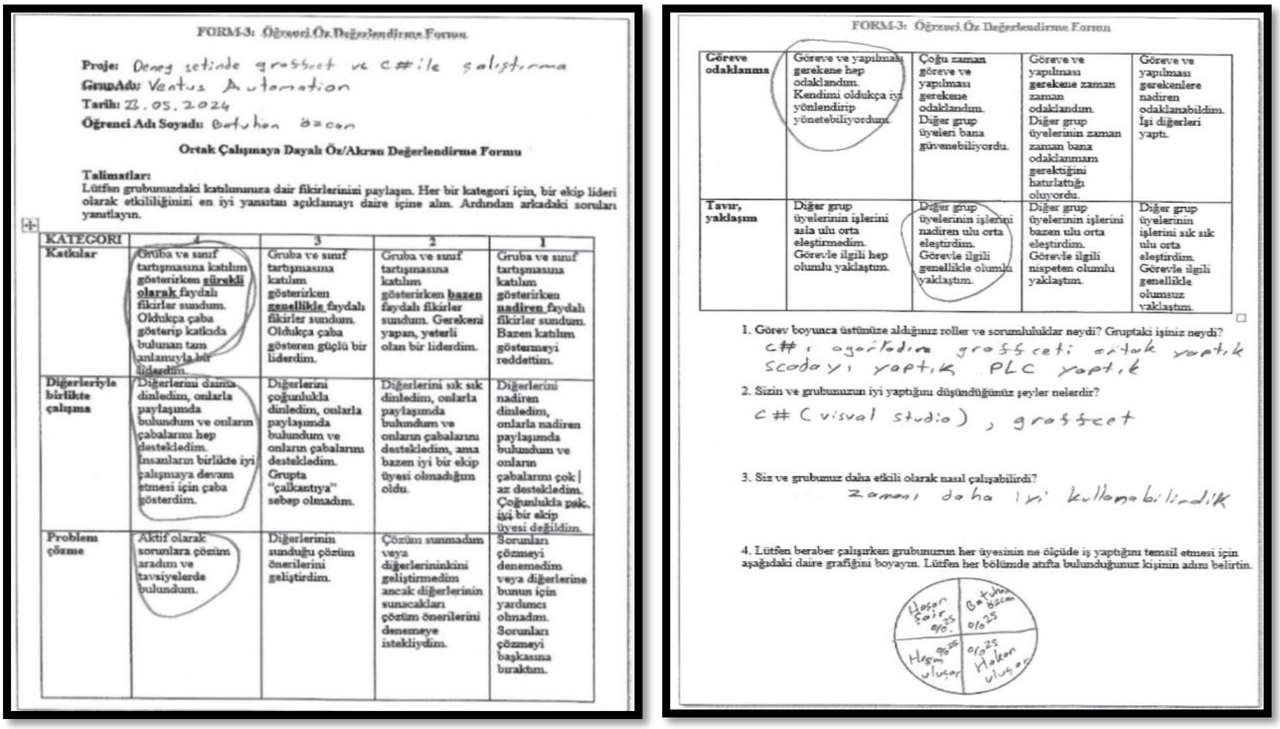


Figure- 8. SCADA design with C#.NET

Figure – 9. Touch panel design

The PBL application process was conducted as follows:

- The sample study was explained to the students on the set, and the students were prepared for PBL.
- Students are divided into 3 groups of 4 each.
- Students were asked to create a virtual company and design their own company logos.
- The PBL plan and rubrics were explained to the students and the project idea and guiding question were given.
- The students held meetings to assign tasks and create work plans. At the end of the meeting, they signed a responsibility agreement among themselves and made plans for task distribution and work plans.
- The teacher observed the students every week in the observation forum.
- Students developed and tested their own designs and programs by connecting to the set via Ethernet.
- They presented their PBL studies to their teachers with reports and presentations.
- At the end of the PBL, the forms were completed, and students had the opportunity to evaluate themselves and their classmates as shown in Figure 10.
- Teachers and students were assessed using rubrics to evaluate product and process.



FORM-3: Öğrenci Öz Değerlendirme Formu

Proje: Deney setinde grafcet ve c# ile çalıştırma
GrupAdı: Ventus Automation
Tarih: 23.05.2024
Öğrenci Adı Soyadı: Batuhan Özcan

Ortak Çalışmaya Dayalı Öz/Akran Değerlendirme Formu

Talimatlar:
Lütfen grubunuzdaki katılımınıza dair fikirlerinizi paylaşın. Her bir kategori için, bir ekip lideri olarak etkililiğinizi en iyi yansıtan açıklamayı daire içine alın. Ardından arkadaki soruları yanıtlayın.

KATEGORI	4	3	2	1
Katkılar	Gruba ve sınıf tartışmasına katılım gösterirken sürekli olarak faydalı fikirler sundum. Oldukça çaba gösterip katkıda bulunan tam anlamıyla bir liderdim.	Gruba ve sınıf tartışmasına katılım gösterirken genellikle faydalı fikirler sundum. Oldukça çaba gösteren güçlü bir liderdim.	Gruba ve sınıf tartışmasına katılım gösterirken bazen faydalı fikirler sundum. Gerekeni yapan, yeterli olan bir liderdim.	Gruba ve sınıf tartışmasına katılım gösterirken nadiren faydalı fikirler sundum. Bazen katılım göstermeyi reddettim.
Diğerleriyle birlikte çalışma	Diğerlerini daima dinledim, onlarla paylaşımda bulundum ve onların çabalarını hep destekledim. İnsanların birlikte iyi çalışmaya devam etmesi için çaba gösterdim.	Diğerlerini çoğunlukla dinledim, onlarla paylaşımda bulundum ve onların çabalarını destekledim. Grupta "çalkantıya" sebep olmadım.	Diğerlerini sık sık dinledim, onlarla paylaşımda bulundum ve onların çabalarını destekledim, ama bazen iyi bir ekip üyesi olmadığım oldu.	Diğerlerini nadiren dinledim, onlarla nadiren paylaşımda bulundum ve onların çabalarını çok az destekledim. Çoğunlukla pek iyi bir ekip üyesi değildim.
Problem çözme	Aktif olarak sorunlara çözüm aradım ve tavsiyelerde bulundum.	Diğerlerinin sunduğu çözüm önerilerini geliştirdim.	Çözüm sunmadım veya diğerlerininkini geliştirmedim ancak diğerlerinin sunacakları çözüm önerilerini denemeye istekliydim.	Sorunları çözmeyi denemedim veya diğerlerine bunun için yardımcı olmadım. Sorunları çözmeyi başkasına bıraktım.

FORM-3: Öğrenci Öz Değerlendirme Formu

Göreve odaklanma	Göreve ve yapılması gerekene hep odaklandım. Kendimi oldukça iyi yönlendirip yönetebiliyordum.	Çoğu zaman göreve ve yapılması gerekene odaklandım. Diğer grup üyeleri bana güvenebiliyordu.	Göreve ve yapılması gerekene zaman zaman odaklandım. Diğer grup üyelerinin zaman zaman bana odaklanmam gerektiğini hatırlattığı oluyordu.	Göreve ve yapılması gerekenlere nadiren odaklanabildim. İşi diğerleri yaptı.
Tavır, yaklaşım	Diğer grup üyelerinin işlerini asla ulu orta eleştirmedim. Görevle ilgili hep olumlu yaklaştım.	Diğer grup üyelerinin işlerini nadiren ulu orta eleştirdim. Görevle ilgili genellikle olumlu yaklaştım.	Diğer grup üyelerinin işlerini bazen ulu orta eleştirdim. Görevle ilgili nispeten olumlu yaklaştım.	Diğer grup üyelerinin işlerini sık sık ulu orta eleştirdim. Görevle ilgili genellikle olumsuz yaklaştım.

1. Görev boyunca üstünüze aldığınız roller ve sorumluluklar neydi? Gruptaki işiniz neydi?
c# ı ağırlıkta grafceti ortak yaptık scadayı yaptık PLC yaptık
2. Sizin ve grubunuzun iyi yaptığını düşündüğünüz şeyler nelerdir?
c# (visual studio), grafcet
3. Siz ve grubunuz daha etkili olarak nasıl çalışabilirdi?
zamanı daha iyi kullanabilirdik
4. Lütfen beraber çalışırken grubunuzun her üyesinin ne ölçüde iş yaptığını temsil etmesi için aşağıdaki daire grafiğini boyayın. Lütfen her bölümde atıfta bulunduğunuz kişinin adını belirtin.

Figure – 10. Student Self and Group Evaluation PBL Form (Turkish Form)

4. Discussion

During the process leading to the completion of the set, the following insights were gained in relation to the hardware:

- The phases of manufacturing and deploying PLC and SCADA systems should be well thought out, planned step by step and with the help of notes. The products to be used should be selected in an appropriate number and variety for the PLC and software. The set we have created has shown us the importance of planned and appropriate material selection for both software and troubleshooting. It has shown that problems can be reduced with suitable materials and software. A student center that focuses on reality-based issues and practices, an interdisciplinary learning approach where activities are distributed among several processes or focus on solving everyday problems, as expressed in (Korkmaz and Kaptan, 2001).
- During the assembly phase of the kit, a variety of hand tools and mechanical parts were required. During the development of the kit, it was determined that mechanical knowledge and skills should be present as well as software and electrical/electronic knowledge and skills. According to Moursund, PBL is an activity that takes place through individual or group interaction and leads to a demonstration, a performance or generally a product over a period (Moursund, 2003). PBL is also defined as a teaching method that provides students in a course with the knowledge and skills to plan, create and then demonstrate a product or performance (Simkins, 1999).
- Thank you to the sufficient knowledge and skills, there have not been many problems in the past when assembling the kit. Problems have generally occurred with the mechanical parts. The vibration problem in the mechanism of the turntable was tried to be eliminated by adjusting the mechanical processing and the motor speed. This problem, which often occurs in pulley systems, has been minimized by intervention in the bearings and other mechanical repairs.
- The stepper motor catalog was examined for the control of the rotary table's stepper motor. The cable connections were connected to the PLC and the device using the motor driver booklet. It turned out that the motor did not move due to the incorrect connection, but the error was later recognized, and the problem was solved.

- Plexiglass was used for the keypad, touchscreen holder and sensor holders of the device. Laser cutting was carried out. The bracket for the conveyor belt alignment was made with a 3D printer.

The following observations were made during the software process up to the completion of the set:

- The PLC software is created according to the grafcet diagram. The shortcomings of the grafcet diagram were reflected in the PLC program. As a result of the tests, the PLC software was supplemented with appropriate time and algorithmic changes.
- Programming manuals for the use of PLC libraries were reviewed, the required ".dll" files were added to the software and the PLC commands could be used.
- All inputs and outputs were initially included in the SCADA simulation. However, the system proved to be slow and cumbersome. To remedy this, the PLC inputs and outputs used in the simulation were reduced. Although the interval value of the timer object used is 1ms (the lowest value), there is a delay of about 3 seconds between the communication between the PLC and the software during the USB connection. For example, the sensor value can be seen on the screen 3 seconds after a sensor sees the product. This is because the speed of the tape cannot be adjusted. When communicating via the Ethernet connection, this time interval decreases and the compatibility between the PLC and the PC increases.
- It was found that the time correspondence between the registration in the database and the recognition of the product is at an acceptable level.

The following results were found in the PBL application:

- It was observed that students took ownership of the course during the process of creating a virtual business and designing their logos.
- It was found that activities such as task sharing and creating work plans during the sessions had a positive effect on students' self-confidence and sense of responsibility.
- In the PBL method, students rated not only the product but also the process positively. It was observed that they were more satisfied with their work and their anxiety decreased. This led to a greater willingness to work.
- It was found that it is more pedagogically beneficial for the students if the teacher is only a guide and solves the problems with the students' own efforts and abilities.
- It was observed that students' skills in leadership, collaboration, critical thinking, problem solving and presentation (21st century skills) have improved. PBL is also defined as a teaching method that provides students in a course with the knowledge and skills to plan, create and then demonstrate a product or performance (Simkins, 1999).
- Students were observed to fairly evaluate the process, group members, and themselves. In PBL, it is of great importance to evaluate not only the activities, but also the resulting product and the process of creating this product, that is, process and result evaluation (Korkmaz, 2002) (Yurtluk, 2003).
- Students indicated that the PBL method was more efficient than the traditional method. This study focused on the manufacturing and programming of a training set for industrial automation training with project-based learning curriculum to be used in distance (online) and face-to-face training.

5. Results

To prepare students for the visions of the "National Industrial Movement" and "Industry 4.0", the focus should be on production-oriented training. The training sets available on the market from external companies are quite expensive. Not every school can have these expensive sets. This work is produced cheaper than equivalent non-local sets on the market.

In this study, we have experienced that we can produce our own training sets with original design using industrial automation products.

The set can be used for training on the following topics:

- Grafcet diagrams
- PLC programming (two different models)
- Electrical-electronic materials and their use
- Electropneumatic
- Control of DC motors and stepper motors
- Sensors
- Sorting products on the conveyor belt
- Production and control of rotary tables
- Visual and object-oriented programming
- SCADA programming
- Use of image libraries
- Database applications
- Touch panel applications
- PBL process and training material

The content of the set corresponds to the syllabus for industrial automation technology in vocational schools. The following lessons can be taught with the set:

- Workshop (grade 9)
- Workshop (grade 10)
- Sensors (grade 10)
- Workshop (grade 11)
- Mechanisms (grade 11)
- Computer Modeling (grade11)
- Industrial visual programming (grade 12)

It is expected that this study will be a reference source for PBL in VET. In this study, VET teachers can learn how to create a vocational curriculum with the PBL method, what forms exist and examples of rubrics that serve as assessment benchmarks.

In addition to traditional teaching methods, our students need to be introduced to the student-centered project-based learning method. This will also allow them to develop 21st century skills.

This study was conducted in Izmir Bornova Mazhar Zorlu MTAL (Vocational High School) workshop under the observation of the students. The students followed every stage of the project. When necessary, they undertook small manual tasks such as stripping cables and installing cable ducts.

The 4-week PBL application was experienced in student groups and its impact and effectiveness on the students was observed. It was found that the set worked according to its purpose. The fact that a group of 12 students developed an application on the set for 4 weeks using the PBL method increased students' interest, love and future goals for their profession.

PBL rubrics were completed by students and teachers, and PBL-based learning was found to be more efficient in vocational education than the traditional learning method.

This study was created and programmed in accordance with the MoE (Ministry of Education) curriculum for industrial automation techniques. The set is suitable for both online and face-to-face teaching, contains two different PLCs, uses Grafcet diagrams, has a PBL curriculum, the materials used were selected from a variety of materials used in the industry and the SCADA software written is based on Visual C# object-oriented programming on the ".NET" platform. The fact that it was written, many programming libraries and methods such as SQL database and image libraries were used, and a PBL curriculum, plan, and rubrics were present enhanced the set and made it a useful and efficient teaching tool.

Finally, it should be noted that the finished set can still be improved. More industrial products can be added to the set, the existing programming language and industrial products can be changed (e.g. a different PLC can be connected), the set's software (SCADA) can be further developed, mobile applications, web-based control, image processing, product recognition and artificial intelligence (AI) applications can be added to the set, virtual reality (VR) and augmented reality (AR) technologies can be used. The set can be used with other existing sets or industrial robots and can be extended with industrial Ethernet, embedded cards, industrial IoT devices and industrial network technologies.

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