

# PREPARING ENGINEERS FOR INDUSTRY 4.0: INSIGHTS FROM A BLENDED INTEGRATED PROGRAM ON INDUSTRIAL AUTOMATION

Giedrius Blažiūnas

*Kauno kolegija Higher Education Institution*

**Abstract.** The transition to Industry 4.0 fundamentally changes the skills required of future engineers. For this reason, engineering studies must increasingly focus not only on theoretical knowledge, but also on an interdisciplinary approach, working with data and developing practical skills. This article describes the experience of implementing and evaluating a five-day international Blended Intensive Program (BIP) titled “Advanced Monitoring and Control of Technological Processes”. The program was held at Kauno kolegija Higher Education Institution, and students from Finland, Bulgaria, Poland, and Lithuania participated. All classes were held in English, with a main focus on practical activities. The aim was to create a learning situation as close as possible to the real Industry 4.0 environment. Various tools and technologies were integrated: PLC programming, monitoring techniques of technological processes, data acquisition, SQL data analysis with Python, and visualization of results in a web-based user interface using the Streamlit library.

Students worked individually and in teams, completing practical tasks. One of the main tasks was the analysis of a virtual sewage pumping station created in the PLC-Lab simulation environment and the development of control programs. The learning process used the learning-by-doing and project method, based on Kolb's experiential learning cycle, so students not only performed tasks but also constantly reflected on their actions and results. During the program, it was observed that students' progress was strongly influenced by their prior experience in PLC programming and automation. Those students who had already worked with PLCs or had more technical knowledge completed the tasks faster and more independently. Meanwhile, less experienced participants often needed additional consultations, especially when integrating SQL databases and performing data analysis with Python. Despite varying levels of preparation, all students were able to work with technologies and create working solutions that included control, data collection, and visualization. The obtained results allow us to state that blended and interdisciplinary learning is an effective way to prepare engineering students for the challenges of Industry 4.0. At the same time, this experience has shown that when planning such programs, it is important to provide preparatory activities that would help to standardize students' initial knowledge and skills. The described program can serve as a practical model for other engineering studies and provides useful insights for improving the content of industrial automation studies.

**Keywords:** Industry 4.0, project-based learning, PLC programming, SQL data logging, virtual simulation

## Introduction

The quick development of Industry 4.0 technologies is fundamentally changing the engineering education environment. Competencies such as Programmable Logic Controllers (PLCs) and Industrial Computers (IPCs), data collection, process monitoring, data analysis, and visualization are becoming essential for engineers working in a digitalized industrial environment. Therefore, educational institutions are forced to review study programs and apply innovative teaching methods to prepare students for work in this constantly changing field. Given these challenges, a Blended Intensive Program (BIP) titled “Advanced Process Monitoring and Control” was developed and implemented. The goal of this course is to provide students with practical, interdisciplinary competencies by integrating the main aspects of industrial automation: PLC programming, process data monitoring and acquisition, and data analysis using Python and SQL.

The program brought together students from Finland, Bulgaria, Poland, and Lithuania, creating an international and collaborative learning environment. The main language was English, which ensured smooth communication and engaged all participants, despite their different cultural and academic backgrounds. During the five-day intensive program, students completed sequentially prepared tasks. They had to:

- analyze a technological process,
- develop a PLC control program,
- define and monitor the most important process parameters,
- create MS SQL database,
- design a web-based user interface for process data visualization using Python and the Streamlit library.

The aim of this article is to reflect on how the program was designed and delivered, evaluate its effectiveness based on student engagement and learning results, and identify key insights and recommendations for improving engineering education in the context of Industry 4.0.

The BIP focused not only on key Industry 4.0 technologies but also on learning by doing, critical thinking, problem-solving, and interdisciplinary teamwork through hands-on work. Similar approaches are described in the literature.

Benis et al. (2021) state that the COVID-19 pandemic has significantly accelerated the transformation of engineering studies and forced higher education institutions to switch to distance and blended learning models. The study highlights that project-based learning is extremely important in preparing specialists for work in the Industry 4.0 environment, as it promotes the development of practical skills, student engagement, and problem-solving. In addition, the authors note that simulations, virtual laboratories, and digital tools are becoming an integral part of today's engineering education, especially when opportunities to work with real equipment are limited.

Coşkun et al. (2019) claim that adapting engineering studies to the requirements of Industry 4.0 must be systematic and include not only updating the study content but also restructuring the teaching infrastructure and student activities. The authors propose a model comprising three main components: modernizing study programs (curriculum), creating new types of laboratories, and integrating student club activities into the learning process. The study highlights the need to incorporate more information technology, data analysis, artificial intelligence, automation, and interdisciplinary projects into study programs. These are the competencies essential for preparing future engineers for work in a digitalized industry. In addition, the authors underline the importance of experiential learning and suggest basing laboratory work on Kolb's experiential learning theory, which allows students to learn through activity, reflection, and experimentation.

Porumb et al. (2013) examine the application of blended learning in engineering studies and argue that traditional education must be supplemented with advanced e-learning approaches to enable a more effective integration of theory, practice, and student collaboration. The authors emphasize that one of the main problems in implementing blended learning is the gap between the real and virtual learning environment, which they name the "blended learning gap". To reduce this gap, it is proposed to implement the "blended learning bridge". This concept refers to a set of interactive tools and methods that enable students and teachers to collaborate in both the classroom and remote environments. The article also shows that project-based and problem-based learning are very important because these activities promote active engagement, independence, and the development of students' practical competencies.

In their review article, Krdžalić and Hodžić (2019) argue that the transformation of Industry 4.0 has a significant impact not only on industry but also on the education system, because new technologies require the preparation of highly qualified specialists. The authors emphasize that engineering curricula need to be updated to incorporate more digital technologies, strengthen interdisciplinarity, and adopt modern teaching methods.

Van der Stap et al. (2024) examine how teachers can promote student engagement in distance-learning activities within a blended learning environment. The authors of the study found that three factors are particularly important for student engagement: a consistent connection between distance and face-to-face activities, clearly visible teacher presence in the virtual space, and purposefully organized student collaboration. The study showed that online activities lose their value if they are not integrated into the overall course structure or if students do not feel the teacher's attention.

Oveissi and Ebrahimi Ghadi (2021) describe the development of an innovative course of study to prepare chemical engineering students for work in an Industry 4.0 environment. The authors emphasize that effective preparation requires integrating digital technologies (e.g., artificial intelligence, digital twins, IoT, big data analytics) with interactive teaching methods and practical activities. The activities presented in the study promoted high student engagement and a positive learning experience. Those activities included project work, case studies, Python programming, working with Arduino microcontrollers, and practical experiments. The authors conclude that combining various active learning methods enables the successful development of both technical and general competencies required for future work in a digitalized industry (Oveissi, Ebrahimi Ghadi, 2021).

Jorge et al. (2020) analyze how universities prepare engineering students for work in an Industry 4.0 environment and emphasize the need to develop not only technical, but also methodological, social, and personal competencies. The authors argue that active learning methodologies, such as project-based, problem-based, and blended learning, are particularly suitable for developing these competencies.

Harris and Park (2016) use a case study of blended learning in a third-year engineering course, in which some lectures were delivered in a "flipped classroom". The authors found that active classroom activities (practical assignments, problem-solving, and discussions) increased student engagement and enabled the instructor to better monitor the learning process.

Abuejheisheh et al. (2023) analyzed the effectiveness of blended learning in Basic Life Support (BLS) training compared to traditional face-to-face training. The authors found that, in most studies, blended learning was superior or at least as effective as other approaches in assessing knowledge acquisition and practical skills development. They also noted that this type of learning resulted in longer and better retention of acquired knowledge and skills.

Sareen and Mandal (2024) identified the main barriers to the successful implementation of blended learning in higher education. They did this by assessing the attitudes of students, teachers, and institutions. The authors identified 16 groups of barriers, the most common being passive learning, poor course delivery, and insufficient preparation (lack of training). The authors also proposed a conceptual model of barriers to improve the quality of blended learning (Sareen, Mandal, 2024).

Rossiter (2020) argues that effective blended learning in engineering studies must be based on a holistic approach to student education, which includes not only technical knowledge but also independent learning, problem-solving, and the development of professional competencies. The author highlights the importance of active learning tools and suggests using virtual and remote laboratories, interactive tests, Virtual Learning Environments (VLEs), and authentic assessment, allowing students to use real engineering tools (e.g., MATLAB).

Yigit et al. (2014) studied the application of blended learning in algorithms and programming in computer engineering. They compared students' achievements between the blended and traditional teaching groups. The study found that students' academic achievement in both groups was very similar, suggesting that blended learning is not less effective than traditional face-to-face teaching.

Pavani and Barbosa (2016) describe how a variety of digital learning resources (videos, interactive tasks, and simulators) were used in a blended learning course. It promoted student self-directed learning and made contact lectures more effective by using them for discussion and problem-solving. The authors emphasize that interactive simulators allow students to change system parameters and observe how results change, helping them better understand complex theoretical concepts. The study showed that students evaluate these tools positively and use them more actively for self-directed learning. Therefore, it can be stated that digital learning objects can significantly improve the quality of blended learning in engineering studies (Pavani, Barbosa, 2016).

The analyzed literature shows clear trends in contemporary engineering education: the use of blended learning, project-based activities, and the development of interdisciplinary digital competencies. These insights provide important context for evaluating the Blended Intensive Program (BIP). The program's structure and implementation reflect many of these principles. The Blended Intensive Program (BIP) described in this study reflects many of the approaches discussed in the literature. The program structure combines interdisciplinary, project-based tasks. They include PLC programming, process monitoring, SQL database development, Python programming, and data visualization in a WEB UI. These elements align well with modern teaching practices that aim to develop the technical, analytical, and teamwork skills needed in Industry 4.0.

Summarizing the literature review, it is clear that the content of engineering studies needs to be updated to align with Industry 4.0 requirements. Effective solutions can include supplementing study programs with interdisciplinary and digital topics, using blended and flipped learning methods, and developing programming and data-based competencies. One of the most important solutions should be project-based and active learning activities. The BIP program is a good example of these changes, as it provides students with a practical, action-oriented learning experience and helps develop the technical and soft skills needed in the future industrial environment.

**Research aim** - to evaluate the effectiveness of a Blended Intensive Program for engineering students that focuses on Industry 4.0 technologies: PLC programming, data logging, process data analysis, and visualization.

**Research object** - the international five-day BIP program titled “Advanced Monitoring and Control of Technological Processes” with practical activities in PLC programming, SQL data logging, Python data analysis, and web-based visualization using the Streamlit library.

**Research tasks:**

1. To describe the structure, content, and learning software of the BIP program.
2. To assess student achievement and learning progress through practical, project-based learning tasks in a blended learning format.
3. To identify the main challenges encountered by students and analyze their relationship to prior technical knowledge.
4. To examine student and instructor reflections on the learning experience and the suitability of the program structure.
5. To provide recommendations for improving engineering education in the context of Industry 4.0 and blended learning methodologies.

## Methodology

This study is based on the design, implementation, and evaluation of a five-day international Blended Intensive Program (BIP) titled “Advanced Monitoring and Control of Technological Processes.” The program was organized and delivered at Kauno kolegija Higher Education Institution by the author, who was also the instructor. It gathered over 20 students from four European countries: Finland (8), Bulgaria (3), Lithuania (5), and Poland (5). English was used as the teaching language throughout the program.

**Learning Structure and Content.** The main goal of the BIP was to bring together key Industry 4.0 technologies and give students practical, interdisciplinary experience in several areas, including:

- Industrial process control using Siemens S7-1200 PLCs;
- Process monitoring and data acquisition;
- Data logging using Microsoft SQL Server;
- Data analysis and visualization with Python;
- Web-based interface development for data presentation.

Participants worked alone or in small teams to complete a series of structured tasks that simulated a full industrial control system project. These tasks included:

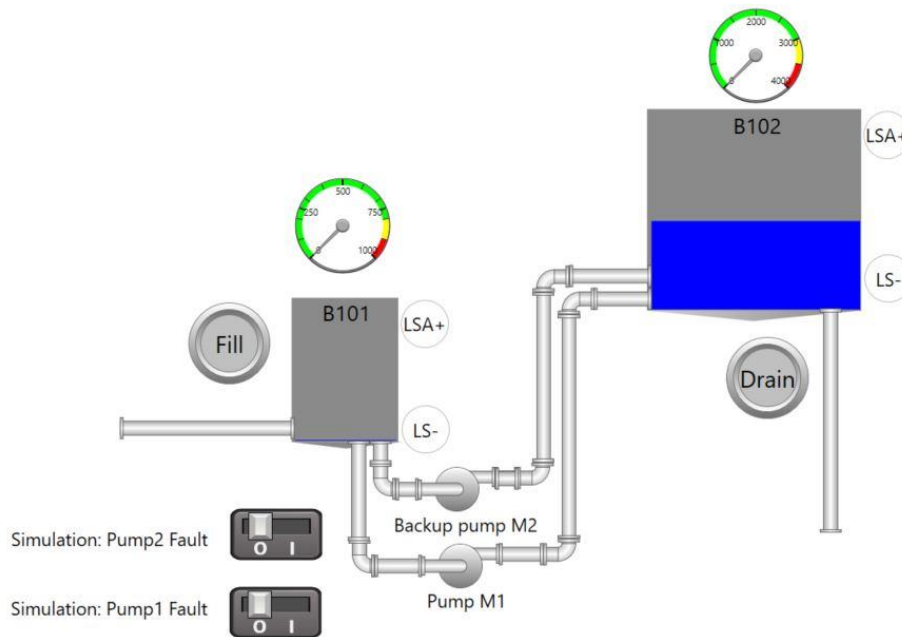
1. Analysis of a technological process and definition of control requirements;
2. Development of PLC control program for simulated virtual control object;
3. Selection of main process parameters for monitoring;
4. Configuration of SQL database and development of a program for storing process data;
5. Development of a program for reading data from SQL and analyzing it using Python libraries (e.g., Pandas, Matplotlib);
6. Development of an interactive web interface using Streamlit for process data visualization.

**Learning Approach.** The teaching method was based on learning by doing and project work, based on Kolb’s experiential learning cycle. Each task was linked to the previous one, so students could consistently work on tasks step by step. Students were encouraged to collaborate, solve problems together, and reflect on their progress. The focus was not only on developing technical skills but also on general skills such as communication, teamwork, and problem-solving. There was no formal assessment by grades. Instead, students received constant feedback, learned from each other, and gradually improved their project work. The program concluded final presentations, during which students presented their solutions, shared their experiences, and provided feedback on the BIP program.

**Project Scenario: Virtual Wastewater Pumping Station.** To create a realistic yet safe industrial simulation, a virtual wastewater pumping station in the PLC-Lab was chosen as the main research object. This allowed students to work with a dynamic process model that closely reflected the operation of a real technological facility. The simulated station included:

- Two wastewater tanks (B101 and B102);
- Two pumps (M1 and M2);
- Level sensors (LSA+, LS-);
- Manual fill and drain simulation.

The main control objectives were to control pump operations based on water levels, detect abnormal events (e.g., overflow, pump failure), and realize advanced diagnostics through data acquisition and visualization of the simulated technological process. Figure 1 shows the simulated wastewater station plan.



**Fig. 1.** Simulation model of wastewater pump station

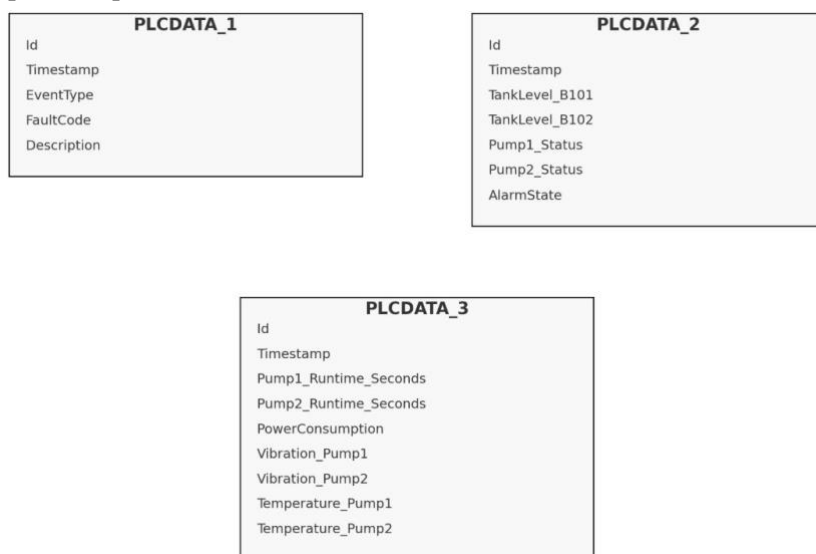
**Diagnostic Parameters and SQL Data Logging.** Students were asked to monitor and record a range of diagnostic parameters, including:

- Water levels in B101 and B102;
- Pump ON/OFF status and runtime;
- Alarm states (e.g., fault, overflow);
- Power consumption;
- Vibration and temperature values;
- General fault and warning signals.

Data had to be transmitted from the virtual PLC to the Microsoft SQL Server database using the LSql\_Microsoft function block. The database contained three configured tables:

- PLCDATA\_1: event-triggered information (e.g., alarm activation);
- PLCDATA\_2: every 5 seconds periodically recorded data (e.g., levels, status);
- PLCDATA\_3: overall runtime and performance data updated every 10 seconds.

Data was saved using standard SQL commands like INSERT INTO and UPDATE, and each record included a timestamp so that past data and trends could be tracked. The database structure is shown in Figure 2.



**Fig. 2.** Database structure

Figure 3 represents data logging results. The figures show two SQL Server database tables used to store and analyze data from a virtual wastewater pumping station. Table (a) stores fault events. Each entry includes a timestamp and a fault identification number, which help identify problems such as overflows, sensor errors, or pump failures. This type of data makes it easier to analyze issues with controlled objects and detect faults early. Table (b) shows the stored regular operation data of pumps. Saved data consists of timestamp, tank level values (B101\_Level, B102\_Level), and pump status signals (Run, Stop, and Fault for Pump 1 and Pump 2). This data provides a view of how the pump station system operates. Using data, it is possible to analyze pump statuses and how they respond to changing conditions.

Results				Results									
id	TimeStamp	Fault_ID		id	TimeStamp	B101_Level	B102_Level	Pump1_Run	Pump1_Stop	Pump1_Fault	Pump2_Run	Pump2_Stop	Pump2_Fault
1	2023-11-07 12:15:00	1		1	2023-11-07 12:27:00	100	200	NULL	NULL	NULL	NULL	NULL	NULL
2	2023-11-07 12:15:00	2		2	2023-11-07 12:27:00	100	200	NULL	NULL	NULL	NULL	NULL	NULL
3	2023-11-07 12:15:00	4		3	2023-11-07 12:27:00	100	200	NULL	NULL	NULL	NULL	NULL	NULL
4	2023-11-07 12:15:00	5		4	2023-11-07 12:27:00	200	300	NULL	NULL	NULL	NULL	NULL	NULL
5	2023-11-07 12:15:00	5		5	2023-11-07 12:27:00	400	300	NULL	NULL	NULL	NULL	NULL	NULL
6	2023-11-07 12:15:00	1		6	2023-11-07 12:27:00	500	900	NULL	NULL	NULL	NULL	NULL	NULL
7	2023-11-07 12:15:00	1		7	2023-11-07 12:27:00	500	900	NULL	NULL	NULL	NULL	NULL	NULL
8	2023-11-07 12:15:00	1		8	2023-11-07 12:27:00	990	99	NULL	NULL	NULL	NULL	NULL	NULL
9	2023-11-07 12:15:00	1		9	2023-11-07 12:27:00	990	99	NULL	NULL	NULL	NULL	NULL	NULL
10	2023-11-07 12:15:00	1		10	2023-11-07 12:27:00	990	99	NULL	NULL	NULL	NULL	NULL	NULL
11	2023-11-07 12:15:00	1		11	2023-11-07 12:27:00	0	99	NULL	NULL	NULL	NULL	NULL	NULL
12	2023-11-07 12:15:00	1		12	2023-11-07 12:27:00	0	99	NULL	NULL	NULL	NULL	NULL	NULL
13	2023-11-07 12:15:00	1		13	2023-11-07 12:27:00	0	99	NULL	NULL	NULL	NULL	NULL	NULL
14	2023-11-07 12:15:00	1		14	2023-11-07 12:30:00	0	99	1	0	0	NULL	NULL	NULL
15	2023-11-07 12:15:00	2		15	2023-11-07 12:30:00	0	99	1	0	0	NULL	NULL	NULL
16	2023-11-07 12:15:00	2		16	2023-11-07 12:31:00	0	99	1	0	0	NULL	NULL	NULL
17	2023-11-07 12:15:00	2		17	2023-11-07 12:31:00	0	99	1	1	0	NULL	NULL	NULL
18	2023-11-07 12:15:00	2		18	2023-11-07 12:33:00	0	99	1	1	0	NULL	NULL	NULL
19	2023-11-07 12:15:00	2		19	2023-11-08 12:37:00	100	200	NULL	NULL	NULL	NULL	NULL	NULL
20	2023-11-07 12:15:00	2		20	2023-11-08 12:37:00	100	200	NULL	NULL	NULL	NULL	NULL	NULL
21	2023-11-07 12:16:00	3											
22	2023-11-07 12:16:00	3											
23	2023-11-07 12:16:00	3											
24	2023-11-07 12:16:00	3											

Fig. 3. Database tables with logged data

**Data Extraction and Visualization.** After collecting the process data, the students used Python and the pyodbc library to connect to a SQL Server database and retrieve the necessary information. Next, they had to prepare, summarize, and visualize the data using tools such as the Pandas library for data processing and the Matplotlib library for plotting. For visualization, the students also created interactive dashboards using the Streamlit library. These dashboards presented the most important data that helped them to understand better performance and efficiency of the controlled system:

- Real-time graphs for values of process and runtimes of pumps;
- Time-series charts (line, area, scatter, bar) for monitoring of trends;
- Donut charts for visualization of fault-type information;
- Text messages for describing fault codes into understandable manner.

These visualizations helped students better understand the status of controlled stations and develop data-based diagnostic skills. An example of the dashboard that students must create is shown in Figure 4 (color legend for the charts: dark blue – runtime of pump 1, light blue – runtime of pump 2, red – total runtime for both pumps).

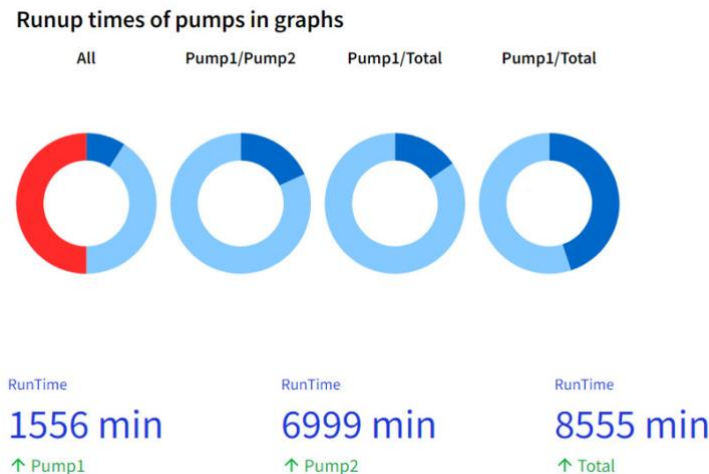


Fig. 4. Visualized data of pump runtimes

The consistently planned learning path provided students with hands-on experience with the key components of Industry 4.0: system control, simulation, data acquisition, database configuration, programming, and visualization. The use of a realistic virtual environment ensured a safe, flexible learning process while maintaining a close connection to real industry challenges. This approach helped students connect theoretical knowledge with practical application and was well-suited to the needs of engineering studies nowadays.

## Results and Discussion

Blended Intensive Program (BIP) gave useful insight into what students learned and what difficulties they faced during the project-based work. The results showed that student performance varied widely, largely depending on their prior technical knowledge and programming experience.

***Student Performance and Work Organization.*** Students had varying levels of success when completing the tasks. Those with programming experience, especially in Python or PLCs, were able to complete the entire project with very little help. Students who were new to Siemens PLC programming needed much more guidance and support.

Teamwork turned out to be very important. Groups usually did better than students working alone because they could solve problems together, share responsibilities, and stay more motivated.

Often, students with a strong background in automation took the lead in developing the control logic, while others focused on database work or the web interface. This way of working helped the team move faster and gave students a chance to learn from each other.

***Technical and Pedagogical Challenges.*** Several technical and pedagogical challenges were identified during the program. The most common difficulties involved PLC programming and Python scripting for the SQL database. For many participants, this was their first experience working with industrial automation systems or writing code for a PLC control program. Some students struggled with basic concepts such as control logic structures, SQL operations, and data processing techniques.

A clear difference was seen between students who worked alone and those who worked in teams. Some students who worked individually gave up when the tasks became too difficult, while those in groups were more likely to finish all parts of the project. This shows how important teamwork, shared learning, and collaboration are in addressing interdisciplinary challenges.

Even though the tasks were complex, the tools used in the program: PLC-Lab, TIA Portal, Microsoft SQL Server, Python, and Streamlit worked reliably. No serious technical problems occurred. However, some delays occurred due to limited hardware performance, especially on older or slower computers.

***Student Feedback and Reflection.*** At the end of the program, students from each participating country took part in a group discussion to share their feedback. The responses were very positive. Students said they enjoyed working with real-world technologies and positively evaluated the project's practical, interdisciplinary nature. One group even jokingly called the instructor the “teacher of the year” because of the clear explanations and continuous support for students with different skill levels.

***Instructor Reflections and Observations.*** From the instructor’s perspective, the program demonstrated that it is possible to deliver a realistic Industry 4.0 learning experience even in a short, intensive format. At the same time, some challenges became clear. Some tasks were too difficult for students who lacked basic skills in PLC programming or Python. Because the program combined automation, data science, and web technologies, it required a wide range of technical knowledge that not all students had at the beginning.

For future editions of the BIP, it would be helpful to include preparatory materials or short prerequisite modules on key topics, such as basic Siemens TIA Portal programming and Python. This would help create a more balanced learning experience and give all students a better chance to achieve similar learning outcomes, regardless of their starting level.

## Conclusions

This study presented the program structure, implementation, and critical reflection on a Blended Intensive Program (BIP) focused on advanced monitoring and control of technological processes. The program successfully integrated PLC-based automation, data analysis, and digital visualization tools to simulate realistic Industry 4.0 scenarios in a higher education automation and robotics program.

Based on the implementation and outcomes of the program, the following conclusions were made:

1. A blended and project-based learning approach can effectively recreate Industry 4.0 scenarios by combining practical engineering tools and interdisciplinary tasks into a seamless learning experience.

2. Students' achievements depend on their technical knowledge, especially in the areas of PLC and Python programming. Students with prior experience worked more independently, while less experienced participants required constant tutoring.
3. Team-based collaboration significantly improved learning outcomes, as group work encouraged the exchange of knowledge, the distribution of responsibilities, and the support of problem-solving.
4. All software components functioned reliably. This confirms that complex industrial systems can be simulated using virtual tools in a learning environment, avoiding critical software failures.
5. It became clear that students need better preparation, especially those who lack basic skills. Future courses should include introductory materials or short modules on key technologies to help students get started more easily.
6. Blended engineering programs can prepare students well for Industry 4.0, but they need clear, step-by-step learning paths that support students with different backgrounds and help everyone stay equally engaged.

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## INŽINIERIŲ RENGIMAS PRAMONEI 4.0: IŽVALGOS IŠ INTEGRUOTOS MIŠRIOSIOS PROGRAMOS APIE PRAMONINĘ AUTOMATIKA

### Santrauka

Perėjimas prie *Pramonės 4.0* keičia inžinierių rengimo reikalavimus ir skatina aukštasias mokyklas pereiti prie tarpdisciplininio, duomenimis grįsto bei praktika paremto mokymo. Šiame straipsnyje pristatomas penkių dienų tarptautinės mišrios ir intensyvios programos „Išplėstinis technologinių procesų stebėjimas ir valdymas“ (*Blended Intensive Program* (BIP) „Advanced Monitoring and Control of Technological Processes“) sukūrimas, įgyvendinimas ir vertinimas. Programa vyko Kauno kolegijoje ir subūrė studentus iš Suomijos, Bulgarijos, Lenkijos ir Lietuvos. Mokymai vyko anglų kalba, taikant praktinio mokymosi ir bendradarbiavimo principus. Pagrindinis programos tikslas – sukurti realistišką *Pramonės 4.0* mokymosi aplinką, integruojant loginį valdymą, procesų stebėseną, duomenų kaupimą SQL duomenų bazėje, analizę *Python* kalba ir internetinės vizualizacijos kūrimą naudojant *Streamlit* įrankį. Studentai, dirbdami individualiai arba komandose, atliko užduotis, susijusias su virtualios nuotekų siurblinės valdymu, kuri buvo sukurta naudojant *PLC-Lab* programinę įrangą. Tyrimas paremtas patirtiniu, projektiniu mokymo modeliu, atitinkančiu Kolbo mokymosi ciklą. Rezultatai atskleidė, kad studentų pažanga labai priklausė nuo jų išankstinių programavimo ir automatikos žinių, o komandinis darbas ženkliai pagerino mokymosi rezultatus. Nepaisant iššūkių, visi dalyviai susidūrė su realiomis technologijomis ir įgyvendino integruotus projektus, apimančius valdymą, duomenų apdorojimą ir vizualizaciją. Tyrimas parodė, kad mišrus tarpdisciplininis mokymas yra veiksmingas būdas rengti inžinierius *Pramonės 4.0* aplinkai. Tačiau taip pat pabrėžiamas poreikis pateikti išankstinę mokomąją medžiagą, kad būtų kompensuoti žinių skirtumai tarp studentų. Programa gali būti laikoma sėkmingu pavyzdžiu, kaip trumpalaikėmis studijomis integruoti *Pramonės 4.0* principus į inžinerinį mokymą.

**Reikšminiai žodžiai:** *Pramonė 4.0*, projektinis mokymasis, PLC programavimas, SQL duomenų kaupimas, virtuali simuliacija

### Information about the author

**Dr. Giedrius Blažiūnas.** Kauno kolegija Higher Education Institution, Centre of Engineering Studies, assistant researcher. Research fields: industrial automation, machine learning.

Email address: giedrius.blaziunas@kaunokolegija.lt

ORCID ID: 0009-0001-7744-7527