FRI-2G.302-1-CCT2-02

DEVELOPMENT OF PROJECT-ORIENTED LEARNING PROCESS IN THE FIELD OF PROGRAMMABLE CONTROLLERS AND INDUSTRIAL COMMUNICATION [12]

Assist. Prof. Ventsislav Keseev, PhD
Department of Telecommunications
University of Ruse "Angel Kanchev", Bulgaria
Tel.: +359 82 888 831
E-mail: vkeseev@uni-ruse.bg

Abstract: *Nowadays, the technology development is fast, the know-how and specialized information explode, and all spheres are becoming more complicated. Many low qualification jobs disappear and the requirements towards the remaining ones are increasing. All these challenges must be met by educational systems. The practical problem-based and project-based educational processes are one of the few good solutions. Both have been applied in the educational process in the field of programmable controllers and industrial communication, which is currently being further developed with additional industrial equipment and practical mock-ups. The educational process achieved is useful and successful, but its development requires a lot of time, and much is also needed for work with students. The easy access to financing and lower level of time-consuming bureaucracy are the second most important prerequisites. In this regard, a change in Bulgarian educational policy is necessary.*

Keywords: *Automation, Education, Exercise, Learning, Model, Project, Problem, Setup.*

INTRODUCTION

Nowadays, technology develops fast and the world changes quickly (Schwab, K., 2017). The fourth and the new fifth industrial revolutions lead to more automated and complex environments. The technology development is fast, the know-how and specialized information explode, and all spheres are becoming more complicated. The industrial revolutions allow the creation of more intelligent control systems that communicate autonomously with other such systems without the need of human operators. This allows the production of multitude of cheaper goods with higher quality for the consumers, but also affects the labour market, which provides income for them. The mass automation of production processes takes over many low qualification jobs from the labour market, while at the same time new work positions appear that require certain practical skills, knowledge and expertise in several technical fields. Some researchers conclude that the requirements towards the remaining low qualification job positions also change with increasing work duties and their complexity (Schwab, K., & Samans, R., 2016), (Schwab, K., 2018).

All these challenges must be met by the educational systems. They must prepare the incoming generations for the real-world constant problem solving, that they will face in life. The high-quality education of the population is very important for every country economic development and for the prosperity of its people. It is a global responsibility for all individuals and governments (Neamtu, D., 2015). The old methods of informative education are irrelevant and often useless in the information age of Internet, in which the knowledge is easily accessible. Nowadays, the information is endless and the educational process in such a case must be endless, but this is impossible. Instead of simply presenting information to students and requiring from them to learn it, they should be taught how to find it in real time. Once they have found the necessary information, they must have the ability to understand it and apply it in structurally ordered manner, in order to solve certain real-life problems. Our experience is that the real-life problems are more interesting to students. The matter becomes even more interesting, if they see

[12] The paper was presented on 24 October 2025 in section "Communication and Computer Technologies" with original title in English: DEVELOPMENT OF PROJECT-ORIENTED LEARNING PROCESS IN THE FIELD OF PROGRAMMABLE CONTROLLERS AND INDUSTRIAL COMMUNICATION

finished products, after their hard work. The educational process must be practical in order students to be able to develop real-life skills and a structured approach to work, based on knowledge, so that students can solve problems and tasks quickly, easily and qualitatively. This is the ultimate goal of each educational process. The result of such education is that the students get a real head start and the opportunity to successfully deal with life's problems. They become useful for the development and growth of society and are willing to recommend the school to the newer generations, which is a prerequisite for continuous and sustainable progress.

The more practical the education the more time it requires for its qualitative development and for working with the students. The easy access to financing is important in many technical fields, but having enough time to work is the most important and limited prerequisite.

The practical education could be problem-based or project-based. They are similar, but the way of processing knowledge is the key difference (Guo, P., Saab, N., Post, L., & Admiraal, W., 2020). The focus of problem-based learning lies in knowledge application while project-based learning emphasizes knowledge construction (Krajcik, J., & Shin, N., 2014). Both methods are actually an integral part of a holistic educational process and when possible, they must be applied in parallel. In this regard, the conclusion of a study is that compared with the traditional teaching model, project-based learning significantly improved students' learning outcomes and positively contributed to academic achievement, affective attitudes, and thinking skills, especially academic achievement (Zhang, L., & Ma, Y., 2023). Another study concluded that the project-based technique improves student engagement by enabling knowledge and information sharing and discussion (Almulla, M. A., 2020).

The aim of this work is to present the currently developing problem-based and project-based educational process in the field of programmable controllers and industrial communication.

CURRENT CONDITIONS FOR CONDUCTING AN EDUCATIONAL PROCESS IN THE FIELD OF PROGRAMMABLE CONTROLLERS AND INDUSTRIAL COMMUNICATION

The learning process is conducted in a specialized "Siemens Industrial Controllers and Communications" Laboratory (Fig. 1). It was created years ago with a Siemens donation of industrial programable logic controllers (PLCs) and network equipment. The wall mounted equipment represents the main levels of an industrial network. The equipment consists of S7-200 PLCs, S7-300 PLCs, industrial personal computers, Human Machine Interface operator panels (HMI), network switches and others. Some of the equipment is in mobile suitcases. The lab has PLC test modules with switches, used for different exercises, and two models. One of the models represents a machine for numerical two-way control of tools. The two screws are rotated by DC and AC motors, controlled by S7-200 PLC. The other model represents an assembly line for sorting parts by color or metal. It is controlled by S7-300 PLC.

The lab has a potential and is used for conducting practical educational process in the field of programmable controllers and industrial communication, but it also suffers from certain limitations. There are only two models that are for a higher educational course. In reality, during the educational process many more different common problems in the industry are solved that are not visualized with real setups. Without representing controllable models, the problems are solved mainly through simulations, but not everything working in simulation is going to do so in reality. The model is the final product which students must see. It makes the educational process more interesting and brings it closer to reality. Different controllable models are especially needed for industrial communication exercises, for the creation of complex synchronized through networks controllable objects. Such objects can better represent the industrial network control problems. Different controllable models, connected to a network, can be combined into one complete project, which must be completed step by step during a specific educational course.

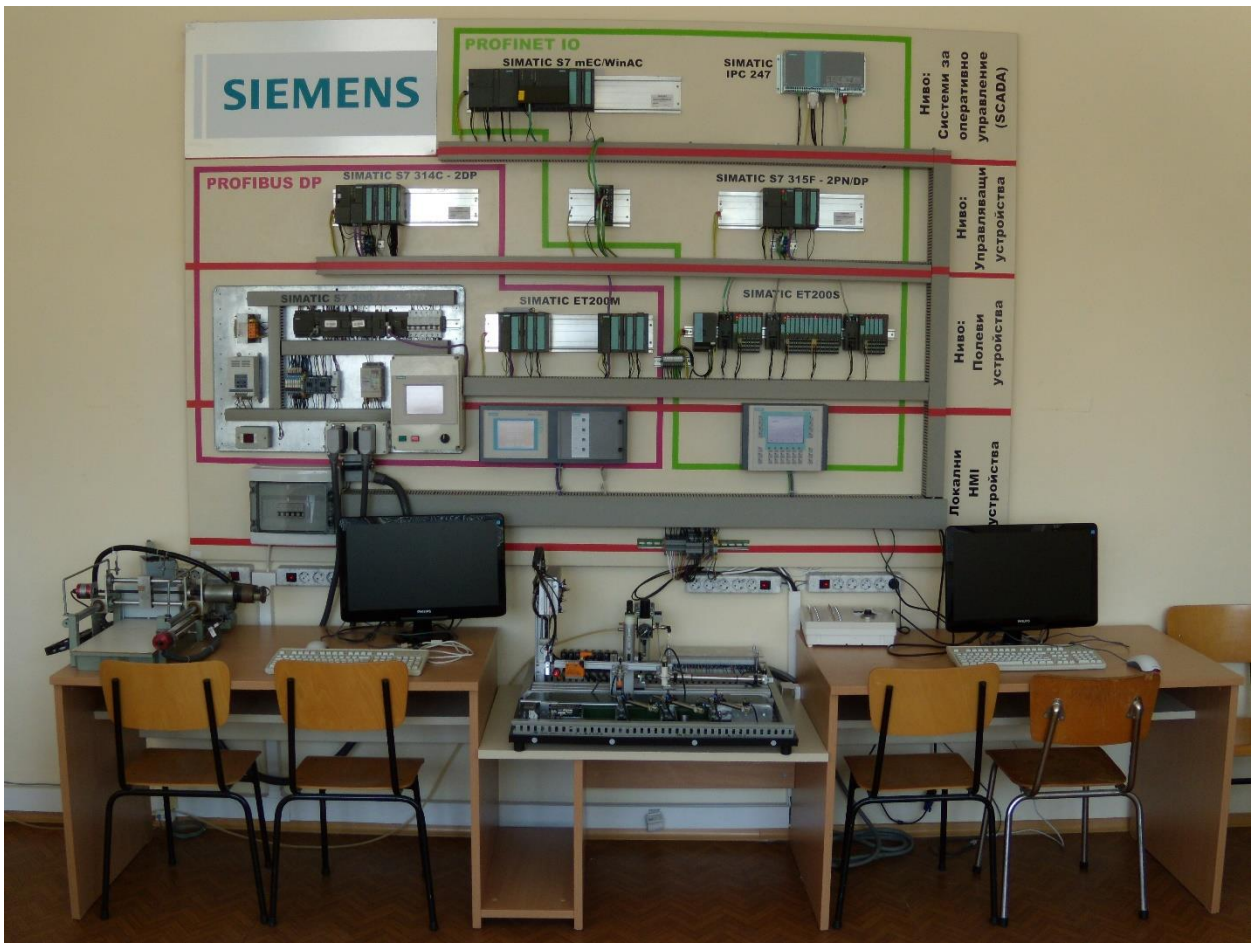


Fig. 1. “Siemens Industrial Controllers and Communications” Laboratory

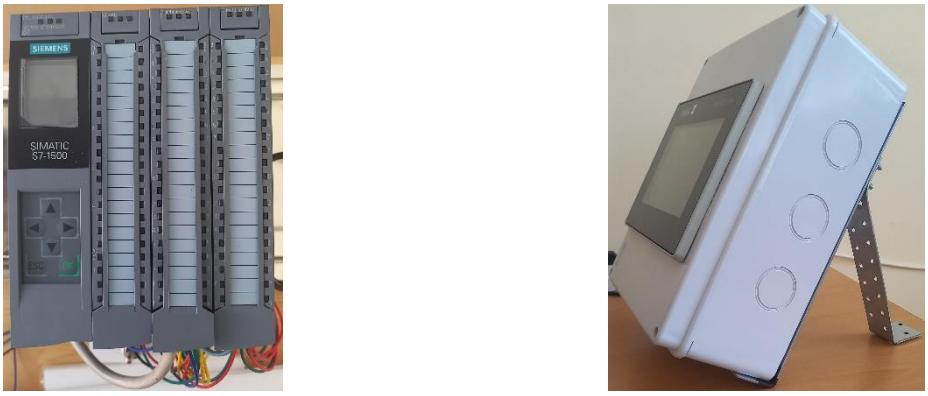
Another problem with the lab is that the S7-200 PLC, although still working, is already too old and needs a replacement. It works with the old MicroWin software, which requires old operating system.

Despite all problems, most of the students find the field and the practically oriented problem-solving educational process very interesting and work with desire. At the end of the courses, they have confidence that they have learned many useful things and developed many useful practical skills. In addition to technical skills, the courses also develop soft skills for leading a team, correct communication, presenting and proving a thesis, proper arrangement of acquired knowledge, and a structured approach to work when solving complex tasks, which allows them to handle tasks faster, easier, and with higher quality, which is extremely necessary for the increasingly complex work environments. They are thought to work in teams as well as to be able to solve tasks individually. The exercises are arranged in way that resembles a real working environment. In this regard, study results indicate that project-based learning may specifically promote the use of collaboration, artefacts, technological tools, problem-centeredness, and certain scientific practices, such as carrying out research, presenting results, and reflection within science education (Markula, A., & Aksela, M., 2022).

The achievements in the organization of the educational process are most important for successful learning and student satisfaction, but each subject requires a different amount of time to achieve this. Time is the biggest constraint. It is needed for the educational process development as well as for enough work with students, because learning is a very time-consuming process, which depends on the student’s abilities and each person is different.

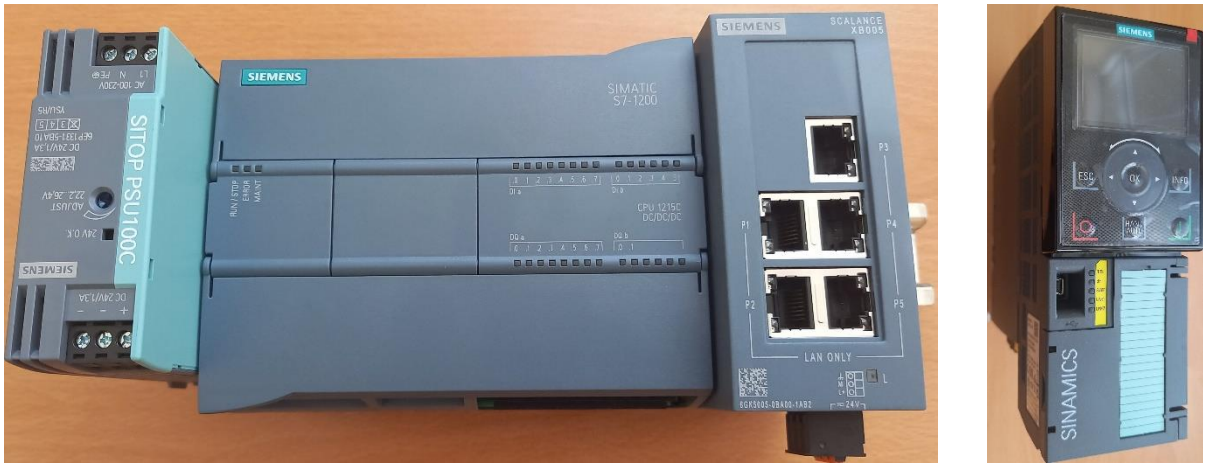
INNOVATIONS AND DEVELOPMENTS OF THE PROGRAMMABLE CONTROLLERS AND INDUSTRIAL COMMUNICATION EDUCATIONAL PROCESS

With the help of Siemens, a new industrial equipment has been acquired, which allows laboratory renovation. The new equipment is configured by the new TIA Portal industrial software, which requires powerful computers, planned for renovation. The new equipment includes S7-1200 and S7-1500 PLCs, HMIs, industrial switches, power supplies, network-managed one-phase power inverter for three-phase motors and others, Fig. 2 and Fig. 3. The diverse equipment allows different models to be developed, representing different automation problems, and they to be combined in a more complex industrial network control project.



a) b)

Fig. 2. New Siemens industrial equipment: a) PLC S7-1500; b) HMI



a) b)

Fig. 3. New Siemens industrial equipment: a) PLC S7-1200 with power supply and switch on the same rail; b) Inverter Sinamics G120

The planned models being worked on are:

- Renovation of the available machine for numerical two-way control of tools. The old S7-200 PLC is going to be replaced by two S7-1200 PLCs, which will complicate the control, because their work will have to be synchronized through network communication.
- Electric drive with an asynchronous electric motor loaded with a DC electric motor controlled by the grid-connected inverter and one of the available PLCs.
- Small temperature process control mockup and versatile PLC control panel with multiple switches, connected to the same controller.
- A multifunctional model representing part of a smart city, managed by two PLCs that need to be synchronized over a network, with multiple input and output signals. The development of the model is in an advanced stage, but it is not yet complete.

- Comparatively easily portable smaller mockup for controlling a miniature DC motor controlled by one S7-1200 PLC.
- Comparatively easily portable smaller mockup for controlling various simple actuators controlled by one S7-1200 PLC.

All models will support network connectivity via Profinet network and thus will allow inclusion in more complex industrial network projects.

The new industrial equipment and models under development allow the modernization of the programmable controllers and industrial communication laboratory, provides the necessary prerequisites for the development of a more complete and realistic learning process and is expected to further stimulate students to work with desire and diligence, and achieve significantly higher results.

DIFFICULTIES IN LABORATORY DEVELOPMENT

As already stated, the time is the biggest constraint. The new equipment and software are different and more complicated, and the documentation is many thousands of pages. It is good that there is complete documentation, but it is not always useful. Many things written on paper do not look the same in practice and in this field many time-consuming tests are needed to clarify them. At the same time the financing is limited and securing it was problematic and lost additional time. The funds for developing the required number of models are extremely insufficient and they must be developed from basic materials, which is not such a big problem for an educational environment, and they will still be useful, but this process is extremely time-consuming. The processing of basic materials is often done with personal specialized tools and supplies that the university does not have or, if it does, has not organized their easy use by all those in need. For example, the cutting of the HMI case was done with a personal small angle grinder with a special disc, and the bending of the metal frame was also done with a personal specialized bending tool, Fig. 2.

The mockups and their example project development require complex knowledge and practical skills in many fields such as Automation, Electronics, Communications, Material Science, Mechatronics, Programming, Computer sciences, Design, know-how, knowledge related to the automation products designed by Siemens and others. The complex knowledge, practical skills and expertise are actually necessary for working in the field of automation and industrial communications in general, and that is why teamwork is essential in this area, with each team member being more highly specialized in specific fields. In this regard, the world has become too complicated and in reality, teamwork among diverse specialists is becoming more and more common by necessity.

In order the development of such useful practical educational processes to be possible the right environment is needed. The right environment is like a fertile soil, allowing plants to produce the best fruit they are capable of. The necessary prerequisites are a peaceful working environment, easy access to financing, maximum reduction of unnecessary bureaucracy, obstacles and restrictions, changing the current Bulgarian policy requiring too much work that cannot be done qualitatively, more time for development, but also more time for work with students and others. Without the right prerequisites and fertile environment, the good achievements will be rare, and even if they do occur from time to time, they will be at the expense of visionary individuals who sacrifice a lot of effort and personal resources to achieve them. Under better conditions, the same individuals could achieve much more.

CONCLUSION

Despite the many hurdles and although being slow, because of too many commitments, the current development of the laboratory is useful and promising. Part of the new equipment is already in use, work is underway to build the new models, and new exercises and guides are to be developed.

The educational process in the field of programmable controllers and industrial communication is already practically oriented, problem and project-based, and backed by industrial equipment and software. It is very interesting for the students and most of them work with desire and diligence. They show keen interest in the trainings and desire more of them. The new equipment is expected to make it even more useful and attractive to them. The models currently being developed will allow for the practical study of a wider range of automation and industrial communication problems and the presentation of a real working final product. Contrary to informative education, the problem and project-based practical education is very important, but it requires a lot of time to be invested in its development and for work with students in order to be helpful and to bring the required success.

ACKNOWLEDGMENT

This publication was prepared with the support of Project 2025-FEEA-03 "Development and Evaluation of Methodologies for the Application of Block-Based Programming and Robotic Platforms in the Education", financed under the Scientific and Research Fund of the University of Ruse "Angel Kanchev".

REFERENCES

Almulla, M. A. (2020). *The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning.* Sage Open, 10(3).

Guo, P., Saab, N., Post, L., & Admiraal, W. (2020). *A Review of Project-Based Learning in Higher Education: Student Outcomes and Measures.* International Journal of Educational Research, 102, 101586.

Krajcik, J., & Shin, N. (2014). *Project-Based Learning.* In R. K. Sawyer (Ed.) The Cambridge Handbook of the Learning Sciences, 2, pp. 275-297.

Markula, A., & Aksela, M. (2022). *The Key Characteristics of Project-Based Learning: How Teachers Implement Projects in K-12 Science Education.* Discip. Interdiscip. Sci. Educ. Res. 4, 2.

Neamtu, D. (2015). *Education, the Economic Development Pillar.* Procedia – Social and Behavioral Sciences, 180, pp. 413-420.

Schwab, K. (2017). *The Fourth Industrial Revolution.* World Economic Forum, Crown Publishing, New York.

Schwab, K. (2018). *The Future of Jobs Report.* World Economic Forum, Geneva, Switzerland.

Schwab, K., & Samans, R. (2016). *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution.* Global Challenge Insight Report, World Economic Forum, Geneva, Switzerland.

Zhang, L., & Ma, Y. (2023). *A Study of the Impact of Project-Based Learning on Student Learning Effects: A Meta-Analysis Study.* Front. Psychol., 14:1202728.