Quality Assurance of PLC Systems Teaching at Secondary Vocational Schools

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Abstract

Education in the field of PLC systems represents an important segment of the curriculum at secondary vocational schools, where students prepare for their future professional careers in the industrial sector. This paper addresses the challenge of how the appropriate quality of PLC systems teaching should be ensured in these schools. The authors present a methodology by which the quality assurance of PLC systems teaching can be supported. Furthermore, based on the results of applying the proposed methodology in practice, they formulate a proposal of measures to enhance the current quality of PLC systems instruction.

Keywords: Teaching PLC Systems, Vocational Education and Training, Quality Assurance of Teaching

1 Introduction

According to a study published by the Organization for Economic Co-operation and Development (OECD, 2024), Slovakia is one of the countries with the highest number of threatened types of employment. This is due to the rapidly increasing influence of Industry 4.0 on the global economy and the high dependence of the Slovak economy on production. Already, the first consequences of this phenomenon are evident, primarily in the form of a shortage of appropriately qualified labour. IT knowledge and skills are becoming increasingly

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crucial in most current industrial environments. Within the scope of the IT skills required by the labour market, PLC systems play an irreplaceable role as key elements of automation and the control of industrial processes. Knowledge and effective control of PLC systems are key factors for the competitiveness and success of industrial enterprises. This means that education in the field of PLC systems represents an important segment of education at secondary vocational schools, where students are prepared for their future professional activities in the industry sector (Hašková et al., 2023; Hašková & Zatkalík, 2020). However, with diverse programmes and approaches to teaching also come various challenges and questions regarding the unification of teaching content and compliance with state and school curricula.

The teaching process at secondary vocational schools is quite specific. This is mainly due to the structure of instruction, where students are taught in two-week cycles; the first week consists of theoretical preparation, followed by a week where they apply the acquired knowledge within practical vocational training. It is clear from the foregoing that teaching at this type of school is important not only from a theoretical perspective but, more importantly, from a practical one. Graduates of secondary vocational schools should be skilled technical experts who possess the theoretical knowledge necessary for the performance of specific work tasks. Taking into consideration the dynamics of the industrial environment, it is important to adapt the content of teaching permanently to the current requirements of employers and the needs of the labour market. Therefore, it is essential to analyse existing educational programmes constantly and ensure that they are in line with the needs determined by industrial enterprises.

Based on the foregoing, we decided to analyse the educational programmes of secondary schools at which the subject of PLC systems is taught, as well as employers' expectations regarding students' knowledge of PLC systems. Subsequently, we sought to identify possible shortcomings and suggest relevant improvements that would contribute to a more effective preparation of the students, reflecting the identified requirements of the industrial sector (Figure 1).

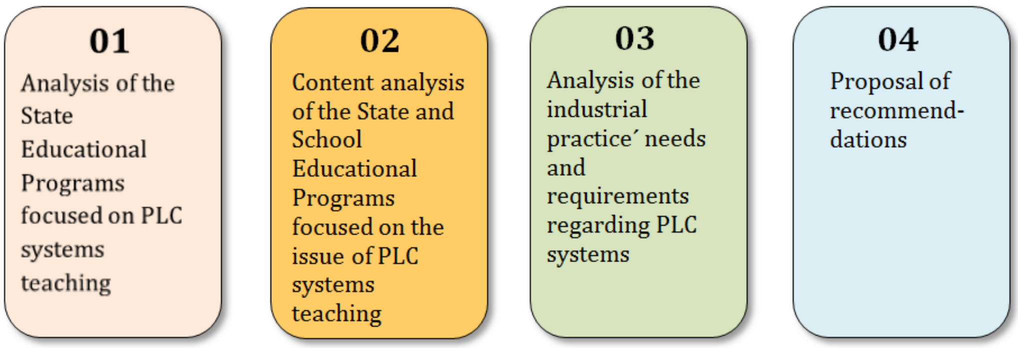

Figure 1: Concept of the methodology to support quality assurance of PLC systems teaching at secondary vocational schools.

2 Teaching PLC Systems at Secondary Vocational Schools

2.1 Analysis of the PLC System Issue Included in the State Educational Programmes of Selected Study Branches of Secondary Vocational Schools

State Educational Programmes for secondary vocational schools are issued and published by the Ministry of Education, Research, Development and Youth of the Slovak Republic. These are developed following negotiations with employers, school founders, and professional associations to ensure a nationwide reach, in co-operation with relevant ministries and in accordance with applicable legal regulations. The curriculum content prescribed within these State Educational Programmes is mandatory for the respective groups of study branches.

To identify the branches in which PLC systems are taught, the curricula of 27 groups of study branches were analysed (ŠIOV, 2010):

- physical and mathematical sciences
- metallurgy
- information and com. technologies
- technical chemistry of silicates
- food industry
- processing of leathers, furs and footwear
- printing and media
- transport, post and telecommunications
- agriculture, forestry and rural development
- economy and organization trade and services
- journalism, librarianship and scientific information
- art, and arts and crafts
- pedagogical sciences
- mining, geology and geotechnics
- mechanical engineering and other metal working production
- electrical engineering
- technical and applied chemistry
- textiles and clothing
- wood processing
- construction, geodesy and cartography
- special technical fields
- veterinary sciences
- legal sciences
- teaching
- physical culture and sport
- security services

Based on the comparative analysis of the State Educational Programmes for the specified study branches, it was found that the subject of PLC systems is included in the State Educational Programmes of only four study branches. These are: Mechatronics (within the mechanical engineering and metalworking production group), Electrical Engineering, Mechanic Mechatronic, and Computer Systems (all within the electrical engineering group).

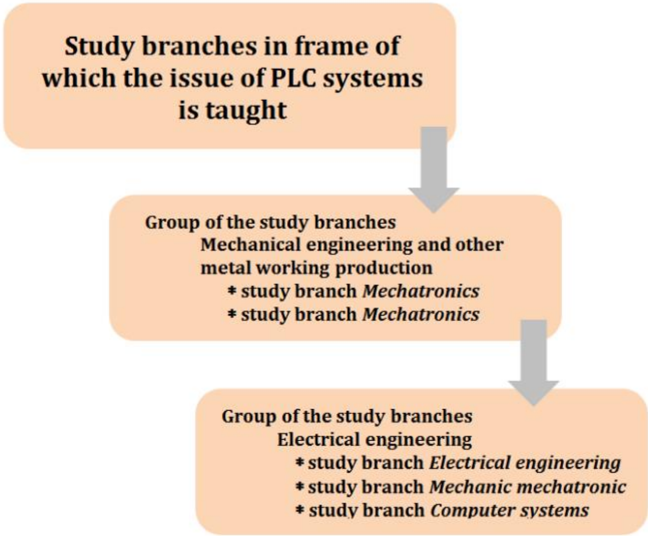

Figure 2: Findings resulted from the analysis of the State Educational Programmes focused on PLC systems teaching included in them.

2.2 Content Analysis of the PLC Systems Issue Included in the State and School Educational Programmes of the Relevant Secondary Vocational Schools

According to the State Educational Programme (ŠIOV, 2010), students (graduates) of the study branch *Mechatronics* are obliged to fulfil performance standards of the theoretical education, which are:

- to know how to explain the operating principles and applications of microcontrollers, robots, and PLC systems;
- to know how to write a simple program for controlling a logic circuit, microcontroller, robot, and PLC system;

and performance standards of the practical vocational training:

- to be able to program and diagnose operation of the PLC-controlled devices.

Within the scope of mechatronic systems control, the content standard requires students to acquire knowledge of the basics of algorithmicising and object-oriented programming, as well as microcontrollers, robots, and PLC systems and their programming. According to the State Educational Programme, students (graduates) of the study branch *Electrical engineering* are obliged to fulfil performance standards of the theoretical education, which are:

- to know how to apply microcontroller systems and PLCs for various methods of control and monitoring,
- additionally, in the amendment of no. 8 (2021), there is a requirement to know how to work with microcontrollers and microcomputers, to connect sensors to them, to

analyse and evaluate collected data, and to understand the basics principles of using PLC systems.

Within the scope of the performance standards for practical vocational training, there are no specifically defined performance standards with regard to PLC systems instruction. For the study branch Mechanic Mechatronic, no specific performance standards are defined which a graduate of this study branch should be able to fulfil. There is only a requirement to know how to characterise basic notions, construction, control systems, and the structure of industrial robots and manipulators, as well as their application in technical practice, the basics of their programming, and inter-operational and operational transport.

A similar situation exists in the case of the study branch Computer Systems. No specific performance standards for theoretical education are defined for graduates of this branch. Regarding the performance standards for practical vocational training, there is a requirement that a graduate of the study branch Computer Systems should be able to program PLC machines.

In Amendment No. 2, by which the State Educational Programme has been changed, sample curricula for professional subjects can be found. These propose to allocate one lesson to the topic of graphical tools for PLC programming within the subject Graphical Systems, taught in the Mechanic Mechatronic study branch. In the subject Basics of Industrial Informatics, taught within the Computer Systems study branch, it is recommended to address the use of LOGO! 230 RC, which is a compact PLC model produced by Siemens.

In the case of the subject Automation, taught within the Electrical Engineer Mechanic study branch, it is recommended that three lessons focus on PLC block diagrams, their internal structure, a comparison of modular and compact PLCs, and their areas of application. In Amendment No. 2, further subjects are recommended; for example, Measurement in Automation Technology has a recommended time allocation of five lessons aimed at remote measurement using PLCs.

Another recommended subject is Control Systems, with a suggested allocation of 12 lessons. The recommended topics include PLC systems, their classification, development, features and architecture, methods of programming, and examples of simple applications. For more complex PLC applications, a further 15 lessons are added. Finally, the subject Professional Training in Automation Technology is recommended within Amendment No. 2. This should address the unit on PLC systems over 140 lessons taught in the third year (covering everything from mounting to applications). In the fourth year, a further 98 lessons dealing with PLC systems in automation task management are recommended.

Amendment No. 4 extends the existing examples of the teaching curricula for the study branches Electrical Engineering – Automation Technology and Mechanic – Electrical Engineer. In the subject Electrical Measurements within the Electrical Engineering – Automation Technology branch, three lessons are recommended for the topic of remote measurement using PLCs. Furthermore, in the subject Control Systems, 12 lessons are recommended to address the subject of programmable logic controllers.

In the schedule of the subject matter for Programming of Automation Facilities, 49.5 teaching lessons are allocated in the second year for the acquisition of basic knowledge related to process control. In the third year, 60 teaching lessons are dedicated to the basic principles of programming programmable logic controllers, where it is specifically recommended to address the design of PLCs from various manufacturers, with a scope of approximately five lessons. In the third year, there is also the subject Vocational Training, with a time allocation of 147 lessons. These should focus on PLC programming, covering everything from workplace safety and PLC construction to various program applications (ŠIOV, 2010).

Based on the identified study branches within the scope of which PLC systems are taught (as defined by the State Educational Programmes), we contacted 20 secondary vocational schools throughout Slovakia. These institutions offer the study branches Computer Systems, Mechanic – Electrical Engineer, Electrical Engineering, or Electrical Engineering – Automation Technology. The purpose was to ascertain which model series and manufacturers they have integrated into their PLC instruction, and whether they would provide their school educational programmes regarding this specific subject matter.

Regarding the model series and their manufacturers, it was found that all the schools surveyed use the S7-1200 model from Siemens. However, the additional model series used differ from one school to another. Among those identified were various model series from manufacturers such as Elsaco, Eaton, Allen-Bradley, Mitsubishi, and Festo. An overview of the other types of PLC models used by the schools (alongside a list of the schools at which each model is utilised) is presented in Figure 3.

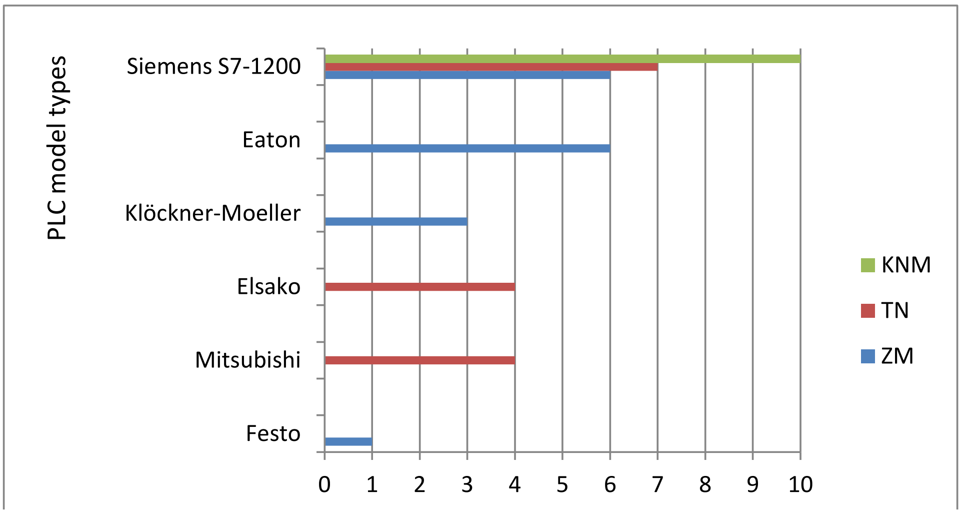

Figure 3: Findings resulted from the content analysis of PLC systems teaching within the selected sample of the secondary vocational schools.

Legend to Figure 3: KNM – Secondary Engineering School in Kysucké Nové Mesto
TN – Secondary Vocational School in Trenčín
ZM – Secondary Polytechnical School in Zlaté Moravce

A comparative analysis of the obtained school and State Educational Programmes revealed no significant differences in the methods used to teach PLC systems at the schools concerned. School curricula (School Educational Programmes) appear to correspond to the recommended state curricula (State Educational Programmes) and are fairly consistent in their content and objectives. Consequently, based on the information obtained, it can be concluded that the schools maintain a similar approach to teaching PLC systems and are relatively uniform in their teaching methodologies and the PLC models utilised (Kuna et al., 2020).

2.3 Analysis of the Needs and Requirements of Industrial Practice Regarding PLC Systems

Frequently, there is a fundamental difference between what students learn at school and what is required of them when they enter the workforce. Consequently, we conducted a survey of industrial enterprises located in the Levice region. Analysis of the survey results clearly indicated that the companies utilised a wide range of PLC models from various manufacturers, such as Siemens, Rockwell, Mitsubishi, and Beckhoff. This broad scope of PLC models is related to the preferences of technical equipment suppliers, who often favour specific types based on their expertise and experience. Additionally, the variety is influenced by the relocation of existing facilities, which frequently contain older PLC models.

Within the operations of the surveyed industrial enterprises, several positions require PLC knowledge. According to the level of expertise required, these positions can be categorised into three main groups:

- *Positions requiring only basic knowledge*: These are usually positions for maintenance and production technicians. It is necessary to ensure that these individuals have an overview of the daily functioning of the machinery. They must be able to perform basic non-electrical diagnostics of the devices, allowing them to identify simple faults and potential problems in the operation of the equipment. Furthermore, a basic knowledge of PLCs is important for setting reasonable and feasible requirements for the maintenance department, thereby ensuring the efficient upkeep and operation of the machinery.
- *Positions requiring diagnostic knowledge:* These are roles for maintenance staff with an electrotechnical focus, specialising in the diagnosis and repair of machinery. Electricians with many years of experience in the industrial sector usually occupy these positions. As shown by the survey, it is common practice for new workers to be sent for PLC training, as the knowledge they gained as pupils in secondary school may be insufficient. This applies not only to young graduates, but also to older workers and those who have transitioned to maintenance from other positions where they did not come into contact with PLC units.
- *Programming work:* These are employees in the positions of PLC programmer or electrical maintenance lead, whose work includes not only diagnostics but also

advanced programming activities. Their task is to solve complex problems associated with PLC systems and ensure their effective functionality. The programming activities of these workers do not always include programming an entire line from the ground up, but rather the modification or supplementation of existing program code as required. In the event of a need for deeper diagnosis or more complex code changes related to line reconstruction, external experts specialising in PLC systems programming are often utilised. In addition to their programming activities, these employees are also obliged to provide training for other workers responsible for PLC diagnostics. Their task is to transfer their knowledge and experience to other team members so that they possess the necessary skills to effectively solve problems related to PLC technology.

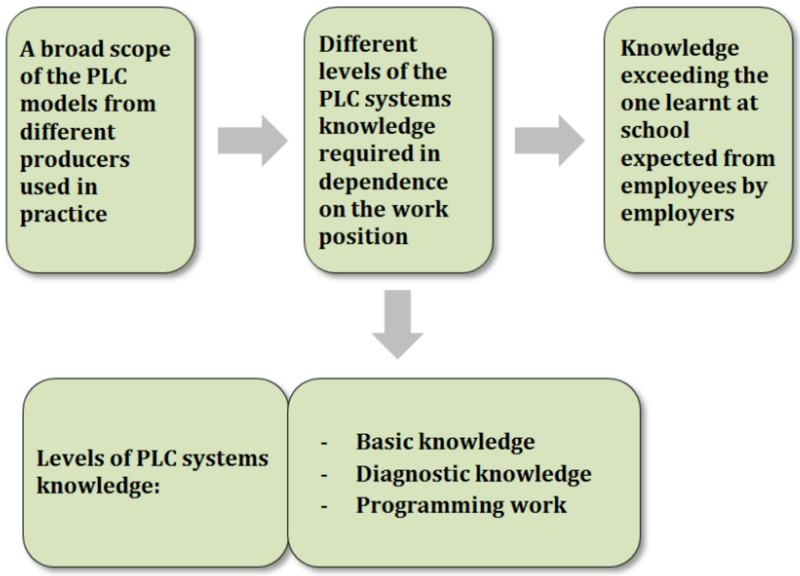

Figure 4: Findings resulted from the survey of the needs and requirements of the industrial practice regarding PLC systems.

3 Suggestions to Quality Assurance

Currently, many PLC systems manufacturers offer their own software tools for programming their systems. One such example is Siemens, which provides a wide range of software solutions for various PLC systems. To enhance PLC systems instruction at secondary vocational schools and ensure its quality, the following measures are proposed.

LOGO! Beginning with their simplest series, LOGO! is often referred to as a programmable relay; although this type is part of the sample educational programmes for the field of Computer Systems, our survey results indicate that it is rarely encountered in practice. This

type is configurable using LOGO! Soft software, which allows for the creation of programs for simple automation tasks.
S7 300/400: Here is the review of this section with the necessary changes for British Academic English, ensuring the tone is formal and technically accurate.

Revised Section
The LOGO! series is followed by the S7-300 and S7-400 ranges, which are programmable using Step 7 software. While this software is still taught and used in schools, it is encountered less frequently in practice, as modern PLC systems belong to newer model series that are not fully compatible with Step 7. Nevertheless, Step 7 remains an important tool for programming older PLC systems and is an essential element of educational programmes aimed at PLC programming.
TIA Portal: In addition to software tools such as Logo soft and Step7, a further fundamental element in modern PLC programming is Portal (Totally Integrated Automation) is Portal (Totally Integrated Automation). This integrated development environment allows programming, configuration and diagnosis of various PLC systems, including the latest series such as S7-1200/1500. The TIA Portal provides a comprehensive automation environment and is the preferred tool for many industrial applications. Through this platform, it is possible to create and test programs, monitor PLC system operations, and diagnose real-time faults. Given the increasing prevalence of the TIA Portal in industry, it is essential that students have access to this software and gain practical experience with it during their vocational education. Educational programmes should include TIA Portal instruction to ensure that graduates are prepared for modern industrial requirements and can effectively integrate into the working environment.
These software tools are necessary for the efficient programming and configuration of PLC systems; proficiency in their use is essential for students pursuing careers in automation and process control within industrial enterprises. It is vital that the educational programmes of secondary vocational schools include not only theoretical knowledge of PLC systems but also practical experience with these software tools. This ensures that students are prepared for the challenges of the industrial sector.

4 Conclusion

Updating the curriculum is necessary to ensure that students have access to the latest software tools and technologies used in industry. However, given the wide range of software solutions from various PLC manufacturers, it is difficult to create universal educational programmes or curricula that cover all possible tools and technologies.
It is important to note that School Educational Programmes should be developed with regard to the needs of the particular school and local industry. Consulting with experts in this field

may be useful when creating or updating these programmes to ensure that their content is relevant and aligned with current industrial requirements and trends.

While focusing on hard skills is undoubtedly a primary task, schools should not overlook the development of students' soft skills, as their importance in the labour market is continually growing. However, it is also important that employers accept this long-term strategic view and do not insist on requirements for School Educational Programmes based solely on their immediate needs.

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