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QUALITY MANAGEMENT APPROACH TO INDUSTRY–EDUCATION COLLABORATION IN ENGINEERING EDUCATION

Research paper

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Abstract: Industry–education collaboration plays an important role in improving the quality and practical relevance of engineering education, particularly in fields characterized by rapid technological development. This paper examines the integration of modern industrial measurement equipment into engineering education from a quality management perspective. The study is based on a case of cooperation between Subotica Tech and Rohde & Schwarz, in which modern measurement instruments were introduced into existing laboratory activities. Building on practical experience and comparative laboratory measurements, the collaboration is analysed in terms of stakeholder needs, educational process improvement, and the systematic integration of industrial technologies into teaching. A Plan–Do–Check–Act (PDCA) framework is used to structure the implementation and evaluation process and to identify opportunities for continual improvement. Particular attention is given to the contribution of modern equipment to measurement procedures, interpretation of results, documentation, and the alignment of practical education with current industrial practice. The analysis indicates that industry–education collaboration can contribute to educational quality not only by providing access to modern technology, but also by creating a structured feedback mechanism between industrial requirements and educational processes. The proposed approach demonstrates how such cooperation can be interpreted as a continual quality improvement process in engineering education.
Key words: quality management, industry–education collaboration, engineering education, PDCA, continual improvement

INTRODUCTION

Rapid technological development continuously changes the knowledge, skills, and practical competencies expected from engineering graduates. Higher education institutions therefore face the challenge of maintaining the relevance of their educational processes while industrial technologies, measurement systems, and professional practices evolve at an increasingly rapid pace (Sima et al., 2020; Thornhill-Miller et al., 2023). Cooperation between higher education and industry can contribute to reducing this gap by providing students and educators with access to current technologies, practical knowledge, and industrial experience (Perkmann et al., 2021; Compagnucci & Spigarelli, 2020).

In engineering education, this issue is particularly important because practical laboratory activities represent a direct connection between theoretical knowledge and its application. The quality of engineering education therefore depends not only on curriculum content but also on the availability of appropriate laboratory infrastructure, measurement equipment, and teaching methods. When educational institutions rely on equipment that no longer reflects contemporary industrial practice, students may require additional adaptation and training when entering the professional environment (Haleem et al., 2022; von Solms, 2018).

Industry–education collaboration can be interpreted from a quality management perspective as a mechanism for identifying stakeholder requirements and incorporating them into the educational process. Students, educational institutions, academic staff, and industrial partners represent stakeholders with different but interconnected expectations (Prdić et al., 2023). Industry requires graduates with relevant practical competencies, while educational institutions seek to provide learning environments that support the development of such competencies. Systematic cooperation between these stakeholders can therefore support the continual improvement of educational processes (Compagnucci & Spigarelli, 2020; International Organization for Standardization, 2015).

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A practical example of such cooperation was previously presented through the collaboration between Subotica Tech and Rohde & Schwarz, in which modern electronic measurement equipment was integrated into existing laboratory activities (Kuljić et al., 2017). The original study focused primarily on the technical and educational advantages of modern measurement instruments and compared their application with older analogue equipment. The results demonstrated advantages related to measurement procedures, interpretation of measured values, and documentation of laboratory results (Kuljić et al., 2017).
Building on this practical case, the present study introduces a different analytical perspective. Rather than focusing primarily on the technical performance of the measurement equipment, the collaboration is examined as a quality improvement process in engineering education. The objective is to analyse how industry–education cooperation can support the identification of stakeholder needs, the integration of industrial technologies into laboratory teaching, the evaluation of practical improvements, and the continual development of educational processes. For this purpose, the Plan–Do–Check–Act (PDCA) cycle is used as a framework for structuring and interpreting the collaboration (International Organization for Standardization, 2015).

QUALITY MANAGEMENT FRAMEWORK FOR INDUSTRY–EDUCATION COLLABORATION

Industry–education collaboration can be considered a quality improvement mechanism when cooperation is systematically linked to the needs of the stakeholders involved in the educational process. In engineering education, these stakeholders include students, academic staff, higher education institutions, and industrial partners. Although their expectations differ, they are closely connected. Students require relevant knowledge and practical competencies, academic staff need appropriate resources and technologies for effective teaching, educational institutions aim to maintain the relevance and quality of their programmes, while industry requires graduates who are prepared to work with contemporary technologies and professional practices (Prdić et al., 2023; Perkmann et al., 2021).
The integration of industrial technologies into education should therefore not be considered only as an equipment upgrade. From a quality management perspective, it represents an opportunity to align educational processes with stakeholder requirements and to establish feedback between industry and higher education. Industrial partners can provide access to technologies, professional experience, and information about current industrial requirements, while educational institutions can integrate these inputs into laboratory exercises and teaching activities (Compagnucci & Spigarelli, 2020; Perkmann et al., 2021). The results of this integration can subsequently be evaluated and used to identify further opportunities for improvement. Such systematic comparison and evaluation can also be interpreted in the context of benchmarking as a tool for identifying improvement opportunities (Prdić, 2017).
The collaboration between Subotica Tech and Rohde & Schwarz provides a practical basis for this approach. Modern measurement instruments were made available for active use in the educational process, enabling students to work with technologies representative of contemporary industrial practice. Their integration into an existing laboratory exercise also made it possible to compare established teaching practices and older analogue equipment with modern digital measurement technology (Kuljić et al., 2017).
From a quality management perspective, this process can be structured according to the Plan–Do–Check–Act cycle (International Organization for Standardization, 2015). In the Plan phase, stakeholder needs and opportunities for improving practical education are identified. The Do phase includes the integration and practical use of industrial equipment in laboratory teaching. The Check phase evaluates the effects of the introduced technology on measurement procedures, interpretation of results, documentation, and practical laboratory activities. Finally, the Act phase uses the identified advantages and limitations as feedback for further development of laboratory activities and future industry–education cooperation.

Table 1. *PDCA framework for industry–education collaboration*

PDCA phase	Industry–education activity	Quality management objective
Plan	Identification of educational and industrial requirements	Alignment of stakeholder needs and educational objectives
Do	Integration of modern industrial equipment into laboratory activities	Improvement of practical teaching conditions
Check	Evaluation and comparison of laboratory procedures and results	Identification of benefits, limitations, and improvement opportunities
Act	Adaptation of laboratory activities and future cooperation	Continual improvement of engineering education

CASE STUDY AND METHODOLOGY

The practical implementation was demonstrated through an existing laboratory exercise dealing with the time and frequency response of a passive second-order RLC circuit. The same measurement task was performed using analogue and modern digital measurement equipment, which enabled a direct comparison of measurement procedures and results. The exercise included measurements at several frequencies and the determination of voltage values, phase displacement, and amplitude characteristics. The recorded results provided a practical basis for comparing the two approaches (Kuljić et al., 2017).

In the present study, this previously documented case is re-examined from a quality management perspective. The methodology does not aim to repeat the technical comparison of the measurement instruments. Instead, the practical observations and results are used as the basis for analysing how the introduction of industrial technology can contribute to the improvement of an educational process.

The analysis is conducted in three stages. First, the main stakeholders and their relevant requirements are identified in the context of industry–education collaboration. Second, the implementation of the modern measurement equipment is mapped to the Plan–Do–Check–Act cycle in order to examine the cooperation as a structured improvement process. Third, the documented differences between the analogue and digital measurement approaches are interpreted in terms of their potential contribution to educational quality, including measurement procedures, interpretation of results, documentation, and alignment with contemporary industrial practice.

The methodology therefore combines a case-study approach with a quality management reinterpretation of previously documented practical experience. This makes it possible to examine the same industry–education cooperation from a different perspective while clearly distinguishing the present analysis from the original technical comparison.

STAKEHOLDER ANALYSIS AND QUALITY IMPROVEMENT

The effectiveness of industry–education collaboration depends on the extent to which the needs and expectations of the involved stakeholders are recognized and incorporated into the educational process. In the analysed case, four main stakeholder groups can be distinguished: students, academic staff, the higher education institution, and the industrial partner. Each group contributes to the cooperation and at the same time expects specific benefits from its implementation (Prdić et al., 2023).

For students, the main benefit is access to measurement technology that reflects contemporary industrial practice. The original case demonstrated that the use of digital measurement equipment reduced the need for subjective interpretation of displayed values and enabled several parameters, including amplitude, frequency, and phase difference, to be obtained directly from the instrument (Kuljić et al., 2017). From a quality management perspective, these characteristics can support a clearer measurement procedure and allow students to focus more directly on the interpretation of the measured phenomena rather than on overcoming the technical limitations of older equipment.

For academic staff, modern measurement equipment provides additional possibilities for organizing and documenting laboratory activities. In the analysed case, measurement results could be stored digitally, including the export of measured data in CSV format, while graphical representations could be transferred directly from the oscilloscope (Kuljić et al., 2017). Such functions can facilitate the preparation, execution, and documentation of laboratory exercises and provide a more systematic basis for reviewing experimental results.
From the perspective of the higher education institution, cooperation with an industrial partner provides a mechanism for updating practical teaching without separating educational development from technological developments in industry. In the documented cooperation, the industrial partner provided modern instruments for active use in education, while the institution incorporated them into existing laboratory activities. This interaction illustrates a two-way relationship in which industrial resources and experience can contribute to educational development, while the educational environment provides a context for transferring contemporary technologies to future engineering professionals (Compagnucci & Spigarelli, 2020; Perkmann et al., 2021).
The industrial partner also represents an important stakeholder. Cooperation with educational institutions creates an opportunity to familiarize future engineers with technologies and working practices relevant to the industrial environment (Perkmann et al., 2021). However, the value of such cooperation should not be understood only in terms of equipment provision. Its broader quality-related contribution lies in establishing a connection between industrial expectations and the practical competencies developed through engineering education.
The stakeholder relationships identified in the case can be summarized as shown in Table 2.

Table 2. *Stakeholder framework for industry–education collaboration*

Stakeholder	Main need or expectation	Contribution of collaboration	Quality-related outcome
Students	Relevant practical competencies	Access to contemporary measurement technology	Improved practical learning conditions
Academic staff	Effective laboratory tools and procedures	Integration of modern measurement and documentation functions	More systematic laboratory activities
Higher education institution	Relevant and up-to-date practical education	Cooperation with industrial partners and access to technology	Better alignment with industrial practice
Industrial partner	Graduates familiar with contemporary technologies	Technology and professional input	Stronger connection with future professionals

The stakeholder analysis indicates that the quality contribution of industry–education cooperation is not limited to the technological characteristics of the equipment itself. Its value emerges from the interaction between stakeholder requirements, educational activities, and feedback from practical implementation. When these elements are systematically evaluated, the cooperation can become part of a continual improvement process rather than remain an isolated technology transfer activity (Prdić et al., 2023; International Organization for Standardization, 2015).

PDCA APPLICATION AND EVALUATION

The PDCA cycle provides a structured approach for interpreting industry–education collaboration as a continual improvement process (International Organization for Standardization, 2015). In the analysed case, the four phases can be associated with the identification of educational needs, the implementation of modern industrial equipment, the evaluation of practical experience, and the use of the obtained findings for further improvement of laboratory education.

In the Plan phase, the improvement opportunity can be identified as the need to reduce the technological gap between existing laboratory conditions and contemporary industrial measurement practice. The cooperation between Subotica Tech and Rohde & Schwarz created an opportunity to introduce modern measurement equipment into the educational environment while maintaining the existing laboratory objectives (Kuljić et al., 2017). The purpose was therefore not to replace the educational content, but to improve the technological conditions under which practical competencies were developed.
The Do phase consisted of the actual integration of the industrial measurement equipment into laboratory activities. The modern instruments were used within an existing exercise dealing with the time and frequency response of a passive second-order RLC circuit. Measurements were performed using both analogue and digital equipment, providing practical experience with the two measurement approaches and allowing their characteristics to be compared under the same laboratory task (Kuljić et al., 2017).
The Check phase is represented by the comparison of the measurement procedures, obtained results, and possibilities for documenting the experiment. The previously reported results showed that the two approaches produced comparable measurement data, while the digital equipment provided additional advantages in the measurement process. In particular, the digital oscilloscope enabled direct determination of several measured parameters and supported the storage and export of measurement results (Kuljić et al., 2017). In quality management terms, these observations provide feedback about how technological modernization can influence measurement procedures and documentation of laboratory activities.
The Act phase involves translating the identified benefits and limitations into further development of the educational process. In this context, successful practices can be incorporated into future laboratory activities, while experience gained during implementation can support decisions concerning equipment modernization, teaching procedures, and further cooperation with industrial partners. This phase is particularly important because it transforms a single collaborative activity into a potential mechanism for continual improvement (International Organization for Standardization, 2015).
The application of the PDCA cycle also demonstrates that industry–education collaboration should not end with the introduction of new technology. Equipment provision represents only one stage of the improvement process. Its educational value depends on how effectively the technology is integrated into teaching, how its effects are evaluated, and how the resulting experience is used in subsequent educational development. The cyclical nature of PDCA therefore provides a suitable framework for maintaining the connection between stakeholder requirements, industrial developments, and the continual improvement of engineering education (International Organization for Standardization, 2015).

RESULTS AND DISCUSSION

The quality management analysis of the case indicates that the main contribution of industry–education collaboration extends beyond the provision of modern laboratory equipment. The cooperation created a connection between industrial technology, practical teaching activities, and the requirements of the stakeholders involved in engineering education. When these elements are considered within a structured improvement framework, technology transfer can become part of a broader educational quality improvement process.
The comparison of analogue and digital measurement approaches provides practical evidence of how technological modernization can influence laboratory activities. The previously documented measurements showed comparable results obtained using the two approaches, while important differences were observed in the measurement procedure and documentation possibilities. With analogue equipment, some parameters required additional procedures and subjective interpretation, whereas the digital oscilloscope enabled direct measurement of several parameters and supported digital storage and export of results (Kuljić et al., 2017).

From an educational quality perspective, these differences can be interpreted at several levels. First, modern equipment can reduce the number of auxiliary operations required during laboratory measurements. Second, direct access to measured parameters and digital data can support more systematic documentation and subsequent analysis. Third, the use of equipment representative of contemporary industrial practice can improve the alignment between laboratory activities and the technological environment that engineering graduates may encounter professionally (Sima et al., 2020; Zhong et al., 2017). These benefits do not imply that traditional measurement methods have no educational value; rather, the comparison demonstrates how different technologies and technology-supported learning approaches can serve different educational objectives (Vlachopoulos & Makri, 2017).

The stakeholder analysis further shows that the benefits of collaboration are interconnected. Students gain practical experience with contemporary technology, academic staff obtain additional possibilities for organizing laboratory activities, the educational institution can strengthen the practical relevance of its programmes, and the industrial partner provides technology and professional input relevant to the development of competencies associated with current industrial practice (Perkmann et al., 2021; Prdić et al., 2023). Consequently, the value of collaboration should be evaluated as a system of stakeholder relationships rather than exclusively through the technical characteristics of the provided equipment.

The PDCA interpretation adds a continual improvement dimension to these findings. The introduction of modern equipment represents the implementation stage, while comparison of procedures and practical experience provides feedback for evaluation. The resulting information can then support decisions concerning future laboratory activities, equipment modernization, and further cooperation. In this way, the case demonstrates how an individual industry–education initiative can be transformed into a repeatable quality improvement process when implementation is followed by systematic evaluation and feedback (International Organization for Standardization, 2015).

At the same time, the analysis has limitations. The present study is based on a quality management reinterpretation of a previously documented industry–education collaboration and does not include new quantitative measurements of student learning outcomes, stakeholder satisfaction, or long-term educational performance. Therefore, the identified quality-related benefits should be interpreted primarily as case-based findings. Future research could complement the proposed framework with student and teacher feedback, stakeholder satisfaction indicators, learning outcome measures, and longitudinal evaluation of industry–education cooperation.

CONCLUSION

Industry–education collaboration can contribute to the continual improvement of engineering education when cooperation is systematically connected to stakeholder requirements, educational processes, and evaluation activities. The case analysed in this study demonstrates that the integration of modern industrial measurement equipment can be considered not only as a technological upgrade, but also as an element of a broader quality management process.

The quality management reinterpretation of the cooperation between Subotica Tech and Rohde & Schwarz identified several interconnected dimensions relevant to educational improvement. Modern measurement technology supported more direct measurement procedures, systematic documentation, and closer alignment of laboratory activities with contemporary industrial practice. At the same time, the stakeholder analysis demonstrated that the benefits of cooperation extend to students, academic staff, the higher education institution, and the industrial partner.

The proposed PDCA-based framework provides a structured approach for linking these stakeholder requirements with implementation, evaluation, feedback, and subsequent improvement. Its main value is that it shifts the focus from a one-time introduction of industrial technology towards a cyclical process in which practical experience can be used to support further development of laboratory education and future cooperation.

The study is based on a quality management reinterpretation of a previously documented industry–education collaboration and does not provide new quantitative measurements of student learning outcomes, stakeholder satisfaction, or long-term educational performance. Future research should therefore include systematic stakeholder feedback and quantitative educational indicators to evaluate the long-term effects of industry–education cooperation and to further validate the proposed quality management framework.

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