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Teaching Business Process Automation in a Learning Factory

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Abstract

Business Process Automation (BPA) requires diverse technical, methodological, social, and personal competences. Project-Based and Problem-Based Learning can support acquiring these skills by having student teams develop automation solutions in projects. However, challenges like integrating automation into enterprise landscapes are often missing due to simplified project settings at university. This Scholarship of Teaching and Learning project explores using learning factories to create more complex, realistic settings, enhancing students' competencies. A learning factory was integrated into existing teaching, and preliminary evaluations with interviews and pilot tests highlight benefits and limitations for educators.

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1 Introduction

1.1 Background

The automation of business processes is in practice a socio-technical challenge and requires a variety of competences. These competences can be divided into technical, methodological, social and personal competences (Nerdinger et al., 2008; Schaper, 2012). Technical and methodological competences required for Business Process Automation (BPA) may include aspects such as the creation of process models in a modelling notation like Business Process Model and Notation (BPMN), the implementation of features in a Business Process Management Systems (BPMS) or the competence to plan and run projects in an enterprise context. In addition, social and personal competences play an important role. Required social competences may include the ability to communicate and collaborate project results to diverse stakeholders with technical or business backgrounds. Personal competences are needed to cope with the high complexity of the project in real life. Ideally, all these types of competences should be covered in the learning objectives of the respective courses.

Known approaches to teach such a range of competences are Project-Based Learning and Problem-Based Learning. In Problem-Based Learning, students are confronted with real-life or near-real-life challenges that they have to solve using specific learning theories or teaching content (Barrows, 1996). This teaching method promotes active learning and the development of practical problem-solving skills. An application of Problem-Based Learning in the Business Process Management (BPM) discipline is described by dos Santos et al. (2023). As described by Chow (2021) Problem-Based Learning can be applied in conjunction with the use of BPM software. This allows students to simulate, test and adapt their solutions and gives them immediate feedback on the effectiveness of their approach for a BPM problem (Chow, 2021). Problem-Based Learning is often implemented in project context and hereby applying the Project-Based Learning approach (dos Santos et al., 2023).

Project-Based Learning enables students to solve specific tasks by going through different project phases. In addition to technical competences, they shall learn the fundamental relationships and interactions between different aspects of a project (Markowitsch et al., 2004). Projects can be based on real-life or fictious scenarios. A practical implementation of Project-Based Learning in BPM with a real-life setting can be observed, for example, in the BPM course at Bentley University. In this course, students work in teams of five to six people on process improvement projects in real organizations, which enables them to gain insights into company processes and identify the causes of existing problems in the business processes (Bandara et al., 2010).

While a real-life setting for Problem-Based and Project-Based Learning is considered as the ideal solution by the authors, it is challenging to implement at university in most circumstances, e.g. with larger bachelor's classes or in projects coping with the implementation of process automation solutions, which would require access to enterprise IT systems.

1.2 Initial situation

The bachelor's degree program in business information systems at TH Köln - University of Applied Sciences requires students to complete two courses in the subject of BPM. The first course introduces the basics of BPM through lectures and exercises using a flipped classroom approach. The content being taught includes concepts, methods and tools for process identification, discovery, analysis, redesign, process automation, and process monitoring, covering all aspects of the BPM cycle proposed by Dumas et al. (Dumas et al., 2018).

In the second course, which uses a Project-Based and Problem-Based Learning format, these topics are explored further with a focus on particular BPM and BPA methods and technologies. For example, the project team is tasked with developing an automation solution based on a BPMS using a greenfield approach. This course, with an average of 100 students, has the dual objective of enhancing the students' technical and methodological skills as well as developing their social and personal competences by working in teams and presenting and discussing the results to fictitious customers.

1.3 Problem statement

The observations in several course cycles at the TH Köln, along with a series of structured interviews with participants conducted in a bachelor's thesis (Gonzalez, 2023) for evaluation, indicates that the majority of students have achieved a satisfactory understanding of the technical aspects of BPM and BPA and would be able to implement simple, standalone process automation solutions, such as a request-to-approval process.

Nevertheless, statements and observations indicate that the students lack a comprehensive understanding of the nature of more complex process applications and their integration within an enterprise IT landscape. To illustrate this point, consider the following classroom observation: On the day of the final presentation of the project results, one student team was surprised by the results of another team, which demonstrated that the BPMS can be initiated from a web application simulation of a company portal. This is a frequently required feature in real-life automation solutions. Although this topic was covered in lectures, aspects related to it were not addressed in the students' project assignment due to the limitations of complexity reduction and the lack of a realistic IT environment at the university. This limitation appears to result in students failing to gain a comprehensive understanding of the range of process automation solutions in practice.

Other observations indicate that the Project-Based and Problem-Based Learning approach enforces students to discuss requirements among each other, agree on common approaches and collaborate on solutions to a certain degree. Still, the utilization of rather simplified project assignments in this university context seems to impede the transmission of non-technical competencies, by allowing student groups to work largely independent. Therefore, it is assumed that the transfer of social and personal skills may be further enhanced by more complex and realistic problem task and project setting.

1.4 Objectives

Whilst the reduced complexity of project tasks is unavoidable to some extent, the aim of this Scholarship of Teaching and Learning (SoTL) project (Coleman et al., 2023) is to explore whether and to what extent more complex and realistic project settings could be used in the teaching of BPA at university level. This is done by creating an environment for business process automation projects, consisting of a business scenario as well as software and hardware components. This environment is used in the existing Project-Based and Problem-Based Learning approach at the TH Köln - University of Applied Sciences.

The project environment is inspired by the concept of learning factories, which have been used in engineering education for more than 25 years. Learning factories are an innovative educational approach that enables learners to translate theoretical knowledge into practical experience, e.g. in the field of lean management or production planning. Such factories – like the LEAD at IIM (IALF, n.d.), TU Graz in Austria (TU Graz, n.d.) - serve as a bridge between higher education and industry by creating realistic learning environments that combine real-world modelling with a didactic approach (Abele et al., 2024).

Accordingly, in addition to developing critical skills such as problem solving, teamwork and adaptive thinking, learners should gain a deeper level of understanding through hands-on learning experiences (Abele et al., 2024). Abele et al. describe 46 learning factories worldwide, that are designed for different application scenarios (Abele et al., 2024). This extensive list of implementations confirms the effectiveness of this pedagogical approach, which is widely accepted in the academic community.

The usually large physical structure and scale of most learning factories were not our expectations or requirements for carrying out a BPA project. Instead, for the purpose of this work, we used a small-scale learning factory setup, the Business Process Automation Lab, with a low complexity and a higher focus on software systems and components. Based on this environment, we conducted a Scholarship of Teaching and Learning project, guided by the research question: "To what extent can the use of a learning factory with software and hardware components improve project-oriented and problem-oriented teaching in the field of business process automation?". To achieve this, the teaching concept at the TH Köln was extended (see chapter 2). A preliminary evaluation was carried out, which is presented in chapter 3. Finally, results and conclusions are discussed in chapter 4.

2 Teaching concept

2.1 Model factory for Business Process Automation

This work utilized an existing model factory at TH Köln (Fig 1.). The Business Process Automation Lab serves as a model factory to support research and transfer in the field of business process automation and data-driven process analysis. The aim of the BPA Lab is to present state of the art methods and tools, but also to develop, implement and evaluate research-oriented concepts.

The building blocks of the BPA Lab are a set of models representing a business scenario, BPA systems and hardware components. This architecture is inspired by the modelling factory at University of Trier (Malburg et al., 2020) used for research in the area of BPM and IOT. A configuration based on Fischertechnik (FT) components has already been employed in educational context other than business process automation (Zarte et al., 2019; University Hohenheim, n.d.).

The models in the factory represent the business scenario of a customer-specific production of bicycles covering customer order processing, production, and shipping. The process models, the decision models as well as the data models represent a 'digital twin' of this business scenario in a virtual company.

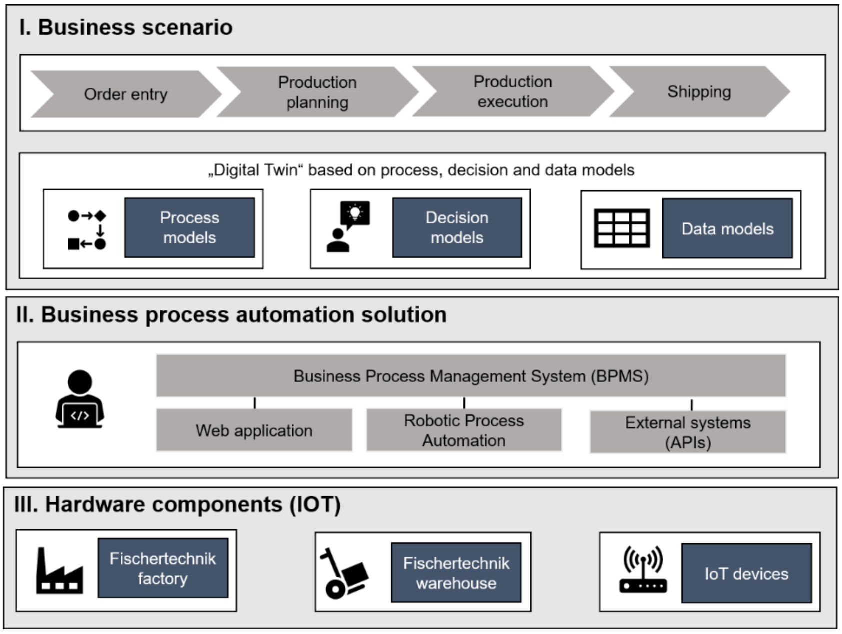

Fig. 1. Conceptual architecture of BPA Lab at TH Köln

With respect to BPA, a BPMS is the central component. It orchestrates software and hardware components based on the process model. Other BPA systems, such as a single page application for customer order entering, a Robotic Process Automation platform, as well as external services, are connected.

The Fischertechnik I4.0 model factory and a Fischertechnik warehouse robot (Fig. 2) are used to simulate production and logistics steps in the business scenario. These lightweight hardware components have TXT controllers running Python programs. In addition, IoT gateways and sensors/actuators have been developed in order to realize IoT data acquisition in the context of the simulated business processes.

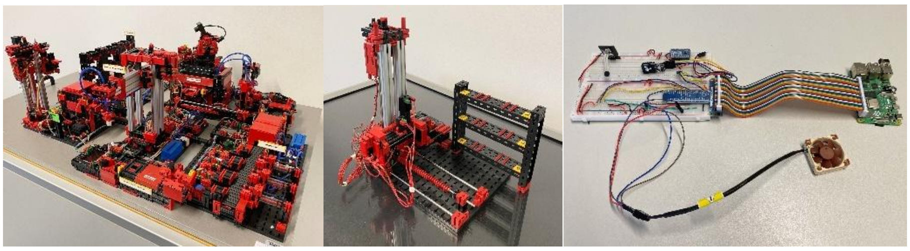

Fig. 2. BPA Lab hardware parts: Fischertechnik factory, Fischertechnik warehouse and prototype of an IoT device

2.2 Teaching concept

This work proposes a pedagogical approach to teaching BPA, utilizing the BPA Lab as a fictitious project environment. This concept addresses the identified need for more realistic, complex project environments. It aims to provide students with the technical and methodological competencies required to embed process automation solutions in an enterprise environment and for identifying and designing application scenarios of process automation solutions. Furthermore, the utilization of this environment is expected to reinforce the development of social and personal competencies.

The teaching concept builds upon the existing Project-Based and Problem-Based Learning format in the field of BPM and BPA at TH Köln: In this format students are required to work on project tasks, which are designed in a way that correlates to projects in enterprises. The objective of project task is to design and implement a process automation solution based on a domain-agnostic process-aware information system, such as BPMS or RPA. In contrast to previous course cycles, the selected business scenarios are based on the BPA Lab, along with the existing software and hardware components.

An illustrative example of a project task is the design and implementation of a shipment process for special goods at an fictious enterprise. This scenario necessitates the integration of a software component of the BPA Lab dealing with shipment planning, which is utilizing an external API for route planning. In addition, the project task requires to integrate a software-hardware module, the Fischertechnik warehouse robot, to implement the integration of the process automation solution with a warehouse management system.

In terms of project organization, existing principles are applied: During the semester, the teams present their progress in milestone meetings. In addition to the presentation and discussion of interim results, these meetings also serve as a direct exchange with a fictitious client, who asks critical questions and provides constructive feedback. The project results consist of the design on a process automation solution, a prototype implementation and an assessment of the solution design. In addition to presenting the results in a final presentation, these results need to be explained in expert talks.

Although the general concept is in force since several cycles and is based on known principles, the impact of using the BPA Lab as a project environment must be carefully evaluated. The following chapter depicts the results of a two-step premilitary evaluation performed to assess opportunities and limitations of this approach.

3 Preliminary evaluation

The preliminary evaluation of the BPA Lab as a teaching concept involved two phases. In the first phase, interviews were conducted with graduates of previous course cycles. The aim was to gain insight into the extent to which former course participants understand BPM and BPA, and what they expect from the use of a learning factory. In particular, they were asked to state their expectation regarding opportunities, challenges, requirements and preconditions of integrating the BPA Lab into project tasks. The second phase involved the practical testing of the teaching concept. This testing was done as part of a project in the Digital Sciences master's program at the TH Köln. At the end of these two phases, the results were analyzed and conclusions were drawn in order to derive concrete recommendations for the future design of the teaching concept and for the benefit of other BPM educators.

3.1 Interviews with bachelor's students

Interviews were organized with two groups of bachelor's students from two course cycles. They were confronted with the proposal of the teaching concept and asked to imagine the integration of the learning factory in their project based on their experiences in the previous course structure.

In general, the idea of integrating a learning factory into the teaching concept was positively evaluated. Students emphasized that the learning factory could be particularly helpful for students who have difficulties in understanding theoretical concepts. They highlighted that the learning factory could deepen the understanding of BPA by making the module less abstract and more tangible. As a result, students rated the potential practical application of the learning factory as very positive and a valuable addition to their theoretical course content, using terms such as "very important", "inspiring", "exciting" and "very interesting". Working directly with technology and experiencing the interplay of hardware and software components was seen as helpful for a deep understanding. According to previous participants, the learning factory could promote transfer thinking and increase motivation and interest.

When asked about potential challenges and requirements for integrating the learning factory into the course, students identified several important aspects: the need for comprehensible instructions and materials, the risk of technical difficulties with hardware and infrastructure, the need for sufficient support from teaching staff, the complexity of the technology used, and challenges in assessing learning outcomes. They also emphasized the importance of thoughtful integration of the learning factory into existing module and project assignments to avoid overload. Suggested solutions included ongoing training of students by teaching staff, ensuring sufficient resources for effective use of the lab, and considering the risk of unforeseen technical difficulties in the course assessment methods.

While these results were interesting in terms of understanding the students' point of view, finetuning the teaching concept and preparing necessary learning materials, the speculative nature of the survey makes it impossible to draw any definitive conclusions.

3.2 Evaluation in a pilot project

Therefore, in a second phase, a project simulation was carried out with eight students of the digital sciences master's program at the TH Köln. At the beginning, the experience level of the participants was analyzed and compared with that of the bachelor students. It turned out that the master's students on average had comparable knowledge in aspects such as process modelling and general BPM concepts, but superior technical skills and practical experience in software development.

The students were asked to evaluate the teaching concept from the perspective of the bachelor's students. For this purpose, they were given a project task and were asked to solve it and in doing so to assess whether the concept could be implemented by students at bachelor's level. As a result, the students prepared reports answering specific key questions about the learning concept to ensure that the learning process was reflected and analyzed.

The findings in these reports were aggregated and interpreted to provide insights into the learning experience and the effectiveness of the teaching approach: Overall, students perceived the opportunities associated with the concepts as positive. In particular, the value of the practical experience of working with real BPM tools and the learning factory as a project environment was highlighted. This included learning new technologies such as BPMS through a 'learning by doing' approach and improving teamwork to solve individual challenges.

However, the students identified a number of challenges associated with using the learning factory. These included the complexity of installing and configuring the required infrastructure of BPA Lab components, as well as individual problems with hardware, software and network components, and difficulties in dealing with certain concepts of the BPMS. The students formulated requirements for the documentation. These should include not only specific aspects of the BPA Lab, but also basic information about various technologies and concepts used in the learning factory. A need for more guidance and support during the project was identified, particularly in relation to troubleshooting and carrying out practical implementation steps.

Based on these results, conclusions for the particular course at the TH Köln and for BPM educators in general are discussed in the following chapter.

4 Summary and discussion

In this work, a teaching approach for business process automation was presented, which extended an existing Project-Based and Problem-Based Learning format at the TH Cologne with the Business Process Automation Lab as a small-scale learning factory. The aim of this innovation was to provide students with a more realistic project environment. Based on experiences from the engineering field, the use of a learning factory was intended on the one hand to help link theoretical concepts with practical experience and on the other hand to enable students to deal with complex BPA scenarios and to promote the learning of technical, but also social and personal competences.

4.1 Chances, challenges and requirements

According to Problem-Based Learning the application of a more complex problem setting promises to enable students to effectively deepen their practical and apply their theoretical knowledge. Faced with realistic problems, they have to come up with creative and innovative solutions. The pre-evaluation provided valuable insights into the chances, challenges and requirements for the particular concept of using a learning factory in BPA course.

Interviews with bachelor’s students showed that the idea of making the project task more tangible and realistic at university is welcomed. After a project simulation, master’s students confirmed a largely positive learning experience in carrying out a concrete and tangible project task, the benefits of the practical 'learning by doing' approach and the benefits of working in project teams. The existing challenges of integrating and managing different technologies also enhance the students' understanding of a realistic application scenario for BPA.

However, a number of challenges were identified. The evaluation showed that the complexity of the envisaged project task is too high for bachelor’s students in regular courses. The use of the entire BPA lab increased the required competences of the participants, as skills from different areas of expertise, such as software development, network and hardware setup, suddenly have to be applied. In addition, the conditions for teaching such a module are demanding in terms of documentation as well as guidance and support. It was noted that little or no basic knowledge can be assumed and that individual technical issues, e.g. related to operating systems, can arise which can easily exceed the capacity of the supporting staff in bachelor courses with larger numbers of participants. It became clear that as the complexity and realism of the teaching approaches increased, so did the demands on the appropriate design of projects and the need for considerable resources. This includes not only the provision of technical equipment such as hardware and software, but also the provision of appropriate and sufficient support from competent teaching staff.

4.2 Conclusions and future work

Based on these findings, the teaching concept is not considered directly applicable to the bachelor’s course at the TH Köln with an average of 100 students. The current bachelor’s course could use the business scenario of customer-specific individual production of bicycles implemented in the BPA Lab as a project background, which can be demonstrated to the students at the beginning of the project and thus provide a more realistic and tangible project setting. However, the technical project task itself should only be extended carefully. In particular, the integration of hardware components proved to require a higher level of prior knowledge and support. Instead, the integration of pure software components of the BPA lab seems to be more realistic for the existing course.

The future potential of the BPA Lab as a learning factory is seen in the creation of new elective course formats, which by design cover a wider range of learning objectives, from BPM and BPA through to the Internet of Things and Cyber-Physical Systems, and allow for a higher student workload.

For BPM educators, the use of a more complex project environment at university in general, and a learning factory in particular, is an interesting consideration. Although the impact of using a learning factory in BPA projects on the learning of technical and, in particular, social and personal skills should be further explored, this work provides insights into the opportunities, challenges and requirements of such an endeavor.

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