A Case-Study to Teach Process-Aware Information Systems[1]

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The digitalization of products, processes, and services - where IoT-technologies facilitate the communication of real-world elements with a virtual instance - pose a challenge in teaching and learning. Modelling of these systems – the real world, its digital twin and their interaction – is hardly done in a theoretical way. Rather gaining and exchanging experiences throughout the learning process should be a significant learning output for the students.

Concrete challenges for teaching how to develop digital twins lie in the following aspects

- Static and dynamic behaviour must be understood and modelled, i.e. the components of the system, their interactions and the interfaces to the outside.
- A wide variety of application domains from end-to-end order business processes to processes on the shop-floor must be considered.
- A number of formalisms is used for the different purposes like scheduling or control.
- Different academic disciplines are involved from information systems to automation.

In order to convey such a comprehensive learning experience, the authors apply problem-based and research-oriented learning in form of a case-study. Students learn how to recognize complex tasks in teams, structure them, weigh up solutions against each other, implement their chosen one, evaluate the implementation and present the results. The case study is applied to 3rd grade bachelor students and 1st grade master students. The students' central task reads as follows: *Develop a holistic, integrated model of a company according to the automation pyramid, link it to reality and control reality via the model*!

The concrete elaboration of this tasks differs on the students' previous knowledge. Bachelors follow a problem-based approach, masters a research-oriented one.

Case setting is a fabrication plant given as a fischertechnik model upgraded with a Raspberry Pi. Sensors and actuators are used to control the operation of work pieces in accordance to given orders. Though the production cell is kept as simple as possible, product variants are viable as to simulate an IoT-setting. Further variations occur from secondary conditions like order priority or limited time budget, all of which need to be considered.

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The problem-based approach begins with the dissemination of theoretical basics, after which the task gets announced. The students now need to consider which of the principles given contribute to a solution and how to apply these. Afterwards, their theoretical solution gets implemented while being guided by the lecturers. Presenting the chosen solution is part of the teaching experience where students both give and receive feedback in plenary. At the end of term, the students reflect their learning process and search for ways to improve it.

The higher degree of freedom research-oriented learning entails requires a more open approach. Students get an overview of the case-study and are tasked themselves with understanding the challenges of modelling holistically. Afterwards, they need to formulate properties modelling languages should possess to be usable in the given context and examine known languages for applicability. As the students don't have expertise in production or automation technology, they have to acquire the relevant knowledge. Contrary to the bachelor students, the master students evaluate possible languages rather than learning one. Now they search for criteria to choose their course of action and implement their solution. Lastly, presentations including the reasoning for the chosen solution are held, feedback is given and taken in plenary and the learning process is reflected and assessed.

While not being able to formally evaluate the success of the presented teaching approach due to varying cohort sizes and a continuing development of the used tool which influences the possibilities to elaborate the task, a series of observations can be made:

- As the students need to present interim results in the course of the term and receive feedback on them, the presentations on term's end are of high quality.
- Even in early semesters, students experience the university as a place of research and teamwork. Thus, they become aware of the difference to school-based learning.
- Due to the received feedback, students develop scrutiny and a more self-aware attitude.

The courses make use of a new web-based tool for higher Petri-nets which reduces the number of needed process modelling languages to one. The choice is due to the following:

- All of the mentioned diverse application domains can be modelled using Petri nets.
- Petri nets are able to represent every level of abstraction.
- The inherent semantics allows for simulatable process models.

The web app is novel as it implements aspects not yet found in other software. It can be used distributed, even on mobile devices. Time data types are included and usage of higher Petri nets enables modelling of complex systems because users may define own data types. The tool supports organizational and data modelling as well as process maps. All of these models can be connected and integrated – even with the real twin – making it possible to impart different aspects of modelling and the competencies needed to create and evaluate the results, making it possible to both teach and utilize process-aware information systems.