Practical Education in Automation for Industrie 4.0

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ABSTRACT

Siemens as global technology leader in automation is supporting colleges of technology, vocational training colleges and universities to adapt the practical education in automation to the digital age through the “Siemens Automation Cooperates with Education (SCE)” program. For this, SCE defined a new Industrie 4.0 structure for education covering the basics of automation technologies (e.g. PLC and programming languages), automation and communication technologies and CAx and cloud technologies. In this paper, we discuss the structure and share best practices of cooperation with selected educational institutions in Germany.

KEYWORDS

Active Learning, Collaboration between Academia and Industry, Engineering Workspaces, Standards: 6, 7, 8

INTRODUCTION

Digitalization in the framework of Industrie 4.0 is a strategic initiative driven at Siemens from the Headquarters. It adds a third growth theme besides “electrification” and “automation” and is aligned with market demands like flexibility (mass customization), faster time to market and efficiency in production etc. The implementation is described in detail in here (Collis et al., 2017).

While “digitalization” can have many different meanings, at Siemens, it does not mean 100% paperless operations nor only utilization of PCs, but every information of corporate activities is electronically stored and it’s mutual relations and dependencies is consistently maintained, as well as the correspondence of digital data to the reality is synchronized with only some negligible time delay.

This is called “Digital Enterprise” and each software tool such as Computer Aided Design/Manufacturing/Engineering (CAD/CAM/CAE) and Manufacturing Execution System (MES) shares common consistent data, instead of passing translated or converted data, which creates potential errors, another data with many dependencies and prevents bi-directional communication.

Specifically, regarding the in the Digital Factory and Process Industries and Drives business, since about 2008, a number of strategic acquisitions have been executed to complement and expand the Siemens digitalization portfolio (Shih, 2016), as well as active unification has been being conducted.

- Product Lifecycle Management (PLM) Software
  Software tools, which enable the process from an idea to a product. CAD/CAM/CAE and MES are well known, but the crucial part is to keep consistency of revised or updated data throughout the whole life of a product.

- Totally Integrated Automation (TIA) portal
  Unified engineering tool for configuring, commissioning, programming and debugging of controllers, sensors, drives and displays of machines or production lines. Widgets on screen can be handled the same way as discrete push buttons and indicator lights, most of the network setting can be done with default parameters automatically.

- MindSphere
  Open and secure cloud-based industrial data analytics platform e.g. for the realization of digital services and Industrial Internet of Things. Includes APIs for app development and covering many different industrial domains.

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Figure 1. Digitalization at Siemens

On the other hand, the educational landscape in Germany is with universities, technical colleges and vocational schools quite diverse having each of them very specific needs to teach future digital skills. For example, there is the so called dual education scheme, where students e.g. in areas of informatics and mechatronics are receiving practical education in companies and in vocational schools at the same time. All these different education systems face challenges like accelerated digitalization trends and need to adapt their teaching methods and teaching tools quickly.

In this paper, we focus on automation technology education in Germany and the role of Siemens. Siemens is a global leader in automation technologies and products and services like programmable logic controllers (PLCs) for discrete and process industry. However, automation technology is evolving rapidly due to digitalization making it very difficult to define and implement educational requirements fast enough.

THE “SIEMENS AUTOMATION COOPERATES WITH EDUCATION” (SCE) PROGRAM

Siemens established a program over 20 years ago to support teachers in Germany. Since 2003, the program is called Siemens Automation Cooperates with Education (SCE) and the focus is to support educators in the field of industrial automation worldwide that their students are educated practically on newest automation technologies. Well trained students are well sought after from the industry including Siemens and Siemens partners globally.

Therefore for example teaching documentations and industrial products offered at a reasonable price and dedicated trainings for educators are essential.

Nowadays, SCE is established in many countries worldwide, although the level of implementation differs among them.

SCE Digitalization Concept

The SCE Digitalization concept is shown in Figure 2. It can be divided into three levels.

- **Level 1:**
  Consists of fundamentals for automation technologies. Like Boolean algebra, PLC programming, Ethernet and higher programming languages.
  With this knowledge, automated production machines or systems are not black boxes any more, and can be utilized appropriately and efficiently.

- **Level 2:**
  Covers the core applied automation technologies and industrial IT technologies. Examples are human machine interfaces (HMI screens), radio frequency ID systems, drive systems, safety, but also industrial Ethernet, industrial IT security and communication networks.
  This knowledge will enable engineers to design, build, commission and debug systems and/or machines for their needs.

- **Level 3:**
  Adds on one hand simulation technologies (CAx) for design and virtual commissioning. On the other hand, cloud technologies like connection and data analytics of smart data, connection of manufacturing execution and enterprise resource planning systems (ERP).
  These advanced skills and knowledge will improve the speed and efficiency of development of systems and machines. Simulation of not only physical phenomena but of behavior of controllers is included and enables debugging and adjustment

without actual hardware. Virtual commissioning is a real simultaneous development and saves time and materials.

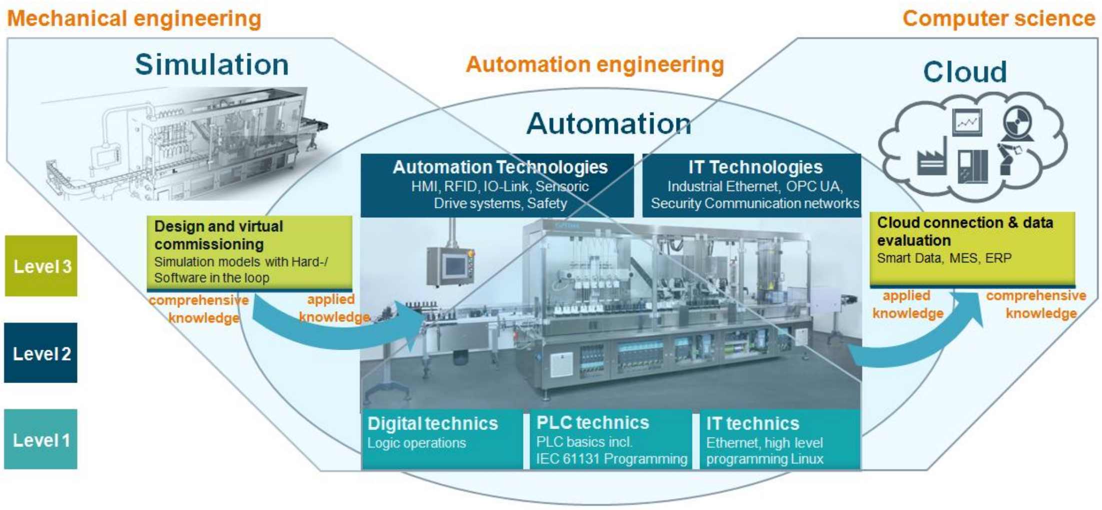

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Figure 2. Siemens Automation Cooperates with Education (SCE) Digitalization Concept (Scheuerer, 2017)

Concrete SCE Offers

To support teachers and students in educational institutions, within SCE, specific offers were developed. Here, we discuss three of them more in detail:

Curricula

There are more than 100 curricula and available for free download (Siemens SCE, 2018). They can be customized are e.g. for universities more abstract, while for vocational schools more detailed and practical. For the design of the curricula, alignment to the specific school curriculum was taken into account, but they also let enough freedom for the educators to customize by occasion. In addition, a list of recommended text books exists.

Trainer Packages

A “trainer package” is defined as a unique combination of hardware and software for educational purposes. One example is shown in Figure 3. It is modular (expandable) and matched to a corresponding curriculum. The trainer packages are for educational institutions especially priced.

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Figure 3. Example of a Trainer Package

Educator Courses for Teacher Education

In the case of vocational schools in Germany, teacher education is typically organized on the state level. SCE signed contracts with a number of German states and is regularly executing teacher education classes on different levels.

IMPLEMENTATION EXAMPLE AND BEST PRACTICES

In the following, we want to discuss specifically an implementation example of a learning system at the vocational school “Berufsbildende Schulen 2 Wolfsburg”, Germany (Figure 4). It is a “Smart Factory” learning system around Industrie 4.0 and is in detail described in Manemann (2017). Concretely, it is a machine for filling chocolate beans into boxes. A touch with a smart phone starts the filling process; a cap is placed automatically on the box, which contains a QR-code referring to cloud based production data.

The system demonstrates the successful implementation of technologies and learning themes according to SCE digitalization concept above:

- **Level 1:**
    - Get the first experiences with Boolean function and programmable logic controllers (PLC) to use SIMATIC S7-1500 with TIA Portal - which operate the Industrie 4.0 machine

- Get the first experiences with C++ or node-RED programming with SIMATIC IOT2000

- **Level 2:**
  - Learn the newest automation and communication technologies on a real Industrie 4.0 machine
  - Secure the Industrie 4.0 machine from internet attacks and establish a secure web access for maintenance personal
  - Intelligent sensor communication implemented with IO-Link
  - Integration of a QR-Code reader and /or of a RFID reader with the TIA portal of Siemens

- **Level 3:**
  - Connect a digital twin (Siemens NX/MCD simulation model) to the SIMATIC S7-1500 PLC and learn how to verify/optimize the real Industrie 4.0 machine e.g. to increase production output
  - Connection of a SIMATIC IOT2000
  - Setup of a SQLite data base
  - Writing of programs to collect the relevant data like sensor data, power consumption data
  - Realizing communication from a Siemens PLC with TIA Portal via the IOT2000 to the cloud server
  - Write a cloud app to analyze the collected data and give advice for a proactive maintenance e.g. for the motor (for computer sciences)

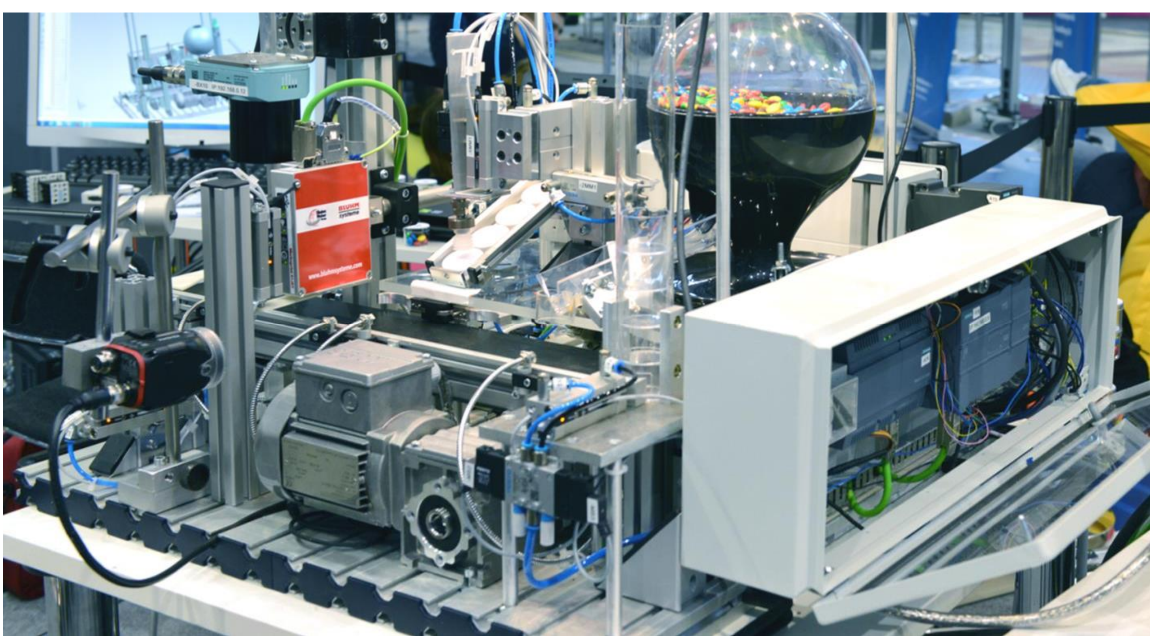

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Figure 4. Example of implementation of a learning system

In addition, the system can demonstrate “lot 1” production (individual text on the box cap), as well as condition monitoring with dynamic augmented reality to identify an error source.

Best Practices in Designing the System

The learning system at the vocational school “Berufsbildende Schulen 2” Wolfsburg was designed with a number of practical aspects in mind:

- **Compactness**
  A small footprint learning system to demonstrate many industrial technologies. They are in principle identical to the technologies necessary to build a car.

- **Openness**
  Offering many materials for students and teachers online as well as offering a learning platform for other schools to join.

- **Blended Learning**
  Tasks to be executed by the students themselves with PC, hard- and software

- **Agile Development**
  Agile principles were used to realize the project to setup the system in a short time was implemented with agile methods and it will be also soon be integrated into the learning platform itself.

- **Proximity to Industry**
  Using the same hardware for education as is used in industry. For example, all components inside the control cabinets in the school lab are identical to the components used in industrial factories in Wolfsburg. This helps the students later to apply their knowledge in real company environment.

These best practices are fully aligned with core principles of CDIO (CDIO Standards 2.0) and we want to highlight here only a few of them:

- **Standard 6: Engineering Workspaces (level 4)**
  The described “Smart Factory” is a hands-on learning workspace, where students learn in teams and fully support all components of hand-on, knowledge and skills learning.

- **Standard 7: Integrated Learning Experiences (level 3-4)**
  Students learn a number of different industrial technologies at one learning system and there is first evidence of the impact across the curriculum. But, it is a first demonstrator and not yet wide-spread or already evaluated due to its very recent development.

- **Standard 8: Active Learning (level 3-4)**
  Above, it is called “blended learning” by having students solving complex tasks involving hard- and software. The impact of such a multi-faceted system on the learning success is already demonstrated in pilot experiments, but needs to be assessed more in the future.

Although quantitative studies of the success of the learning system have not yet been done, we received positive feedback and observe the following:

- Students ask on their own if they could participate in future developments of the concept after a project phase has been finished
- Tests at the school are carried out with real programming tasks including a machine simulation to test if all required functionalities are programmed successfully. The results of these tests are in average good.
- Concentration of students during the lessons is very high, so that a focus of the teachers on content and not on adequate participation is possible.

OUTLOOK

The SCE initiative is a growing, global program. It will be important to continue to customize towards the local educational needs as well as to increase the speed to bring cutting edge automation technologies into real courses. For this, the full support of faculty, school administrators as well as policy makers in essential. So far, first integrated learning systems have been demonstrated, which can be scaled and integrated into many different schools. CDIO principles play an important role in designing such systems keeping the learning success of the students in mind.

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BIOGRAPHICAL INFORMATION

Helmut Wenisch, is in promoting the „Siemens Automation Cooperates with Education" program in Japan. Previously, he was heading Siemens' Corporate Technology consisting of University Relations and IP licensing in Japan as well as working on strategic partnering in the areas of electromobility and smart grid. He also worked more than 10 years for Sony Japan in different roles as researcher (blue laser development), corporate strategist in global HQ and R&D planning (Open Innovation). Helmut Wenisch holds master degrees from University Wurzburg (Germany) and SUNY Albany (US), an PhD from Bremen University (Germany) and an MBA from Temple University (Japan).

Osamu Ito is working in the same group in Siemens with Dr. Wenisch. Besides education, his current tasks include Quality Management, and the Export Control and Customs. He worked in the machine tool division of Toshiba Machine Co. Ltd. with CNC and PC applications for manufacturing for eleven years, before joining Siemens K.K. In Siemens, he supported customers to create real-time add-ons for Siemens' Computerized Numerical Control, and made its own add-ons, besides connecting a regional company to headquarters as a regional product manager.

Roland Scheuerer joined the SCE program in 2009 and since 2012 he is heading the global SCE program. Previously, he was working in Tokyo as the Siemens global key count manager for the Fuji Electric Group for the complete Siemens AG portfolio. In the years 1985 till 2003 he worked in Germany in different SIMATIC automation departments such as in marketing, product management and development of SIMATIC products. Roland Scheuerer holds a Diploma degree from University of Applied Science in Regensburg (Germany)

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