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Multimedia Support for Learning Factories

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Abstract

Today Learning Factories are used to teach lean production, automation technology, energy efficiency or the development process. Common to all learning factories is the constructivistic learning approach. But to achieve a deep understanding of the theories an alternation of casuistic and systematic phases are necessary. Electronic Media can support this process since it makes the related theory easily accessable while working with the learning factory.

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1. Introduction

In the last years learning factories have become more and more popular also in the academic world.

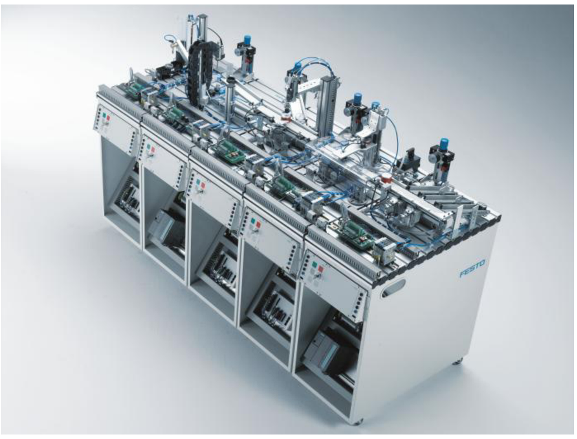

Fig 1: MPS – a learning factory for automation

Since many years companies like Festo offer learning factory solutions to teach and train automation technology like MPS (see Fig.1). Systems like this are used since many years to teach students the basics of automation, PLC-technology, sensors or industrial networking. At the same time topics like setup, optimization or troubleshooting can be addressed as well. The basic idea of this type of learning factories is to create a simplified (didactical reduction) copy of a real automated production line, which allows studying the function of the automation technology without being bothered by the complexity of a real factory. According to this goal the model production process is usually very simple and does not copy a complete value creation process from industry. The main focus is on presenting state of the art automation technology. Latest developments of this type of learning factory covers aspects of Industry 4.0 or Smart Factory, by integrating RFID-based control processes, Ethernet-based networks, cyber-physical components and mobile robots (see Fig.2).

Another type of learning factory is the process learning factory. Examples can be found at the Technical University Darmstadt [3] or Munich [5]. Students shall learn about the optimization of processes and not about technology. Hence the setup is completely focused on modeling the process in question. The model must be accurate enough to use the same optimization methods used in industry, e.g. Kanban, value stream analysis, SMED etc. The factory usually consists of

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industrial equipment and has a staff (often students) who runs the plant. Very often the only didactical reduction is the limited capacity of the plant and the lot size produced. Furthermore the initial setup makes optimization easy (e.g. change of layout).

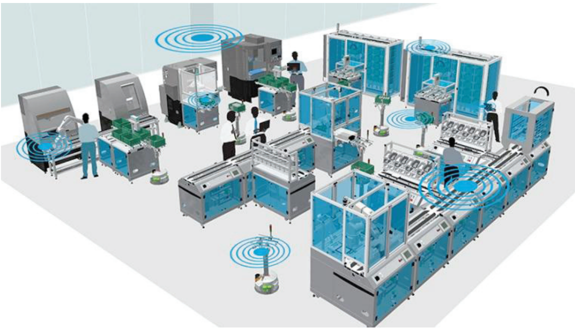

Fig. 2: Transfer Factory – a learning factory for Industry 4.0

Process Learning Factories has been realized for different domains like:

- Lean production (e.g. Darmstadt [3])
- Development Process (e.g. Wien [4])
- Logistics (e.g.TU Stuttgart [1])
- Energy Efficiency (München [5], Braunschweig [2])

A completely new approach which could also be considered as a learning factory is focused on competition- or gamification. An example for this type of “learning factory” is the RoboCup Logistics League. The factory consists of several model production machines (MPS stations), each performing a certain step of a complete, multistage production process. Mobile Robots have to transport workpieces from station to station. In the competition the initial setup and layout of the factory is unknown, so the robots has to build up a landscape of the factory in a first step, the so-called exploration. The second step is to create optimized transport with the three mobile robots to produce as much goods as possible in a limited time. Randomly there are “Express-Orders”, which have to be fulfilled with higher priority.

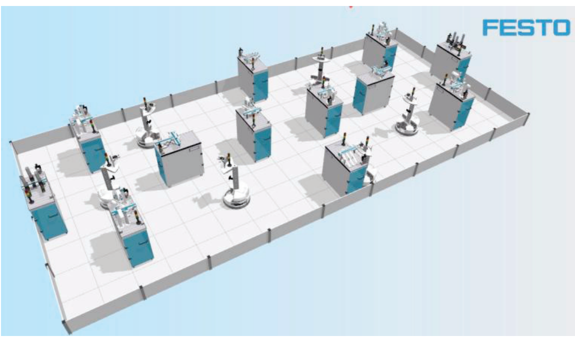

Fig. 3 Layout of the RoboCup Logistics League

Here the limits between teaching and research become fluent. On the one hand the teams (consisting of students) have to use and develop latest technology (mainly software algorithms), on the other hand all participants learn a lot. Surprisingly in the first competition none of the teams were really able to fulfill the task. Now at least some of the teams show superior performance, so that the demands can be increased year by year.

Some Universities participating in the RoboCup uses the challenge as project work in their courses, choosing the best students for the championships. So this competitions forces students to learn in a very intense way.

Often learning factories are used for research, too. This is because it is easier to integrate new technology or control strategies in these simplified environments than in real factories.

2. Didactical Setup of Learning Factories

The idea of learning factories is “learning by doing” or – more scientific – based on the learning theory of constructivsm.

Constructivistic learning theories postulate that learners construct their knowledge themselves rather than acquiring it from others (e.g. teachers). Thus the learner has to be actively involved in the learning process. Obviously the project based approach of learning factories fits perfectly to this model.

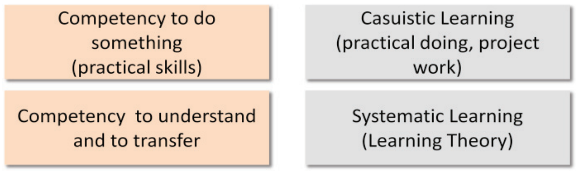

Fig. 4: Competency Model

In Fig. 4 the relation between the two levels of competencies and knowledge is described.

The most visible competency is the ability to do something (e.g. to fasten a screw). This competency requires (manual) skills in the first place, which can be achieved by repeated practical training only.

But there is another type of competency, which is as important. This is the ability to understand why one should do something exactly this way and how to transfer what has been learned to other fields of action. In our example: if the relation of torque, force on the screw, stress, material strength and notch effect is clear, then one can decide whether it is possible to use a screw with different material parameters if the original screw is not available.

This kind of knowledge can’t be achieved by project work alone. The student needs an overview about the related theory, too, which is usually taught by presentations, lectures, reading a book or working with a web based training. But to convert this theory into applicable knowledge it needs to be applied. And this means that phases of learning theory needs to alternate with practical work. But this is not enough. The practical work needs to refer to what has been learned before, and the theory lessons needs to refer to the project work ([7], see Fig. 5).

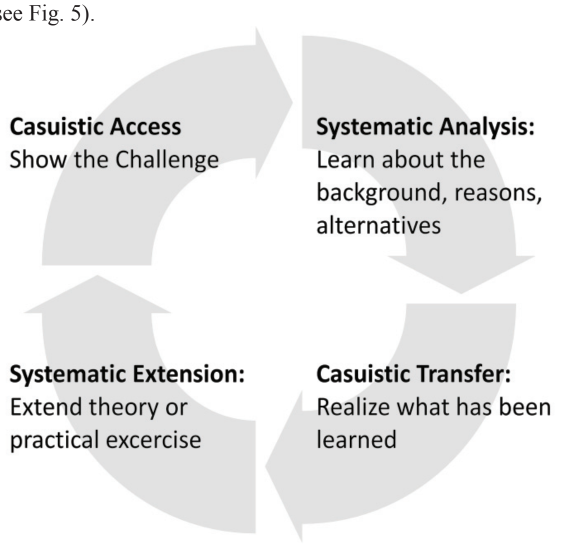

Fig 5: Alternation between theory and practice

For learning factories this leads to a complex didactic setup, wherein practical work alternates with phases of learning the theory which are the basis of the practical work.

Ideally the alternation of phases could vary for every student, depending on the individual speed of learning and preferred way of perceiving information. Obviously this can't be realized when the instructional part is given by a teacher only. Therefore multimedia support could be used to provide information whenever the student needs it and in his preferred kind of media.

3. Tec2Screen as Multimedia Support for Learning Factories

Tec2Screen has been developed to merge learning theory and practical exercise in one system. Core of the Tec2Screen system is a tablet computer with an extension called Base. Attached to the base there are Connects. These connects allow a direct interaction with components of the learning factory (see Fig. 6).

The Connects are designed to make the flow of signals as clear as possible. There is a visible connection from the device to the components on the screen (see Fig. 7).

The tablet computer with the Tec2Screen extension can now be used for learning theory by providing:

- E Books
- Electronic Learning Programs
- Datasheets
- Cut Away Drawings
- Web Content
- Animations /Videos

And at the same time Tec2Screen can be used for practical exercises like:

- Programming
- Manual control of equipment
- Using Simulations

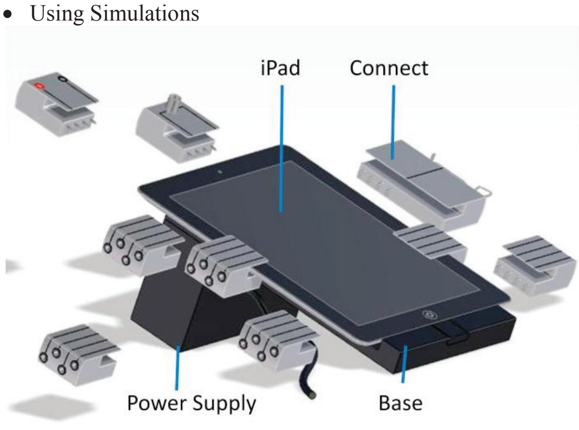

Fig. 6: Hardware Setup of Tec2Screen

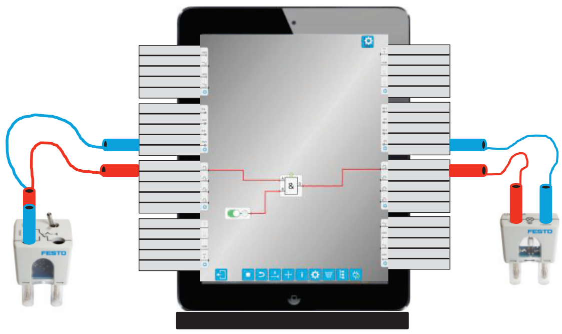

Fig. 7: Connects make the connections of real devices virtual devices visible

4. Samples

The following chapter gives an overview about possible use of Tec2Screen in the didactical setup of a learning factory.

4.1. Simulation

There are several reasons for using simulations instead or additionally to a real system:

- No danger of destroying equipment or injuring students
- Cost effective
- Reduction of complexity: simulations can be simplified compared to real machinery to make clear the principle.

In a simulation the system can be reduced to the most important components, e.g. the number of sensors or actuators involved. Fig. 8 shows an example: The simulated system is a tank with an outlet- and an inlet-valve, a heating system and a temperature gauge and some end switches to measure the filling level. Such a simple system is ideally suited to learn the principle of closed loop control. The complexity can be reduced even more by ignoring the temperature control, but in any case there is no danger of overheating or overflow. To make the simulation as realistic as possible the controller itself is an real PLC, which is connected to the system via the Connects.

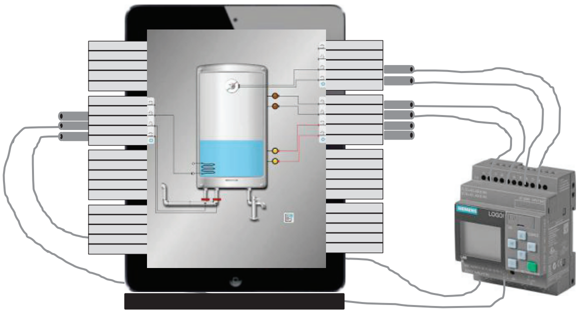

Fig. 8: Simulation of a tank with level control system on Tec2Screen, connected to a PLC to train closed loop control

Furthermore it is possible to show the simulated system in different levels of abstraction like circuit diagram, block diagram, technical scheme etc, even if the simulation is working. Both is not possible with the real system.

In addition simulation allows to create learning situations which are not possible in a real environment, e.g. because it is too dangerous (the best known example is the training of pilots in flight simulation) or much too expensive (e.g. complex factory installations).

Simulation helps to understand, but also helps to create opportunities to train what has been learned and understood before. With real learning factories this is sometimes difficulty due to the limited resources.

4.2. Providing Information

As described in Chapter 2 it is vital to combine practical exercises with related theory. Tec2Screen can help to provide exactly the type of information students need. This is achieved by different approaches:

- Nugget Concept: Information and explanations are organized in nuggets, small portions of information that can be found and received quickly.
- QR-Code Reader: Important components of the learning factory are marked by QR codes. Scanning the QR code leads directly to related information, e.g. data sheets, cut away drawings, component descriptions or exercises.

The information could be used as a formal introduction into the lesson (in this case organized as an electronic course), but it is even more useful as an instant source of information while working in the laboratory. The mobility of Tec2Screen makes this extremely easy.

Providing information by scanning QR-codes is the first step towards Augmented Reality. But instead of providing just datasheets or other written information it is possible to do more: one application shows the interior of a heat tunnel in the moment you scan the QR code on the outside of the machine.

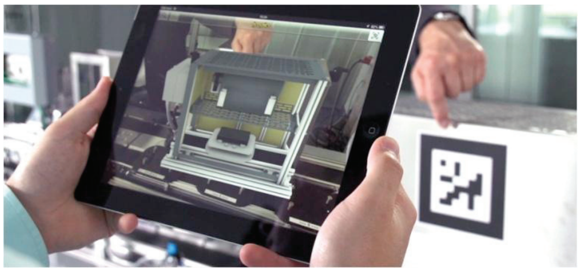

Fig. 9: Use of Augmented Reality in a Learning Factory

4.3. Sample of a lesson

Let us assume students shall learn the initial setup of production machines. The machine is a MPS station (see chapter 1). The lesson could be organized like this:

- Casuistic Access: the students watch a video of one complete cycle the station shall perform (part of the exercise in the course)
- Systematic Analysis: learn about the components and their function. Learn the function of a PLC and the meaning of input / output channels, using the QR scanner of Tec2Screen.
- Casuistic Transfer: study the function of the components by manual control and derive a table with input / output channels of the station. Create a control flow chart. Use the manual control interface of Tec2Screen.
- Systematic Extension: learn about logic functions and logic controllers (PLC) in the electronic course.
- Casuistic Transfer: create a simple logic control program for the station using iEasyLab.

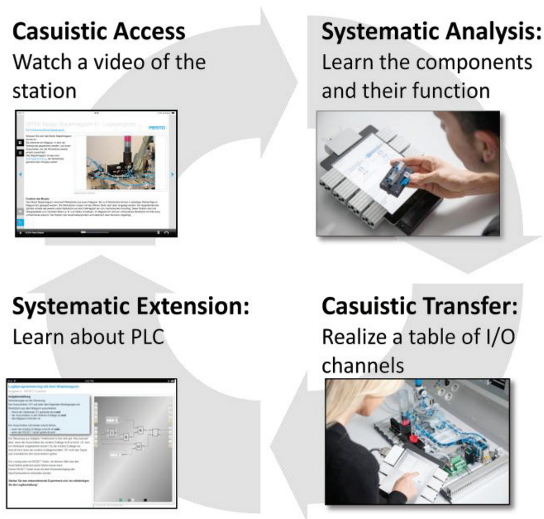

Fig. 10: Sample Lesson with Tec2Screen

This sample lesson (domain: PLC programming) demonstrates how theory (systemtic parts) and practice (casuistic parts) alternate to maximize the learning success of the students. Furthermore it shows how Tec2Screen can help to merge both parts of the didactical concept in an individual way for every student (see Fig. 10).

5. **Outloo**k

Following the constructivistic learning theory, many learning factories focus on the aspect of casuistic learning, practice or learning by doing. Nevertheless also the systematic approach of learning related theory must be included. Tec2Screen is a multimedia, tablet based approach to connect theoretical and practical aspects in a seamless way. However, today Tec2Screen is originated in the fields of mechatronics and automation. There is still research to be done to cover topics like lean production, energy efficiency and others, which are currently the most important topics in learning factories.

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