Proceedings of the 21st International Conference on Modelling and Applied Simulation (MAS), 024
19th International Multidisciplinary Modeling & Simulation Multiconference

2724-0037 © 2022 The Authors.
doi: 10.46354/i3m.2022.mas.024

Conceptual framework of a Learning Experience Platform (LXP) to strengthen AI competence by linking simulation technologies and AI

David Weigert[1,*], Fabian Behrendt[2]

[1,2]Department of Economic, Magdeburg-Stendal University of Applied Sciences, Osterburger Str. 25, Stendal, 39576, Germany

*Corresponding author. Email address: david.weigert@h2.de

Abstract

Artificial intelligence is considered one of the most important driving forces for future economic development. In order to sustainably increase this potential, this paper describes a conceptual framework for a holistic and spiritual Learning Experience Platform (LXP). The basis is formed by the application areas of production and logistics within Industry 4.0. Through this, all subareas of a modern model factory with fischertechnik components are mapped with simulation, automation and visualisation modules.

Keywords: AI; Learning Experience Platform (LXP); Digital Twin; MQTT

1. Introduction

The intended development of a Learning Experience Platform (LXP) pursues the goal of didactically innovative and high-quality teaching-learning development in the subject complexes of Artificial Intelligence (AI), Industry 4.0 and simulation technologies of the Fischertechnik 4.0 Training Factory.

Based on the five AI competencies according to De La Higuera (2019) the contents will be didactically prepared and integrated into teaching and further education. For the technical and practice-oriented realization, a conceptual framework will be presented below. The application areas are business administration, supply chain management, Industry 4.0, automation as well as production and logistics.

The field of AI encompasses numerous methods and tools. Especially for people with a low level of experience in AI, the methods and tools lack clarity. Integrating AI into an LXP and combining it with simulation and automation technologies can further enhance the learning experience in the forementioned application areas. Communication widgets and learning bots can be used to customize learning paths for users. AI bots and widgets provide helpful review and support tips and remind users of important milestones. Based on the analyzed user data, personalized learning and training recommendations will be issued. The integration into the simulation technologies of the model factory enables the embedding of entrepreneurial processes, problems, and decisions for action. The framework is intended to strengthen the necessary needs for knowledge transfer on AI in science and industry.

As a conceptual model (s. Figure 1), it shows the complete digitalization and automation of the model factory. In the concept, automation levels as well as vertical and horizontal business areas are linked with digital system components. A virtual world, as a test and experimentation environment, accommodates the different needs and user levels. The digital tools range from sensor nodes and the use of digital twins to higher-level control and knowledge transfer through AI. Through the model factory, a real simulation and automation of the plant is realized via PLC modules.

2. State of the art

Artificial intelligence is considered one of the most important drivers of future economic development. Companies that have filed AI patents have been shown to increase labour productivity (Alderucci & Ashley, 2020; Damioli et al., 2021; Graetz et al., 2017).

To realise these studies, AI technologies must be adopted by companies and integrated into their operations. At the same time, successful education on AI is essential. However, it is unclear to what extent European companies are actually using AI at present. Estimates vary widely because data collection is inconsistent and there is no standard definition or taxonomy of AI. What is clear is that the use of AI in Europe, and especially in Germany, is low and probably lags behind other parts of the world. (UNESCO, 2019.; OECD, 2018)

Research by du Boulay (2019) and Hooshyar et al. (2019) found that intelligent tutoring systems and smart environments lead to better learning outcomes than teaching by a single teacher in a traditional seminar or lecture.

Instruction by a qualified human teacher who provides one-to-one support led to even better test results. The main impact of AI on higher education is in predicting learner success or failure (Bates et al., 2020). This is related to the categorisation of students according to their engagement and their formative assessment through ML data analysis of activity logs from learning management systems. AI and learning analytics technologies are enabling the transition to concepts of hybrid course designs, active learning concepts and new approaches to measuring individual learning progress and designing personalised learning support (de Witt & Karolyi, 2021). Learning experience platforms as part of a learning management system (LMS) are at the beginning of an important role in general education for automation, simulation and AI. With the importance of AI, data analytics and automated content generation, it will be possible to create personalised learning opportunities and to accompany learning processes individually. In this way, it is possible to offer learning opportunities in a needs-based and personalised way. LXP differ significantly from LMS in terms of their functions. LXP are characterised by the following functions:

- Modern UI (User Inferface) and UX (User Exeperience); LXP are oriented towards the design expectations of the users.
- Supports user-generated content (UGC); users can make their own contributions, comment, recommend and rate.
- (Partially) automated creation and presentation of content; content is (partially) automated searched, analysed, compiled and offered as learning recommendations.

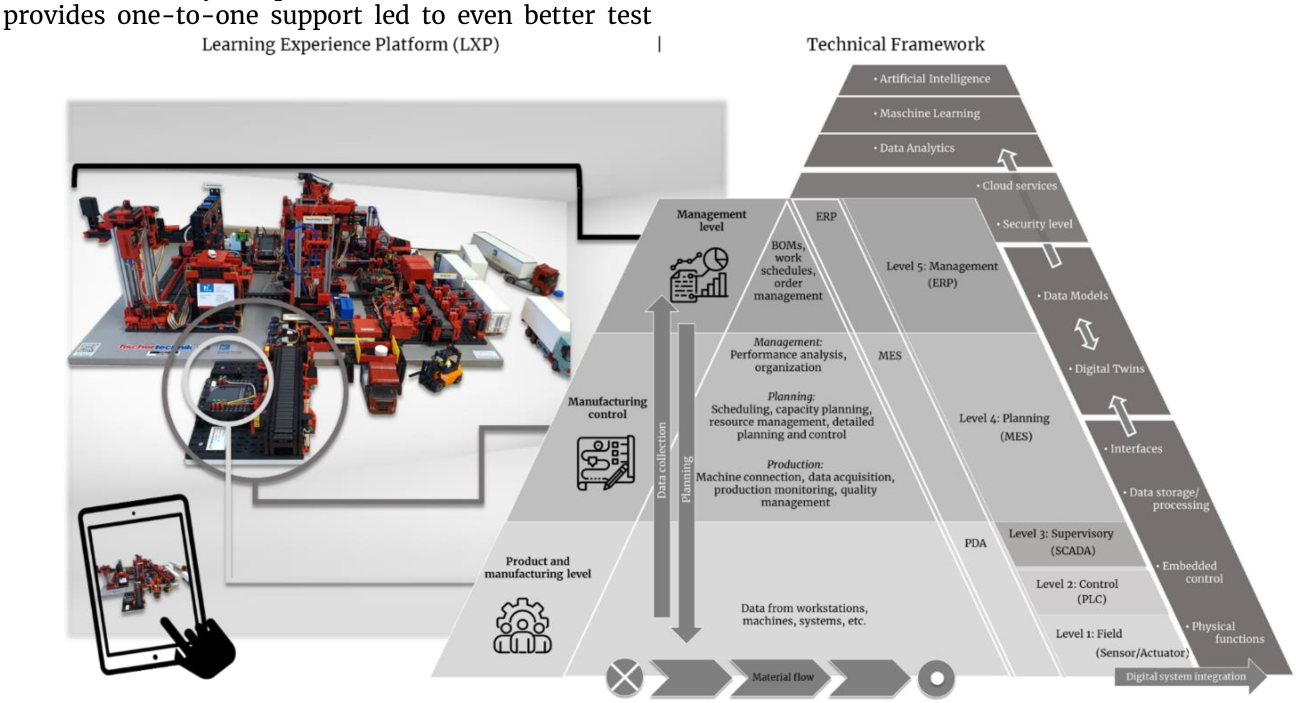

Figure 1 Overview of the conceptual framework

- Transparent and targeted data insights; graphical dashboards show user current development status.

- Social learning, sharing and reward system; Social learning is a major didactic focus of LXP as well as rewards and recognition for achieving goals or nudging when the learning process is stalled.

3. Materials and Methods

3.1. Lab description

The laboratory used is a Fischertechnik Training Factory 4.0 as a 9V version for testing teaching-learning scenarios. The purpose is to train and promote technical and scientific skills in automation, simulation, VR/AR and AI. The topics addressed are Industry 4.0, Logistics 4.0 with the basic subjects of mechanical engineering, production, logistics, automation and AI. The model is flexible and modular. The training model simulates logistical and production-logistical issues and enables a wide range of applications through the use of microcontrollers (here: TXT controller). The aim is to be able to examine, simulate and evaluate the processes and procedures in a factory, production plant or company. Within the framework of higher education, the laboratory is to be upgraded to a comprehensive LXP. In addition to imparting technical knowledge, this also includes the didactic concept to create a systematic teaching-learning environment. The Fischertechnik product consists of classic elements of the Fischertechnik construction kit. For the laboratory, NFC/photosensors (CS, NFC) for object identification in the Delivery and Pickup Station (DPS) (summarised in Figure 2 under CS/NFC).

The production sequence consists of an "Automated High-Bay Storage" (HBS/HBW), a "Multi-Machining Station with Oven" (MPO), a "Vacuum Gripper" (VGR) and a "Sorting Line with Colour Detection" (SLD). By linking several stations and additional systems (including conveyor lines, additional HBS, additional processing line), the processes of a processing line up to complex production networks can be simulated. The model is controlled by fischertechnik TXT controllers. These controllers control the actuators and evaluate the information from the sensors. In the laboratory presented, a "Sensor Station with Camera (Main)" (SCC) takes over the task of the local MQTT broker. MQTT stands for Message Queuing Telemetry Transport. MQTT is an open messaging protocol for M2M communication (machine-to-machine).It enables the transmission of telemetry data in the form of messages between the individual TXTs. Local communication between the MQTT clients takes place via port 1883. Encrypted communication to the cloud is fulfilled via port 8883 SSL. Physically, the TXT controllers (TXT 0 - 4) on the TP-link nano router are connected via WiFi with a fixed IP address. They are all operated in "WLAN-Client" mode, the TP-link nano router establishes the connection to the Internet.

The process sequences are specified by the training model and are hard-coded. During storage, the object passes through a light barrier and triggers the storage process. The object (RFID; red, white, blue) is transferred to DPS, CS, NFC by the VGR and identified. The VGR places the object in the pick-up device of the HBW and returns to the initial position. The HBW stores the object according to a sequential order from A1 to C3. The initialisation of the stock is done via the cloud and the webshop. Only then does the warehouse know its correct occupancy. The removal from storage is more extensive, as the object passes through all the remaining stations until it is delivered. An order is triggered by the webshop. The HBW starts the removal, the VGR takes over the object and brings it to the MPO. After the MPO, the object moves to the SLD, where the colour is read by a photo sensor. Depending on the colour, the object is sorted into a red, blue or white area of the storage area. Then the VGR takes the object, reads out the colour and ID of the object in the DPS, CS, NFC and hands the object over to the end user.

The main process steps of delivery and ordering can only be processed sequentially and not in parallel. Overtaking processes and changes to the sequence are not permitted. Likewise, the main processes are first completed (" stored" or "order completed") before a new process begins.

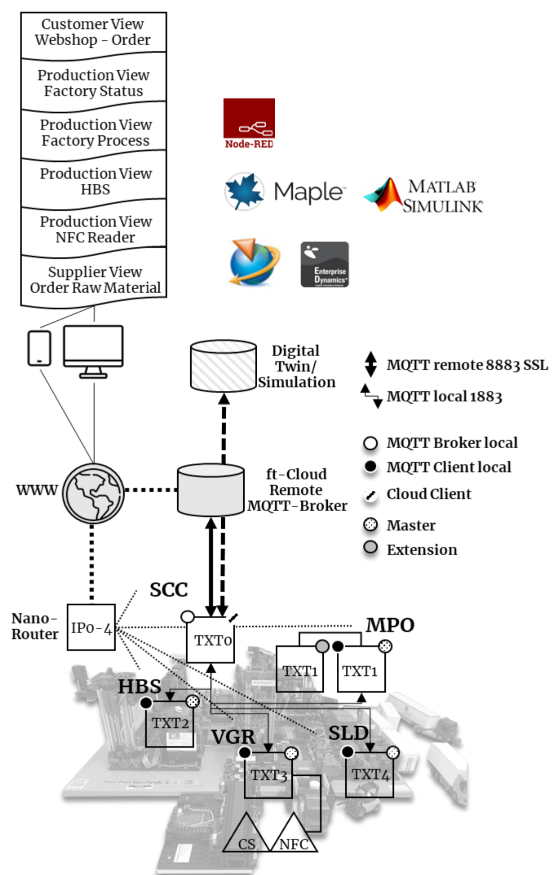

Figure 2 Technical implementation and interfaces

The factory can be accessed and edited locally from a host computer. Remote access via a cloud solution is also possible. The model factory is equipped with its own cloud solution ex works. However, for the transfer of the real factory into a digital twin, it is necessary to leave the proprietary system and set up a separate web service solution. Through MQTT and the software solutions IBM Node-Red, Maple and Matlab-Simulink, the project is able to achieve the necessary infrastructure in the area of automation, simulation and virtual interface. Through additional simulation tools such as Enterprise Dynamics and Plant Simulation, CAD drawings of the plant can be linked to existing process parameters. This creates simulation-based predictive models while generating additional data sets. The use of AI extends across the entire mode of operation of the model. On the one hand, AI should provide solutions for the user, on the other hand, it should also collect and evaluate data about user behaviour. The last point requires extensive consideration of ethical and data protection issues. Aspects of AI application can be taken into account via the solutions of RapidMiner, Orange Data Mining and KNIME. Due to the many application areas of AI, it is of great importance to introduce AI in selected application scenarios. These use cases can be, among others, speech recognition for operating the plant, monitoring of faulty storage and retrieval processes, pattern recognition of the producing NFC tokens, site and factory planning, AI-based layout planning, as well as maintenance and servicing.

3.2. Interfaces and software

The laboratory has a variety of possibilities for data visualisation through the TXT controllers and their interfaces, the Fischertechnik cloud as well as through the laboratory's own web shop. Due to the fixed-programmed sequence routines of the 9V version, it is not possible to access the automation and sequence control of the entire system with these programs. Fischertechnik offers "ROBOPro", a development environment in the form of graphical sequence programming. The software is established, is sufficient for the amateur sector and is suitable for single models. Complex and interlinked model structures with several controllers could not be mapped or programmed at the present time. However, due to the new development of TXT 4.0 controllers at the end of 2021, this programme environment will no longer be supported. In dealing with the original laboratory state, the possibilities are therefore limited. By using a community firmware (CFW), the TXT controller can be programmed with Python. Using the Python module "ftrobopy", own scripts can be stored on the TXT controller and the inputs and outputs can be read and written. Another possibility is the integration of a Raspberry Pi (3). For the connection, Fischertechnik specifies the setup as follows: Raspberry Pi + Adafruit DC and Stepper Motor HAT for Raspberry Pi + Adafruit 4-Channel ADC Breakouts + fischertechnik motors/ sensors/ construction kits. As shown in Figure 2, the lab has an MQTT (Message Queuing Telemetry Transport) interface. Through the protocol, devices can send information about a specific topic to a server that is set up as an MQTT broker. The communication is thus suitable for the use of machine-to-machine communication (M2M) and machine-to-human communication (M2H). The broker transmits the information to clients that have previously subscribed to the client's topic (s. Figure 3).

The MQTT message protocol is beneficial for low bandwidths and high latency times. It speeds up internal communication and relieves existing capacities. Another advantage is the independence, because systems such as ERP (e.g. SAP), SQL (e.g. MongoDB), SOA (e.g. OPC-UA) can also be used to subscribe to the topics and process them further. Another advantage is the display of visualisation processes. Here, status data of the laboratory could be displayed graphically and used, for example, as a representation of process flows or web shop.

3.3. Favourite development environment

Simultaneous access to all TXT controllers and free programming via a data interface is limited by the precompiled C++ files and routines. Access to the laboratory through the MQTT interface is therefore preferable. Access was realised via the IBM Node-Red software. Alternatives to this include "Blockly" or "Scratch". The open source software Node-RED runs on the cross-platform runtime environment Node.js and enables a graphical user and programming area through data stream-oriented programming.

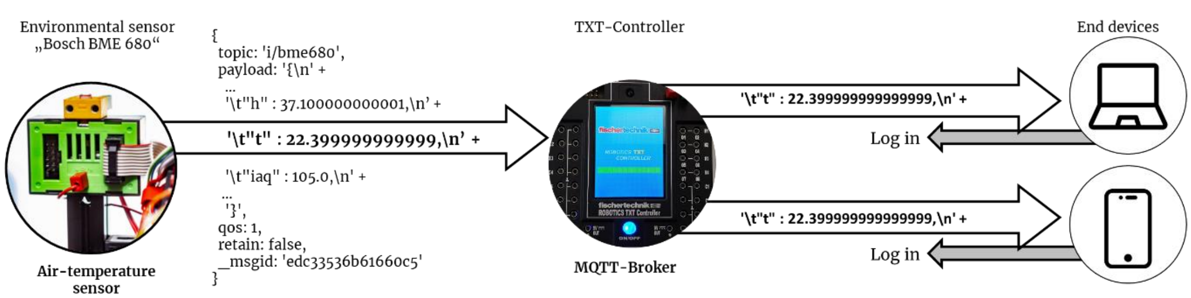

Figure 3 Functionality of MQTT using the example of the installed Bosch BME 680 environmental sensor

The editor can be accessed through any web browser. Different "nodes" can be connected by logical links to form an extensive "flow". In addition, own routines can be programmed and external extensions can be integrated. The Node-Red library provides an extensive community solution for using solutions or extensions that have already been developed.

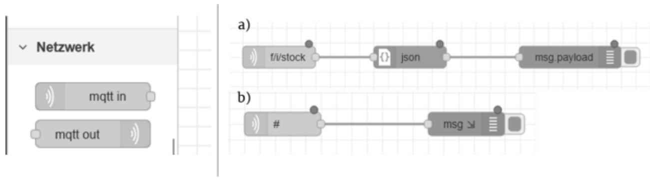

Figure 4 Overview of nodes and flows used in Node-Red

Figure 4 shows the queries used for the laboratory. To simplify the process, the design of two flows is shown using the example of a) and b). Both flows start with the node "mqtt in" and gain access to the TXT controller (TXT0) as MQTT broker with the IP address 192.168.0.10. Flow b) subscribes to all topics with the operator "#" and outputs them in the command line through node "debug" (here msg). The output is limited to naming the channels and does not allow any further information. In flow a), the topic "stock" is subscribed to and provides information on the status of the high-bay warehouse (HBS/HBW). In this case, a parser is used by the node "json" to convert the transmitted information of the channels into a JSON string and object.

4. Results and Discussion

4.1. Data extraction and use

The described concept is still at the beginning of its implementation. It should be noted that the laboratory only carries out identification in incoming and outgoing goods via an NFC reader (ID) and colour sensor (COLOUR). All other steps are hard-coded by the laboratory, automated and form a black box for the user. Access, data acquisition and visualisation is only possible via external software. The in-house software solutions do not meet the requirements of an LXP. The laboratory has no feedback loops for plausibility control. Thus, it is possible to remove objects or change the colour in the storage compartment at any time after the initiation of the occupancy from the high-bay warehouse. The laboratory does not recognise these changes and does not react adequately to this error. Therefore, the high-bay warehouse was given higher priority in further consideration. By accessing the laboratory through the MQTT protocol, a basic data acquisition has been created. Subsequently, the interfaces to other systems (e.g. ERP, SQL, SOA) can be analysed and continued. The raw data can be determined and stored error-free via the Node-Red software. At the same time, they can be further processed, bundled, evaluated and visualised via the Node-Red. At the current stage, however, it is important to generate and analyse uncorrupted raw data. As an example, the process from ordering a white component from the fischertechnik webshop to delivery is to be illustrated (s. Figure 5).

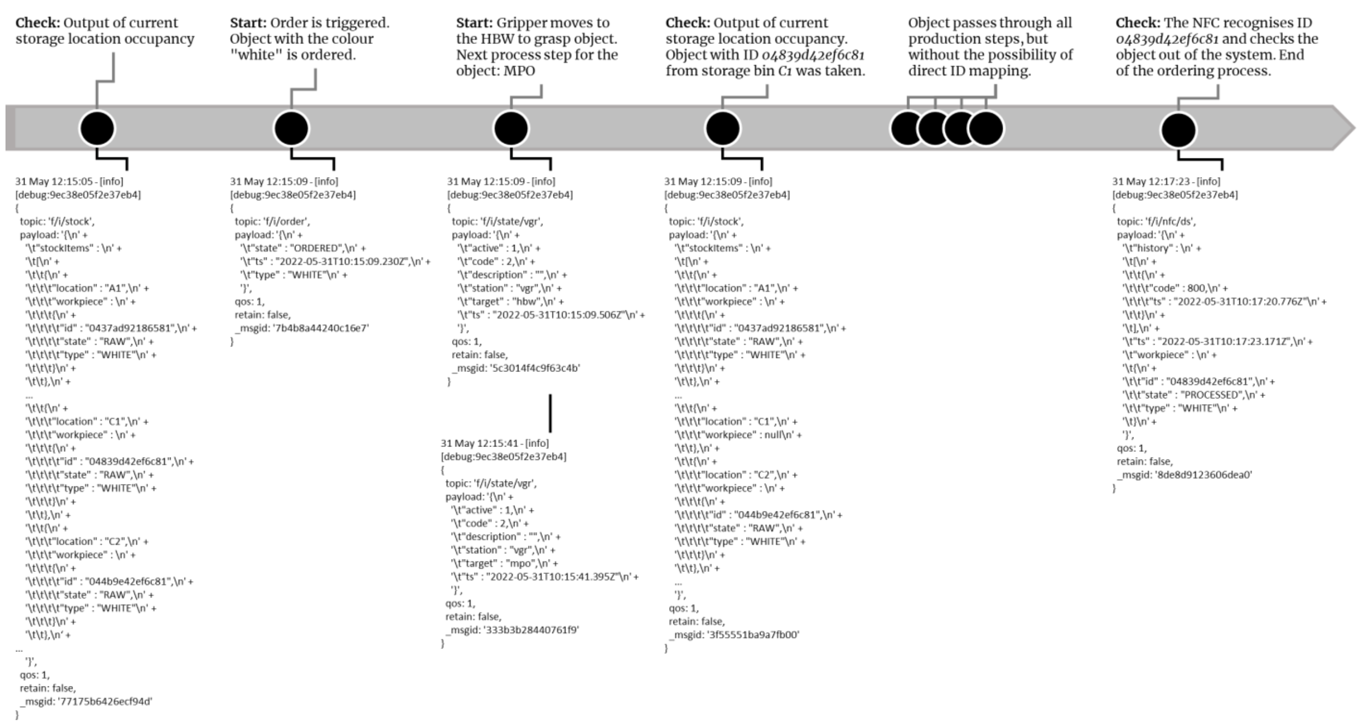

Figure 5 Combination of the collected raw data (via MQTT) and reconstruction of the main process "Ordering".

4.2. Data preparation and further utilization

The raw data shows clearly where the current weaknesses and strengths of the laboratory lie. At the moment, many process steps run automatically without having insight or access to them. The retrieval processes and processing steps are mostly FIFO controlled. In many areas of the laboratory, there is no identification of the object. The laboratory is sufficient for use as a training object for logistical and production-related processes. The laboratory offers initial possibilities for setting up a comprehensive teaching-learning environment on the topic of simulation and AI through the MQTT interface. Adaptation to the real world is also possible. In the industrial environment, partially automated solutions are often sought for testing existing systems, processes and objects. This is where the platform to be developed comes in and generates a benefit for school, university and industrial training and further education. Transparency, traceability and explainability are essential elements in the development of an LXP. Decision-making processes based on AI should be designed in such a way that they are verifiable and comprehensible for those affected. Learning experiences must be primarily designed around compact content (micro-learning), interactivity and personalized recommendations to encourage learner engagement and involvement. It must not be possible to delegate responsibility to machines. AI systems must be designed to be secure, robust and resilient in order to have a positive impact and not be vulnerable to misuse or misapplication.

5. Conclusions

Further fields of application and case studies are being created to achieve the technical goals. The high-bay warehouse is a suitable example for training and developing AI skills. As mentioned, shelf monitoring cannot be enabled with the current automation solution. Various additional solutions exist to monitor the racking. In the context of strengthening AI competence, camera-based surveillance and monitoring of colours and objects is target-oriented.

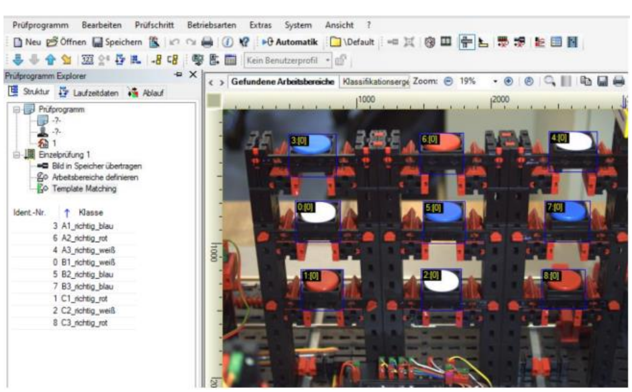

Figure 6 Outlook for AI- and camera-based storage location monitoring

In the future, a test approach will deal with the establishment of camera-based condition recognition for the laboratory. For this purpose, fixed cameras will be used to check storage compartments, occupancy status, colouring and order plausibility (s. Figure 6). In addition, the laboratory is to be controlled via an ERP system and accessible via its own web shop. The basis is a functional digital twin, which is currently in use in prototype models (s. Figure 7).

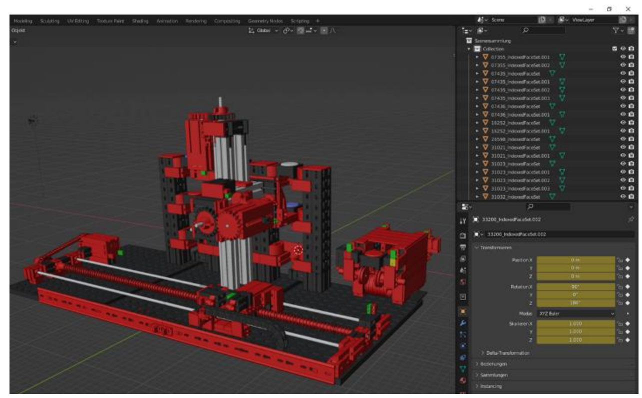

Figure 7 Prototype of the HBW as digital twin

In general, the feedback from the laboratory is to be processed in a more targeted manner than at the current state. If the ID of an object is known at the end so far, a complete tracking and tracing of the objects is to be made possible. Likewise, the status data is recorded and evaluated at any time via the MQTT interface. These data records are to be used further for the purposes of maintenance and servicing. The largest further development envisaged is the merging of the partial aspects into an AR environment. Through plug-and-play, elements of the laboratory factory are to be added or removed. The coupling with the digital twin enables the immediate, automated parameterisation of the real and virtual system. Users get the opportunity to access the factory at different locations as well as via cloud access and digital live demonstrators. On this model system, users can follow the triggered and designed business process or use case and get to know the various logistical and production processes within an exemplary production company. The aim is to make new AI, simulation, Industry 4.0 and Logistics 4.0 technologies accessible to users, to familiarize them with digital/automated processes and to implement their use in a simulative and practical way using demonstrators and use cases

The conceptual framework is understood as a "building block box" in which different solution approaches can be developed, tested and evaluated in a practical way. Furthermore, the fischertechnik Learning Factory 4.0 and other system elements are used to determine near-real-time data in the research area, e.g. via environmental or image sensors, and to achieve and evaluate findings about system behaviour using learning methods.

References

Alderucci, D., & Ashley, K. (2020). Using AI to Analyze Patent Claim Indefiniteness. *IP Theory*, *9*(1). https://www.repository.law.indiana.edu/ipt/vol9/iss1/2

Artificial intelligence in education: challenges and opportunities for sustainable development - UNESCO Digital Library. (n.d.). Retrieved May 13, 2022, from https://unesdoc.unesco.org/ark:/48223/pf0000366994

Bates, T., Cobo, C., Mariño, O., & Wheeler, S. (2020). Can artificial intelligence transform higher education? In *International Journal of Educational Technology in Higher Education* (Vol. 17, Issue 1, pp. 1–12). Springer. https://doi.org/10.1186/s41239-020-00218-x

Damioli, G., Van Roy, V., & Vertesy, D. (2021). The impact of artificial intelligence on labor productivity. *Eurasian Business Review*, *11*(1). https://doi.org/10.1007/s40821-020-00172-8

De La Higuera, C. (2019). *A preliminary report about Teaching and Learning Artificial Intelligence: Overview of key issues*. https://www.k4all.org/wp-content/uploads/2019/11/Teaching_AI-report_09072019.pdf

de Witt, C., & Karolyi, H. (2021). Anforderungen an ein Next Generation LMS zur Unterstützung von Personalisierung aus bildungswissenschaftlicher Perspektive. *Eleed*, *14*(1). http://nbn-resolving.de/urn:nbn:de:0009-5-52841

du Boulay, B. (2019). Escape from the Skinner Box: The case for contemporary intelligent learning environments. *British Journal of Educational Technology*, *50*(6), 2902–2919. https://doi.org/10.1111/bjet.12860

Graetz, G., Michaels, G., Beerli, A., Caselli, F., Falck, O., Garred, J., Manning, A., Nordström Skans, O., Pischke, S., & Schönberg, U. (2017). Georg Graetz and Guy Michaels Robots at work Article (Accepted version) (Refereed) Robots at Work *. *Direct.Mit.Edu*. https://direct.mit.edu/rest/article-abstract/100/5/753/58489

Hooshyar, D., Kori, K., Pedaste, M., & Bardone, E. (2019). The potential of open learner models to promote active thinking by enhancing self-regulated learning in online higher education learning environments. *British Journal of Educational Technology*, *50*(5), 2365–2386. https://doi.org/10.1111/bjet.12826

The Path to Becoming a Data-Driven Public Sector | OECD iLibrary. (n.d.). Retrieved May 13, 2022, from https://www.oecd-ilibrary.org/sites/059814a7-en/index.html?itemId=/content/publication/059814a7-en