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Published in:
Proceedings of the 12th Conference on Learning Factories (CLF 2022)

DOI (link to publication from Publisher):
10.2139/ssrn.4072839

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

12th Conference on Learning Factories, CLF2022

Design and implementation of Management Information System for UCN Industrial Playground

Kurt Lindgren[a,*], Helge Glinvad Grøn[a,b], Lasse Christensen[a,b], Ib Helmer Nielsen[a]

[a]Department of Technology, University College of Northern Denmark, Denmark
[b]Department of materials and production, Aalborg University, Denmark

Abstract

The industry of the future requires employees with strong digital skills. However, these types of skills needs both maintaining and development through education and career. One way to do this is through Learning Factory activities, where the digital agenda is integrated into the learning activities in several stages of the product life cycle or the supply chain. UCN Industrial Playground (UCN IP) is a Learning Factory concept that supports undergraduate student's theoretical and practical training in acquiring digital competencies within Industry 4.0. This paper describes the design and implementation of a Management Information System (MIS) for UCN IP. Based on the didactive principles from Reflective Practice-based Learning, a demonstrator is being developed to show how a paper-based system for handling preventive maintenance of manufacturing equipment can be digitized and be an active part of a Smart Factory solution. The system is designed to inspire SME's in how new technology and End-User Development (EUD) can be used in automating and streamlining business processes. Case studies in modular knowledge and skill improvement are evaluated using a summative assessment for both reactions to the learning activities and learning outcome.

Peer Review statement: Peer-review statement: Peer-review under responsibility of the scientific committee of the 12th Conference on Learning Factories 2022.

Keywords: Learning Factory; Industry 4.0; Education; Training; Reflective Practice-based Learning; Management Information System; UCN Industrial Playground

1. Introduction

In a global business environment of limited time and resources, leaders have to seek and develop innovative ways to keep ahead of change [1]. The Covid-19 pandemic has accelerated the need for emergent technologies. Small and medium-sized companies (SMEs) struggle to keep up with digitalization [2]. They are particularly challenged on knowledge, competencies, and resources. Maintaining and developing competitiveness require companies to identify, qualify, and implement new digital solutions [3]. The challenge is to retain, develop and recruit employees with strong digital skills. European skills and jobs (ESJ) survey reveals that more than 7 in 10 adult employees in the EU need at least some fundamental ICT level. About one in three of those employees are at risk of digital skill gaps [4]. According to studies carried out by the European Commission 64 percent of large enterprises and 56 percent of small and medium-sized enterprises in Europe that recruited ICT specialists in 2018 reported that these vacancies were hard to fill [5]. The power of action and agility are important in decision making. The validity and availability of data are vital parameters and create a natural need to develop intelligent solutions that meet documentation, usability, traceability, and mobility requirements. Starting the digital journey requires courage and thoughtfulness. Several studies have shown that value stream mapping (VSM) is a useful

* Corresponding author. Tel.: +45 7269 1587
E-mail address: krl@ucn.dk

analytical method to determine information flow, identify critical bottlenecks and remove non-value activities [6, 7]. This provides access to valuable knowledge about improvement opportunities and optimization and efficiency potential by introducing digital solutions. Start with small manageable projects and thereby gain useful experience. Educational institutions have a special responsibility to meet companies' demand for employees who are actively able to initiate, inspire and lead digital processes. One such demand is competencies within Preventive Maintenance (PM). PM was introduced in the 1950s and refers to any regularly scheduled machine maintenance intended to identify problems and repair them before failure occurs [8]. It has a proactive approach and is a very important step in keeping manufacturing equipment operations running smoothly [9]. PM helps maintain efficient production and reduces the risk of sudden failure, production delays, and product defects. An approach to this is ideal for Learning Factories, where activities with a clear operational model, purpose and didactics can aid the learning of the student. This can also be seen as the Learning Factory Maturity [10]. UCN Industrial Playground (UCN IP) [2, 11] is a Learning Factory concept that supports undergraduate students to acquire digital competencies through theory, interdisciplinary collaborations and hands-on teaching related to Industry 4.0. This paper describes the design and implementation of a Management Information System (MIS) for UCN IP. A demonstrator is being developed to show how a traditional paper-based system for handling preventive maintenance of manufacturing equipment can be digitized and be an active part of a Smart Factory solution. The system is also designed to inspire SME's in how new technology and End-User Development (EUD) can be used in automating and streamlining business processes.

2. Research Methods

This paper aims to increase how teaching and training can motivate End-User Developers to develop conceptual applications demonstrating and using elements from industry 4.0. The first objective is to improve students, lecturers, and future employees' digital skills in using end-user software. Secondary objectives are developing a MIS for UCN IP that helps identify and reduce non-value activities and improve decision-making. This paper is based on a case study research design. Applying the didactive method Reflective Practice-based Learning (RPL) [12] allows participants to work theoretical and practical with a problem-based learning approach. Skills acquisition and transfer of knowledge between theory and practice are carried out through hands-on training, workshops, training through internships, project work and supervision. The Deming Cycle (PDSA) [13] is used as the incremental quality improvement model for improving training sessions and the iterative process of developing the MIS system for UCN IP. The research question formulated in this article are:

- *How can teaching and training in developing a MIS for UCN IP help to improve the digital skills?*
- *How does the design and implementation of MIS for UCN IP help to identify non-value activities and at the same time contribute to reflections on improving the decision-making process?*

To achieve the aim and objectives of this paper and answer the research questions, the following data collection methods have been adopted: mixed-method methodology performed by group interviews, observations, and surveys. 37 students from the bachelor's degree curriculum, Product Development and Technical Integration (PTI) [2] and 6 lecturers/researchers has participated in the research program. The modular knowledge and skill improvement are evaluated using a summative assessment for both reactions to the learning activities and learning outcome. The evaluation was submitted to all participants.

3. What is a Management Information Systems?

A Management Information System is an integrated IT system that involves interaction between people, organizations, machines, procedures, databases, and data models. The main purpose of a MIS is to gather, present, and supply intelligent information in a form that assists managers in decision-making [14]. MIS supports successful manager's need to make critical and correct decisions based on timely, relevant, updated and organized information [15]. Concerning all three levels of strategy (corporate, business, and functional) a MIS helps provide a holistic overview that decision-makers can use together with theoretical models like Porter's generic strategies [16] to prepare and execute short-term and long-term strategies. It is possible to obtain a higher level of organizational agility, reduce the impact of disruption, create increased customer value and achieve competitive advantages. The development of MIS systems has changed from a centralized MIS to a distributed and knowledge-driven, user-triggered MIS system. This requires a new development approach. It is no more a structural system in terms of regularly processed preformatted reports [15]. With cloud computing, improved networking technology and connected devices with levels of mobility are added to the system. Software development has gone through numerous changes in recent years. Processes and tooling utilized to facilitate implementation activities are rapidly growing in terms of capabilities and ease of use [16]. The demand for end-user software in software engineering has led to a wider range of software that makes it affordable for small and medium-sized enterprises to explore, experiment and develop applications targeted strategic decision-making. Companies and special SMEs' challenges are the lack of resources, skilled labor, and knowledge about what opportunities end-user software can offer. To identify digitalization potentials within the value stream of UCN IP, digital inefficiencies and non-value activities have been identified related to preventive maintenance for the manufacturing equipment. In the initial state of UCN Learning Factory setup all information is handled in a manual paper-based system with little or no opportunity for collecting data and decisions making.

4. Concept and design approach

The concept behind the design and implementation of a MIS for UCN IP is based on a desire to demonstrate how end-user software can transform a paper-based system into a digital system and thereby improve the strategic, tactical, and operational decision-making processes. End-user software is chosen as the primary development platform due to design criteria that it must be affordable software already available in the market, widely used among companies and without deep programming experience requirements. The MIS system is developed by lecturers, researchers and students connected to the UCN IP program. Through hands-on training and workshops, students acquire specific skills in designing and developing software applications for mobile devices resulting in a working system that can be used in UCN IP. Design Thinking Process approaches are used to focus on creating a demonstrator. The following requirements were decided to be incorporated in the development of MIS for UCN IP:

Table 1: Requirements incorporated in the development of MIS for UCN IP.

Easy access to relevant information	Improve quality of available information	Supports end-user involvement
Handle unstructured/structured data	Reduce knowledge hiding in organization	Supports data-driven decisions from anywhere
Improve business decision making	Reduce wasteful delays	Supports paperless transactions

5. MIS system development and implementation

The development and implementation of the MIS system for UCN IP are based on several different elements.

5.1. Database development

A conceptual data model was used to provide a structured view of data required for supporting the business process and defining the relationships between entities to design the database. An Entity Relationship Diagram (ERD) was constructed, and a data dictionary was used to catalogue and communicate the structure and content of data. Each attribute is provided with meaningful descriptions and records of entities are clearly defined. Various types of Key Performance Indicators (KPIs) are required to be displayed on monitors and mobile devices, and having that in mind the following three tables were identified, shown in the following bullets:

- *Maintenance* – the performed maintenance needs to be traceable and transparent.
- *Equipment* – all machines should be uniquely identified and linked to warranty and running service data.
- *Operator* – the person who performed maintenance on equipment should be traceable.

5.2. Software selection

Microsoft 365 cloud content platform has been chosen as the End-User Development platform because it meets our design criteria for UCN IP and the following requirements, see Table 2:

Table 2: Software requirements.

Easy to build low-code apps	Drag-and-drop user interface (UI)	Supports mobile devices
Easy to deploy across iOS, Android, Windows, and web	Flexible user interfaces (UI)	Supports cloud computing
Easy to update and maintain	High degree of integration	Supports Innovation

The MIS system integrates four software programs, SharePoint, PowerApps, PowerBI and Visio, to streamline the business processes. SharePoint lists are used as a database. Power Apps Studio is used for developing mobile Apps. Finally, PowerBI Desktop is a data-driven Visio drawing used for analyzing, visualization, and creating interactive reports/dashboards.

5.3. Hardware and mobile devices (System setup)

The software is based on a subscriber-based platform, where Microsoft handles maintenance, operation, and updating servers and other hardware. The advantage of choosing software that runs in the cloud is very limited on-premise hardware requirements. The basic requirement for the on-premise hardware is an internet connection and a WiFi access point (ap) that monitors, PCs and mobile devices (see figure 1).

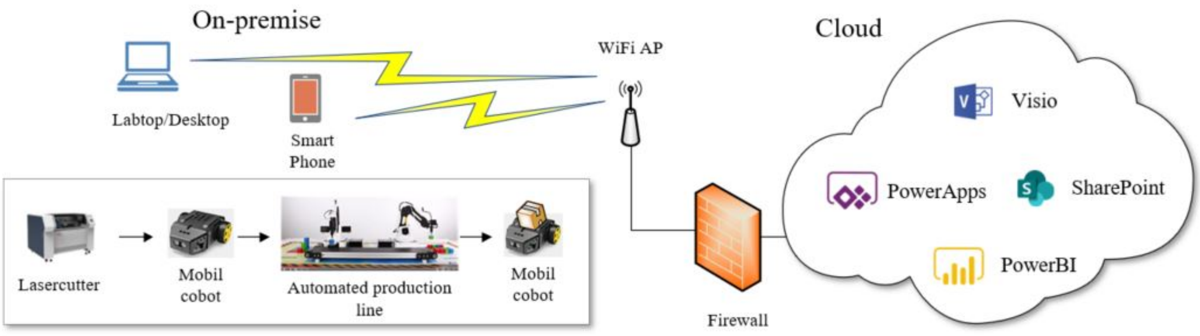

Figure 1 - Figure 1:Overview of system setup.

The interconnection of the UCN IP MIS between the MS 365 components are illustrated in Figure 2.

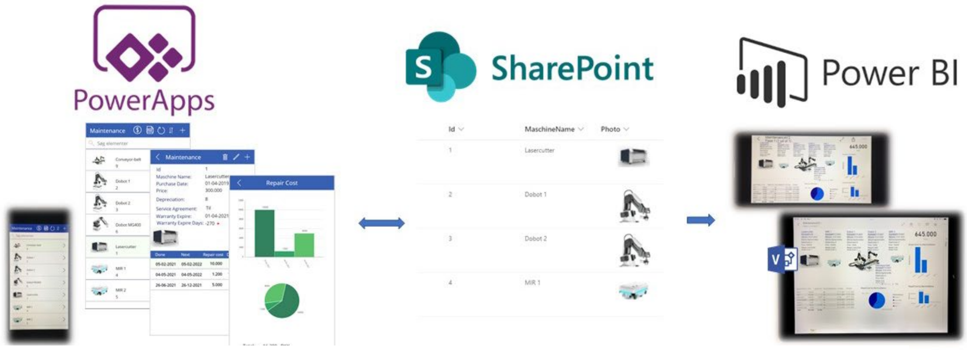

Figure 2 - Overview of the management information system for UCN IP.

6. Result and discussion

The results are based on data collected from 24 students (65% of the questionnaire population), that responded to the surveys to uncover knowledge and skills before and after the lessons have been completed. 9 students have been interviewed. Quantitative data show that 21% of the respondents are women, and 79% are men. The gender gap follows the general representation in STEM education participation and has been the subject of extensive research over many decades [17]. The age distribution in Table 3 shows a relatively large age distribution among the respondents.

Table 3: Age distribution among respondents.

21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	Total
9	6	4	1	2	0	1	1	24
38%	25%	17%	4%	8%	0%	4%	4%	100%

6.1. How can teaching and training in developing a MIS for UCN-IP improve the digital skills?

The analysis of quantitative and qualitative data has made it apparent in the identification of students' hands-on knowledge before and after teaching that respondents have gained significantly greater hands-on knowledge while assessing that their own digital skills have been lifted and improved, see Figure 3 and Figure 4.

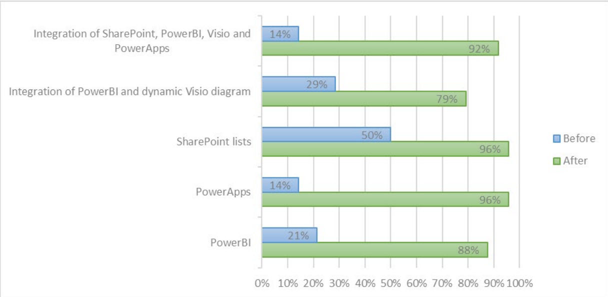

Figure 3: Hands-on knowledge.

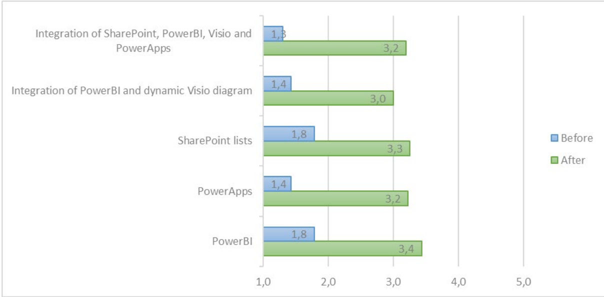

Figure 4: Assessment of own skills. (1 is no skills, 5 is an expert)

Respondents have all indicated that the teaching had opened their eyes to the possibilities of digitizing business processes and given them knowledge and understanding of the use of end-user tools in developing conceptually application that demonstrates and use elements from Industry 4.0. The dataset shows that 92% believe that they will develop applications based on the teaching. Faced with the question: "Do you see the possibilities of including your acquired knowledge of the tools in relation to future study work?" 83% indicate that they are open to incorporating it into projects, internships, and collaborating with companies in connection with the final thesis. 83% also say that the teaching has given them an appetite and desire to improve their skills in using digital tools, including Learning Factory and Industry 4.0. The dataset also shows that 43% of respondents acknowledge that they had no knowledge or acquaintance with the topic of preventive maintenance of machine equipment at the start of the teaching. Students express that the teaching and hands-on training have given them an in-depth understanding of the need to carry out systematic preventive maintenance of production equipment and that digitizing the process can reduce or eliminate time-consuming paperwork. Example of feedback from students "*Preventative maintenance can reduce the number of crashes and ensure operational savings"*. Observations have shown that students have participated with great commitment and perseverance in exploring and acquiring new digital skills. Feedback from group interviews has also shown that digitization and the use of ICT motivate female students when the focus is on application and purpose rather than a narrow interest in the technology itself. Meaningfulness and the possibility to use problem-solving skills are important trickers [18].

6.2. How does the design and implementation of MIS for UCN IP help to identify non-value activities and at the same time contribute to reflections on improving the decision-making process?

Adding a MIS for preventive maintenance and a continuously expanding Learning Factory setup for UCN-IP empowers the students to recognize the relevance. The character generates motivation to learn and the possibility to act hands-on immediately [19]. In previous employments, 36% of respondents have acquired knowledge about the management of production machinery maintenance. The characteristic of all is that they are organized and guided by physical paper-based systems with little or no opportunity for collecting data and for tactical/strategic decisions making. This has given rise to a valuable dialogue and reflection on the need to digitize work processes. As a student describes it: *"Creates good value to have all information about the machines right by the mobile"*. The respondents' insight, knowledge and understanding of the value of a Management Information Systems has increased from 14% to 64% during the teaching process and can be encapsulated in students' reflection: *"The use of MIS can support decision-making processes and can have a direct effect on the efficiency of a business"*. At the same time, it has opened up a number of creative ideas from students to areas where the use of end-user software and elements from MIS for UCN IP can be included in developing prototypes and demonstrators for automation streamlining business processes and improving decision-making. In addition, the same examples for action, communication, visualization and reporting of data related to; quality assurance, traceability of metal parts, work environment, registration of processing times, an overview of ongoing orders and finally dynamic production plan with an overview of order from the ERP system.

7. Limitations, challenges, future goals and work

Parts of the teaching and training to be a hybrid between physical and online lessons because of COVID-19. The didactic planning and coordination had to be modified and adjusted throughout the teaching process. Consequently, additional training and supervision will be provided in the following semester. While Learning Factory is a technical discipline, the goals are human-centric as learning. Hence, educators should test the Learning Factory accordingly, with a naturalistic testing environment and a long formative test phase [20]. In a

Learning Factory environment, this means that, e.g. the UCN digital playground still needs to go into the summative testing phase, where Kirkpatrick testing [21] as an example of reactions, learning, behavior and (industrial) results are evaluated. Hence, the UCN industrial playground is still under development and will need to enter this phase before concluding the impact. The MIS for UCN IP will be further developed with barcode and QR code scanner functionality along with the use of an integrated smartphone camera. Two SME companies have shown interest in testing the system. Students, lecturers/researchers are invited to participate in implementing the system. Their knowledge and experience will be used in the platform's quality assurance and future teaching. UCN has chosen Industry 4.0 and Learning Factory to be an area with high attention for future research. The goal is to continue the successful development and expansion of UCN IP. The expansion makes it possible to work with a complex setup and provides access to programming of PLCs. Furthermore, attention and focus will be on collaborating with companies in developing demonstrators that support value-adding activities.

8. Conclusion and future works

The UCN IP is focused on training undergraduate students with a focus on applying industry 4.0 competencies. With a focus on tools like the MS 365 cloud content platform, an average MS user will be familiar with functions and interfaces that provide a starting point for the data needed to connect different databases and services into a functional MIS system.

The results of the summative survey, comparing the participants both before and after the sessions at the UCN IP, shows that the participants expect to have improved their digital skillset by approximately 212% and group interviews show that a large number ranks themselves as on an "applied level". The session has enlightened participants, with and without prior knowledge of workflows and maintenance at production sites, of the value of going from a paper system with data in hardcopy form to having full access to all data via a connected device.

The students must relate to the subject to give them sufficient knowledge and competencies to actively design and implement similar systems in the industry. Therefore, the UCN IP will continue its expansion into a larger production setting focusing on data collection and decision-making combined with building low code demonstrators for SMEs.

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