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Outline of an Industry 4.0 Awareness Game

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Abstract

The introduction of Industry 4.0 brought a demand outside the academic world for understanding the Industry 4.0 principles and how they will influence the industry and education domain. Aalborg University has developed an Industry 4.0 Awareness Game to address the new paradigm and rapidly emerging technologies. The game is based on the Aalborg University learning factory, AAU Smart Production Lab. The game is an introduction to Industry 4.0 where the participants gain knowledge about the driving technologies and new qualifications. The scope of the game is to provide a platform where the participants will produce the right product at the right time. The participants, who are non-experts and may have different educational backgrounds were divided into six roles/departments: Operator, Production Managers, Logistics, Circular Economy, Service Technician, and Game Observer. Role cards, given to each group, at the beginning of the game, stating the responsible areas and the task descriptions. By introducing new Industry 4.0 technologies, by a deck of game cards, continually in the game, e.g., collaborate robots, data mining, analysis tools, and reconfiguring manufacturing systems, the participants gain first-hand experience on how these technologies influence the production but also on the impact of needed qualifications and management of the production. The game cards may introduce disruptions, e.g., errors of process or conveyors, to create awareness of a weakness in the production and how vital adaptability is in the production. The game received favorable reviews from both participants from the industry and the education domain. Through the experience in the AAU Smart Production lab, the participants gain an understanding of the complexity of a holistic approach. They gain awareness and get inspired on the various ways that different technologies may be integrated and create impact across several traditional functions. As main outcome of this game we highlight the need for an interdisciplinary approach for utilizing Industry 4.0 technologies.

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Keywords: Smart Production Lab; Learning Factory; Learning Game; Game-based Learning; Industry 4.0

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1. Introduction

The introduction of Industry 4.0 (I4.0) technologies will enable manufacturers to cope with the increasing product variety and global competition. However, adapting the rapid and frequently is a challenging task. Companies must learn new technologies and develop new products, processes, and services with ever-increasing frequency. Furthermore, the nature of many of the solutions involves multi-disciplinary activities involving experts, which may not be present in the companies (in particular true in small and medium-sized enterprises (SMEs)). This requires fundamentally different approaches to knowledge acquisition and learning. One way of learning is the use of learning games. Learning games, also known under the name game-based learning or serious game, have been used in centuries, from war-games in the 19th century over Lean Games in the late 20th century to high-tech realistic flight simulation games in the recent years, and have proven to be an effective learning approach [1]. Serious games motivate the participates in achieving new conceptual knowledge and transforming it into conditional knowledge by taking part in the game [1–3]. In the recent decades learning factories have been acknowledged as a platform for both academic and the industry to learn about new technologies and strategies in the manufacturing domain [4–7]. The learning factories utilize the benefit of having a realistic manufacturing environment and recently commissioning learning factories to integrate I4.0 technologies such as cyber-physical systems, RFID-tags, collaborative robot technologies, and vertical and horizontal integration [5,7]. Several learning factories have merged learning factories with learning games, e.g., a logistic game [8], a holistic lean game [9], and an energy efficiency game [3]. Even with the use of learning factories and learning games, SMEs are challenged, due to limited resources in time and money, in gaining new knowledge about the I4.0 technologies and how the new ideas may be implemented [10]. Fairs and typical presentations about I4.0 technologies may give a brief introduction to the various utilized methods, but they lack to provide useful, practical information on the integration of these technologies into the context of an SME. This paper will try to provide a platform to bridge this gap between theory and practice with the proposal of an interactive and immersive I4.0 Awareness game. There the participants will gain experience through playing in a modular, changeable, I4.0 learning factory while they become aware of the implementation potential of I4.0 technologies in SMEs.

The remainder of the paper is divided into four sections. Section 2 will present Aalborg University's learning factory which is the foundation of the Industry 4.0 Awareness Game presented in Section 3. Section 4 describes the learning outcomes from three initial use cases and Section 5 concludes the paper.

2. Aalborg University Learning Factory

Aalborg University (AAU) learning factory, AAU Smart Production lab, illustrated in Fig. 1a, is based on the FESTO cyber-physical didactic system and the principle known from changeable manufacturing systems [11,12]. AAU Smart Production lab is classified as a narrow sense of learning factory with the real value chain, on-site communication and physical manufactured product [13]. The AAU Smart Production lab manufactures a dummy cell phone, illustrated in Fig. 1b, consisting of a product house, circuit board, fuses, and product cover which can be manufactured in 816 variants.

Fig. 1. (a) Illustration of the AAU Smart Production Lab; (b) Illustration of the dummy product.

The AAU Smart Production lab consists of three types of conveyor modules, in total eight conveyor modules where nine different process modules may be mounted on top leading to over 9 million configurations of the system. From the commissioning, in August 2016 a constant development and implementation of I4.0 technologies have been realized to support academic and industrial needs both in teaching and research [13,14]. The AAU Smart Production lab has implemented eight of the nine core technologies identified by [15].

The implemented technologies are: collaborative robots, virtual environments, horizontal and vertical system integration, industrial internet of things, cyber security, use of cloud service, additive manufacturing, and big data and analytics.

3. Industry 4.0 Awareness Game

3.1. Learning Goals

The learning goal of the Industry 4.0 Awareness Game is to provide insight into the potential of I4.0 through a simulation-based, role-play game founded in the driving technologies of I4.0. The primary expectation of the game is to train the participants' conditional systematic knowledge in addressing which technologies/strategies to apply for the right process, on the right module, at the right time with considering the appropriate dependencies. In addition to the technologies and strategies, the participants will gain awareness about the need for new qualifications driven by the latest technologies.

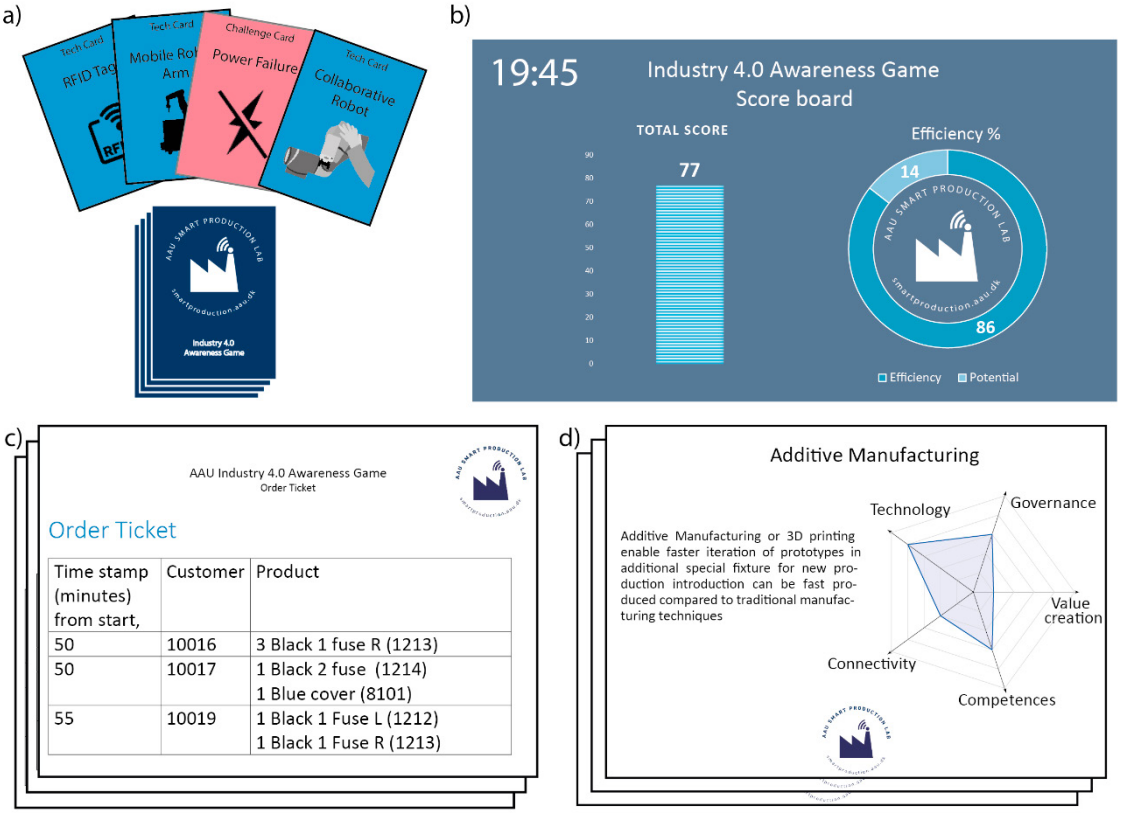

Fig. 2. Illustration of some of the content of the Industry 4.0 Awareness Game. (a) Game Cards; (b) Scoreboard with timer; (c) Order cards; (d) Impact cards.

3.2. Game Contents

The game consists of; the Smart Production Lab as shown in Fig. 1a, Game Cards illustrated in Fig. 2a, a Scoreboard and Timer depicted in Fig. 2b, Order Cards illustrated in Fig. 2c, Impacts Cards illustrated in Fig. 2d, and in addition: Role Cards, Standard Operating Procedure (SOP) sheets, and a Facilitator.

3.3. Game Roles

The participants are divided into six roles/departments: Operator, Production Managers, Logistics, Circular Economy, Service Technician, and Game Observer. The product manager's role is to plan and start production orders while ensuring the target production time is matched. The operator's role is to operate all manual operations supported by SOP, e.g., manual packing products and fill up parts for the machinery. The logistics role is to transport the finished products to the circular facility and ensure that parts return to the production system limited by a minimum waiting time. The circular facility is responsible for the disassembly of the finished products for reuse of the raw material in the production system. The game observer updates the scoreboard (Fig. 2b), registers quality issues, and observe the overall development of the game. Each of the participants receives a role card, describing the nature of the role its responsibilities.

3.4. Game Preparation

Before the game begins, the sequence of game cards deck (Fig. 2a), is packed by the facilitator. The fixed sequence ensures the introduced technologies and challenges are executable in relation to their dependency. However, the participants will experience the game card deck as a randomizer in the game. The facilitator also has the option to customize the Game Deck for specific focus areas or tailor it according to the participants' qualifications. Each technology is prepared for implementation in advance, e.g., if the game card with the collaborative robot is turned a predefined program for the collaborative robot is executed and the right tool is attached before the game starts.

3.5. Game Play

The participants work as a team and must perform accordingly to achieve the game objectives. Fig. 3 illustrates the timeline of the game. The beginning of the game, t0, is an introduction to the game where the AAU Smart Production lab is run as an Industry 3.0 factory. The introduction round familiarizes the participants with the learning factory and sets the conceptional knowledge base for the later reflection of I4.0 technologies and strategies. The introductory manufacturing task is to produce a simple product without any variants (mass production) with dedicated machinery (dedicated manufacturing system). In additional many manual operation tasks and paper information flows are needed to keep producing parts.

After the system familiarization, the first round of the game will begin. The following rounds, game sessions, (t0-t1, t1-t2, t2-t3, t3-t4, t4-t5) are alike in the overall structure. The participants must produce the right product at the right time. This sequence of production orders and product variants are announced by the Order Cards illustrated in Fig. 2c. The Order Cards are given on specific time in the game, so all orders are not known by the participants in advance. The facilitator has the possibility to add "Express orders" or "Cancel orders" to increase or reduce the pressure on the participants. After a product is produced the manufacturing details are added to a spreadsheet updating the scoreboard (Fig. 2b). The scoreboard shows the total score of the game along with an effectivity score, both calculated based on the produced products, the required time and the final product quality.

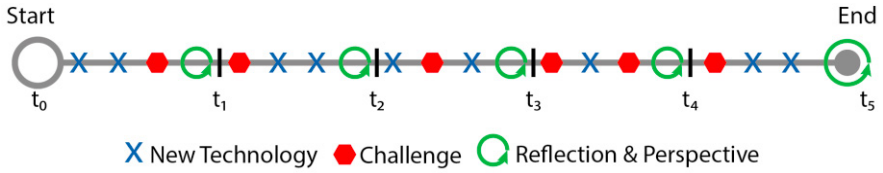

Fig. 3. Timeline of the Industry 4.0 Awareness Game. New technologies introduced by the blue Game Cards and challenges introduced by the red Game Cards. Note that the sequence of technologies and challenges may change from game to game.

Furthermore, to keep producing the right product at the right time, the participants must face changes in the bounding conditions of the manufacturing system introduced by the Game Card deck (Fig. 2a). The participants are asked to draw cards, with an interval of ~3 per section, this interval may be shortening or prolonged depending on the competence level of the participants, from the Game Cards pile to decide if a new I4.0 technology is available (blue background) for the team or a challenge occurs (red background). When a new technology is available the participants will pick the correlating Impact Card (Fig. 2d). The Impact Cards (Fig. 2d), aid the participants in understanding the I4.0 technology and how it will affect the manufacturing system. All Impact Cards hold an explanatory text for the technology along with a spiderweb diagram to visualize its impact. The spiderweb diagram shows the impact on the following topics; technology, governance, value creation competence, and connectivity based on the AAU 360 Digital Maturity Assessment [16]. Each game section concludes with a reflection and perspective session guided by the facilitator. The participants are asked to reflect upon the ways that the newly encountered technologies and/or challenges had affected the manufacturing setup in the learning factory and in which ways they can relate the gained experience in the context of their own business. After the last game session, a longer evaluation and perspective session is performed, t5. The goal of the session is to evaluate the learned awareness level of I4.0 technologies, the appropriate level of qualifications needed, and general evaluation of the Industry 4.0 Awareness Game. The evaluation is performed as an unstructured interview with the participants.

4. Play to be Aware

Two pilot games and one full-scale game test have been conducted to test the prototype idea of the Industry 4.0 Awareness Game. The result from the performed trials indicate that a learning game is a viable approach to create awareness of industry 4.0 technologies for non-expert participant. One of the major learning outcomes from the participants, of all three sessions, was that interdisciplinary qualifications are a requirement for a successful implementation of I4.0 technologies and methods.

The initial pilot game tested the overall concept and interaction with the AAU Smart Production lab as a game platform proved the significance of the respective roles and game goals. The total duration of the first pilot game was two hours including one hour of introduction with 24 non-expert participants. Two 1-hour sessions were conducted where each concluded with a reflection and discussion session. The main learning point from the first pilot was that a reduction of the number of participants was necessary to ensure sufficient immersion and hands-on experience and to create better awareness of the specific technology impact and potential. Furthermore, a reduction of production orders was needed to ensure lower stress factor during the game. Participants expressed strengthened awareness of the technologies impact and effect on the qualification level of the traditional production roles. The participants displayed an awareness of the impact of new technologies and could relate these and their potential to other production scenarios.

The second pilot game experimented with the full game structure and elements as presented in Section 3. The second pilot game was conducted with fewer participants and lasted an hour including the introduction. The participants were a mixture of experts and novices who managed to reach a total score of 27 points. Two game sessions were conducted. The participants expressed that a strong involvement was reached and a general awareness of the complexity of the production was gained.

The first two games pointed out the fact that a higher emphasis on the introduction to the AAU Smart Production lab and general I4.0 knowledge is needed. Therefore, a full-scale game test with a total duration of 3.5 hours including an hour of introduction was conducted with non-expert participants. Four game sessions were conducted, resulting in 1.5 hours game time and an hour of discussions and reflections on both awareness and gameplay. The participants reached a total score of 49 points. Participants expressed high levels of engagement and stressed the importance of the facilitation role during game sessions and discussions. Several challenges experienced by the participants in lower level of the game were addressed by new technology introductions, and the potential impacts discussed between sessions. The challenges in the lower level lead to a discussion on how the traditional operator qualifications need to change for such production line, e.g., a demand for higher IT competencies in relation to work with I4.0 technologies.

5. Conclusion and Discussion

The initial test of the Industry 4.0 Awareness Game indicates that a role-play learning game based on a learning factory platform can provide a deeper understanding of the driving technologies in I4.0 and the derived qualifications. The participants gain awareness and get inspired on the various ways that different technologies may be integrated and create impact across several traditional functions. As main outcome of this game the need for an interdisciplinary approach for utilizing I4.0 technologies were highlighted by the participants. It has been evident that the use of a physical learning factory sets the limitation on the number of participants, to ensure a higher learning outcome. One learning outcome from our tests is that having two participants occupying each role, as presented in Section 3, in total 12 participants is a favorable number for the use of the AAU Smart Production lab as a game platform. Regarding the duration of the game, we can conclude that 2.5 hours per session preceding of an hour of introduction is the optimal point where the participants can remain engaged and reach a satisfactory awareness level of I4.0 technologies and qualifications.

For future research, an awareness level measurement will be developed enabling a more quantitative evaluation of impact of the Industry 4.0 Awareness Game. Ten regional SMEs will be invited to try the Industry 4.0 Awareness Game. It is expected that these SMEs will gain a better insight into which technologies are relevant to their business as well as what qualifications they need to develop themselves or acquire from others. A preliminary study among regional SMEs indicates that 2.5 hours game time is appropriate concerning the SMEs resources. Future development of the game may involve a template for how to introduce new technology to the game.

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