Research

E.2 An Educational Serious Game for investigating perceived Impacts of Digital Technologies on Employee Well-Being and Organizational Performance

Jan-Phillip Herrmann[1], Yutaro Nemoto[2], Dennis Kobelt[3], Marvin Goppold[4], Sven Tackenberg[1]

[1]Ostwestfalen-Lippe University of Applied Sciences and Arts, Department of Production and Wood Technologies

[2]Tokyo Metropolitan Industrial Technology Research Institute, IoT Development Sector

[3]Nachwuchsstiftung Maschinenbau gGmbH

[4]RWTH Aachen University, Institute of Industrial Engineering and Ergonomics

1 Introduction

Students at universities of applied sciences have to be able to transfer learned skills and knowledge to solve practical problems in the industry after graduating. Industrial engineering students at the Ostwestfalen-Lippe University of Applied Sciences and Arts need to apply acquired knowledge when designing work systems that contribute to the organizational performance of companies and the individual well-being of employees. Digital technologies transform human work in manufacturing and affect both sides of the same coin (Becker & Stern, 2016; Kadir & Broberg, 2020). Thus, industrial engineers need to evaluate the impact of these technological solutions on multiple objectives of organizational performance and employee well-being when designing work systems.

The advancing adoption of digital technologies by society has spurred a debate on their impacts on human well-being and ethical issues (Burr, Taddeo, & Floridi, 2020; Floridi et al., 2018). E. g., human-centered assistance systems can support workers by automating monotonous work, and VR-based training can enhance workers' capabilities effectively. Issues such as excessive surveillance, data governance, and jobs at risk represent the downsides of these technologies. Research has shown that the initial success of technological solutions depends on people's attitude towards their perceived usefulness and ease of use (Venkatesh & Bala, 2008). Some studies suggest that people's perception changes with cultural background (Straub, Keil, & Brenner, 1997).

This paper presents a serious game in which players assess digital technologies' impact on organizational performance and employee well-being, enabling to collect data about intercultural differences between people's decisions. Serious games are games designed to acquire knowledge or skills through playful applications (Dörner, Göbel, Effelsberg, & Wiemeyer, 2016) but enable to collect data from collective activities while playing the game.

Applying the serious game in an educational context, the aims of the serious game are twofold:

1. To educate players about evaluating the impact of technological solutions on multiple objectives of employee well-being and organizational performance.
2. To investigate intercultural differences in people's choices between traditional and technological solutions concerning organizational performance and employee well-being.

2 Related Work

The relations between individual well-being and organizational performance are not simple and linear. There are three notable reasons for this. First, an organization is not merely the sum of individual workers. At the individual level, subjective well-being and work performance strongly relate to each other (Gagné & Deci, 2005). On the other hand, the indicators of organizational performance include not only drivers (e. g., time-related, cost-related, and process performance) but also outcomes (e. g., financial, customer, and social/environmental performance) (Hubbard, 2009; Van Looy & Shafagatova, 2016). While the former is the sum of work performance of individuals in large part, the latter cannot be reduced to individuals. Second, there are ambivalences between some components of well-being and performance. For instance, rules and regulations for the improvement of organizational performance sometimes force a sacrifice of the autonomy of individual workers, one of the basic components of well-being (Ryan & Deci 2000), is sometimes restricted to improve organizational performance (Taris & Schaufeli, 2014). Third, as examined in well-being studies, well-being components and their priority depend on an individual's goals and, thus, different across cultures (e. g., Oishi & Diener 2009). In a similar way, there can be intercultural differences in how people define and prioritize components of individual well-being and organizational performance. For these three reasons, assessing the impact of digital technologies or solutions on well-being and performance is challenging for industrial engineers. Therefore, it is required to offer a tool (1) to acquire knowledge and skills for the assessment in the educational context and (2) to investigate differences in the prioritization and assessment especially from the intercultural aspect in the scientific context.

The term "serious game" can be defined from several perspectives (Laamarti, Eid, & El Saddik, 2014) and intersects with definitions of other types of games like business games or simulation games (Greco, Baldissin, & Nonino, 2013). We adopt the term serious game orienting at other games similar to ours, like e. g. "Factory Planner", a serious game based on the VDI 5200 standard for factory planning. This is a classic board game where players should learn about applying a simplified version of the VDI 5200 standard, designing material flows, and learn to identify and react to sustainability- and digitalization-related events (Severengiz, Seliger, & Krüger, 2020).

A simulation game by Da Silva, Xambre, and Lopes (2013) in the context of industrial engineering demonstrates the applicability and potential advantages of lean production to students or professionals. This game allows gaining experience and understanding the lean production principles by focusing on experimental learning (Da Silva, Xambre, & Lopes, 2013). However, in addition to the educational benefit that serious games create, they can collect data from players. These specific types of serious games are called "games with a purpose" (Von Ahn, 2006). The reviewed serious games do not allow players' choice between equivalent traditional and technological solutions. Additionally, they do not incorporate an assessment of players' choices regarding organizational performance and individual well-being. We present a serious game to meet these requirements and explain its didactical concept, design, and application with students from Germany and Japan in the subsequent sections.

3 Serious Game Design

3.1 Didactical Concept for Player Education

The lecture production planning and control at the Ostwestfalen-Lippe University of Applied Sciences and Arts aims to foster students' comprehension of production planning and control principles and design options as well as reasoned application of basic methods. The conceptual foundation is the constructive alignment (Biggs, 1996). For instance, these selected learning outcomes derive with the help of Krathwohl (2002):

- Students solve situated problems in the domain of production planning incorporating classical (traditional) and modern Internet of Things (technological) solutions. They focus on the main problems as well as professional and enterprise perspectives to derive substantiated choices of favorable solutions reflecting their impact.
- Students find compromises for clashes of personal and professional interest and disciplinary conflicts while solving problems of strategic production planning.

The learning outcomes include without limitation the following disciplinary scientific knowledge and ascent during the learning process in the lecture:

- Objectives and production functions, data basis, production plan generation.
- Kanban, CONWIP, Just in time, Just in sequence, Optimized Production Technology, Load Oriented Order Release.
- Production planning and control systems and their relation to work systems.

Due to the practical implications and references to work in the engineering disciplines at a university of applied sciences, the chosen professional knowledge does not satisfy all aspirations.

Therefore, situated and problem-based learning need to complement traditional higher education learning to achieve the learning outcomes. Hence, applying the serious game will help transfer scientific knowledge in a situated work context (cf. Schwägele, 2015). In light of the problem-based gaming model (Kiili, 2007), playing the game helps to reflect and learn problem-solving strategies for workplace problems, referring to double loop learning (cf. Argyris & Schön, 1978). Students test their strategies while making decisions based on previous experience and assumptions. Playing the game with a maximum of four players allows them to support each other when discussing the game's outcomes and reflect their decision-making based on preliminary information. They reason alternating positions and differing perspectives resulting in improved strategic planning and problem-solving skills based on scientific knowledge in the double loop. So, students present and discuss different norms and values that relate to the different solution options and are part of typical inner-company and social debates concerning technological or organizational change processes.

To motivate the students extrinsically, they can earn an exam bonus when playing the game. The game will also prepare students for assessing the learning outcomes that take place in written exams. The intended findings of the intercultural study shall enhance the further development of the game and are part of a scholarship of teaching and learning approach to reflect the design of the own lectures.

3.2 Setting, Structure, Processes, and Mechanics

The serious game called "Fridge Factory" confronts players with problems of a medium-sized manufacturer of refrigerators facing several problems. These problems address e. g. work system design, personnel management, employee health, or sustainability in different departments after releasing a new refrigerator variant into the market. A players' goal is to adopt the best solutions to solve the problems and improve organizational performance in combination with employee well-being. Four players play four rounds supervised by a game master who enters the players' decisions into a game application. The game application computes the players' scores for each round. The player with the highest score wins after the last round has finished. The game components include the following five types of game cards (Figure 1):

- 24 criteria cards: Representing twelve individual (employee) well-being and twelve organizational performance criteria, identified in the authors' literature review. These cards help to measure the impact of a solution selected by a player.
- 16 problem cards: Describing various problems that occur in the company.
- 16 solution cards: Comprising eight technological solutions and eight traditional solutions. Every technological solution has a substantive traditional card. The solution cards have a predefined positive or negative impact on every criterion and problem card, which players do not know.

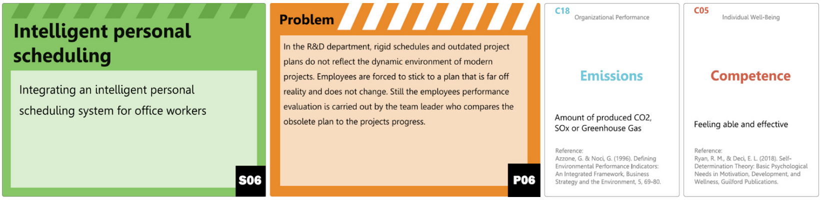

Figure 1: Examples of Criteria (right), a solution (left), and a problem (center).

Initially, players select six criteria from the 24 criteria c_k serving as a basis for their score calculation. They select three criteria from the set of twelve individual well-being criteria ($12 \geq k \geq 1$) and three criteria from the set of twelve organizational performance criteria ($12 \geq k \geq 1$). To each criterion, players assign a weight $w_k = \{1,3,5\}$ used in the normalized form $w_k^* = \frac{w_k}{(1+3+5)}$ in the score calculation. In each round, players are confronted with the problem p_j which they are ought to solve using one of the 16 solutions available on the game board. The score of a player in each round computes as follows:

$$Impact_{ji} \cdot \left(\sum_{12 \geq k \geq 1} w_k^* \cdot Impact_{jk} + \sum_{24 \geq k \geq 13} w_k^* \cdot Impact_{jk} \right)$$

Where $w_k^* = 0$ if the criterion k is not a chosen criterion of the player and , $Impact_{ji}$, $Impact_{jk}$ represent the predefined impact of the solution j on the problem i and the criteria k. Applying the distributive law, a players' score for individual well-being and organizational performance can be calculated separately. The setup of the game illustrates Figure 2.

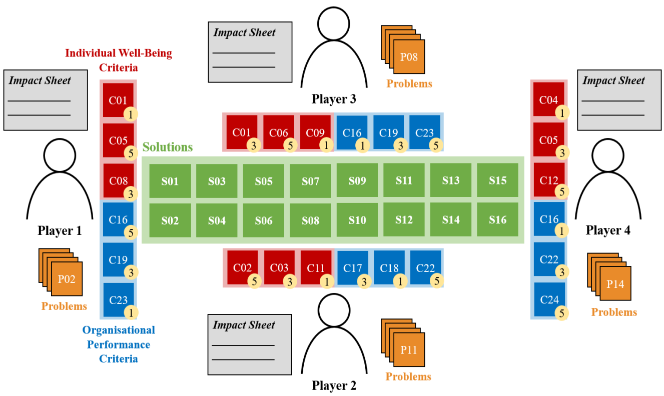

Figure 2: Setup of the game "Fridge Factory".

4 Study of Intercultural Differences in Perceived Social Impacts of Digital Technologies

4.1 Aims, Hypotheses, and Methodology

The present study aims to investigate the differences between German and Japanese players. A previous publication presented a data analysis of the game played in Germany (Nemoto, Kobelt, Herrmann, & Tackenberg, 2021). Two research questions were addressed: (1) When players select between organizational performance and individual well-being criteria, do players show a preference, and, if yes, which criteria do players prefer? (2) When selecting between traditional or technological solutions, do players show a preference for a category, or do they decide indifferently? Based on previous studies about technology adoption across cultures (Straub et al., 1997; Lee, Trimi, & Kim, 2013), we expect a non-evenly distributed frequency of selected criteria and solutions comparing German and Japanese players. Twelve games were played with 43 German students of the lecture Production Planning and Control at the University of Applied Sciences and Arts in Lemgo, Germany, and thirteen games with students of the lecture Design Engineering at the Tokyo Metropolitan University, Japan. Initially, students were introduced to the topic of organizational performance and employee well-being and the aims, purpose, and practical relevance of the serious game. In Germany, due to the global pandemic COVID-19 during November and December 2020, the game was played online using the web conference tool Cisco Webex. Instead of picking cards from stacks, the criteria and solution cards were provided in a PDF file through the university's e-learning system. Additionally, four problem sets with problems in a random order have been prepared. During a game, the game supervisor sent the problems in one problem set to each player in the private chat provided by Cisco Webex. The players then communicated their choices and reasoning to the game supervisor, who entered the information into the game application and shared the player's scores through screen sharing. 72% of players were male, and 28% female students with an average age of 24 years. In Japan, the game was played in May 2021 during a lecture. Initially, the lecturer explained the available criteria, and on that basis, students chose their set of criteria. In each round, students selected a problem card and chose a solution to solve the selected problem. Due to a lack of game supervisors, players stored their choices in a Google spreadsheet. Problem and solution cards were provided in a Google Drive folder. The scores were computed after playing the game and communicated via the e-learning system.

4.2 Results

For answering the first research question, a one-way Pearson Chi-Square test on the German data rejects the null hypothesis that each criterion was selected with the same frequency ($\alpha = 0.05$). Performing the same test on the Japanese data yields the same outcome. These results indicate that German and Japanese players select some criteria over others more often.

The relative number of times the criteria were chosen and the relative number of times the criteria were chosen multiplied by the chosen weight in the corresponding game illustrate the bar charts in Figure 3.

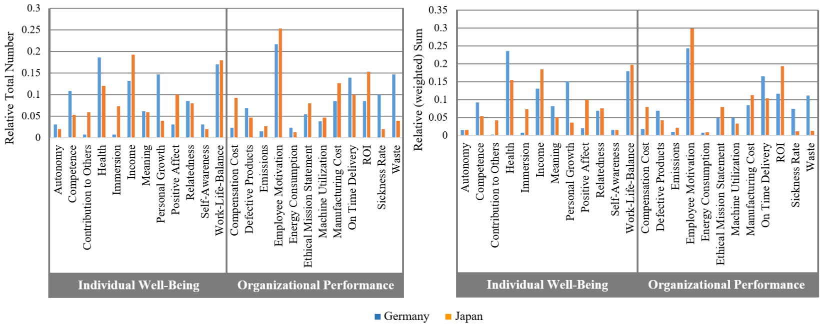

Figure 3: Players' Criteria Selection.

Addressing the second research question, we compare the frequencies of players choosing a traditional solution or a technological solution illustrated in Figure 4. In the German data, a two-sided binomial test ($\alpha = 0.05$) rejects the null hypothesis of players choosing either a traditional or technological solution with equal probability. It indicates that German players tend to tackle the problems given in the game with traditional instead of technological solutions.

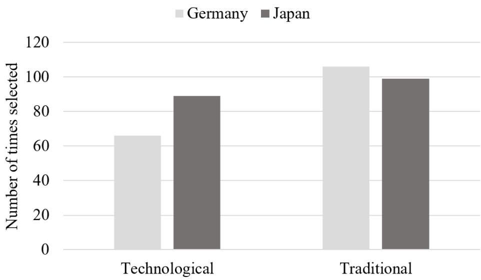

Figure 4: Selection of traditional and technological solutions.

In the Japanese data, the null hypothesis could not be rejected, which means that Japanese players do not show a preference between traditional and technological solutions when tackling the problems in the game. These results provide evidence that German players may perceive lower positive or higher negative impacts of digital technologies on employee well-being and organizational performance.

5 Discussion

The results illustrate a balanced game design between traditional and technological solutions that fits the game's intention for Japanese students. Moreover, it points out that the German lecture seems to support preferences in traditional solutions. That might align with some managerial-oriented learning outcomes, or a too less emphasized contradiction towards possible cultural biases of German students. From a didactical perspective, the study highlights possible differences in both underlying lectures besides the investigated cultural differences. The lectures in Germany and Japan differ in their intended outcomes and linked content. In Germany, they address the engineering or shop floor area and solutions on a managerial level, while in Japan, they focus in major parts on engineering. Varying the cultural background and the lecture simultaneously is a limitation in combination with the chosen research design. Thus, the results do not allow interpreting any cause-effect relationship from the observed data.

6 Conclusion

We developed a serious game in which players choose between traditional and technological solutions based on perceived impacts on initially selected organizational performance and individual well-being criteria. We outlined the didactical concept of the game and showed how the game's data provides a potential for different analyses. Future studies will employ the serious game to measure students' learning outcomes and investigate differences in players' choices regarding age, gender, and culture. In addition, a mobile phone app version of our game will be developed, enabling players to play the game without a game board and remotely, rendering our serious game fully enhanced by software. For sophisticated future studies, challenges are the didactic adjustments of the lectures in Germany and Japan to achieve comparable learning outcomes and learning processes in order to neglect its role as a confounding variable.

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