

Evaluation of Empirically Collected Feedback from a Simulation Game for Digitalised Production

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Abstract: Digitalisation causes a fundamental change in industrial production and brings new challenges for which employees in the manufacturing industry must be trained. A simulation game developed by researchers of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA supports this change process, from lean production to digitalisation in production through a game-based qualification. To evaluate how qualified employees are and to what extent they accept digital transformation, a quantitative survey was designed and filled out by the participants after each simulation game workshop. This paper aims to examine the mindset of different focus groups regarding their awareness of ongoing challenges concerning digital transformation. The survey results show that despite challenges due to the changes in production technologies and environments caused by Industry 4.0, the simulation game has generally contributed to a better understanding of the impact of digitalisation and the acceptance of the changes in production caused by the digital transformation.

Keywords: Simulation game, digital transformation, digitalised production, game-based simulation, evaluation

1. Introduction

The simulation game (Yesilyurt *et al.*, 2019) described here is integrated into the Future Work Lab (FWL) - the innovation lab for work, people, and technology of Fraunhofer IPA and Fraunhofer IAO in Stuttgart. The FWL (Issa *et al.*, 2018) is a research project funded by the German Federal Ministry of Education and Research (BMBF). It opened in 2017 and was in its second three-year funding period while collecting feedback during the simulation game. It is a platform that bundles numerous activities to research future production work. In this course, it also deals with production systems, the associated technologies, and how they will be innovated in the future.

Due to the diverse thematic approach of the FWL research project, a wide variety of different user groups need to come together. Especially in the interaction with the simulation game participants, the different views on Industry 4.0 specific topics become apparent, and other user groups bring a different level of experience and knowledge.

Industry 4.0 describes the fourth industrial revolution following the invention of the steam engine, industrialization, and the dawn of the computer age (Bauer *et al.* 2019). The specific term 'Industry 4.0' was first introduced in 2011 and is broadly published in Germany because of its strategic initiative status for the German federal government (Dombrowski, Richter and Krenkel, 2017), with which the digital transformation has gained more significant importance for the manufacturing companies.

The ongoing digital transformation in manufacturing companies leads to a wide variety of new digital solutions and applications introduced on the shop floor. They do not only have an impact on current working processes but also require new skills of the company employees (Pittich, Tenberg and Lensing, 2020). This results in a twofold challenge for a manufacturing company. On the one side, employees must learn how to deal with the new technologies; on the other side they must become familiar with the new processes (Bauer *et al.*, 2018). Both challenges bring about significant change for the workers. Hence, suitable change management for a significant fraction of the workforce is needed during the company's digital transformation. This includes a human-centric approach (Leyer, Richter and Steinhüser, 2019) results in a higher acceptance rate for the new digital solution. The term Human-centric means not only having the workers and their needs in mind but also helping them understand what will change with the new solution, why this change is necessary and what kind of benefits it brings to the workers. As presented and discussed in this paper, a simulation game can be a cornerstone for reaching this target.

Section 2 introduces the survey motivation for the simulation game. After that, the study design with the simulation game survey is introduced in section 3. Section 4 presents the collected feedback from different focus groups. The last section concludes with a summary, and overall critical appraisal of the focus groups' statements, highlighting future research plans for the simulation game.

2. Survey Motivation

New technologies support the company's vision of digitalised production, but they also entail a constant change through the deployment of new solutions. The simulation game is designed to sensitize participants to the current challenges of digital transformation and give them an understanding of the practical use of new technologies. After the successful execution of the simulation game, quantitative surveys (questionnaires) are handed out to the participants to get feedback on learning achievements, motivation, game organization, and execution.

The survey was performed with three focus groups: manufacturing company employees, works council representatives, and future qualified employees (FQE) (students). The manufacturing company employees are the employees on the shop floor with either equipment (manufacturing machines) or IT systems focus. Secondly, the works council representatives are employees on the shop floor who also work in a works council to protect the rights of the employees and support them in the internal company problems. Last, the FQE are university students and working students in the companies.

The survey's motivation is to investigate the differences of the focus groups in raising awareness of digitalised production with the simulation game and to comprehend the mindset of different roles and generations in the companies. The following section describes the survey design.

3. Study Design

All data were collected by hand, and no secondary, already existing data set was used. Therefore, the data collection for this paper can be characterised as the primary analysis. The data was collected through a survey in the format of a quantitative questionnaire in written form.

The paper follows a descriptive approach to describe the entirety of the respondents or group of respondents as precisely as possible about selected characteristics. The data acquisition can be characterised as a group study. However, this does not represent a comprehensive survey but only a sample of the people in the group. Also, it does not represent the entire group who completed the simulation game fully and partly because the feedback collection was only integrated later from the simulation game's executions between 14-12-2018 and 28-10-2021. Consideration should be given to the fact that the simulation game was only carried out to a very limited extent during the restrictions in force due to Covid-19. The number of participants hardly increased significantly during this period.

Likewise, the sample cannot be declared as a random sample selection. Therefore the sample must be classified as non-random and arbitrary. The reason for this is that not all potential participants have completed the simulation and provided feedback on it. The entirety of all potential participants would consist of the entirety of the defined and addressed target group. Accordingly, the results presented in this paper cannot be considered representative of entirety of the focus groups. The aggregated findings, representations, and statements presented here refer only to the sample that participated in the survey. Statements about the population of all potential participants of the simulation game, qualified employees with a manufacturing background, cannot be derived from this. Therefore, the formation of interference statistics is impossible, and the results presented here refer exclusively to the respondents.

A questionnaire in written form is used as the quantitative empirical survey. The raw data obtained from this was encoded using IBM SPSS Statistics (IBM, 2022). The resulting numerical data set was also analysed using SPSS and the available descriptive analysis methods.

The survey was created in two main categories. In the first category, the content of the simulation game was assessed. This category consists of 10 closed-ended statements. With the help of these statements, the learning outcome and the acceptance of the participants built up by the simulation game could be measured. The second category includes the assessment of the execution of the simulation game and contains 12 statements. The focus

of this category lies in the execution and organisation of the simulation game and the participants' motivation. The response options for the respective statements are all characterised by ordinal scales indicating the degree of agreement in the form of a ranking. The particular type of ordinal scale used here, a so-called Likert scale (Likert, 1932), has the same answer options across all statements:

- 1: Strongly agree
- 2: Agree
- 3: Neutral
- 4: Disagree
- 5: Strongly disagree
- No statement

The response options for the respective statements are all characterised by ordinal scales that indicate the degree of agreement in the form of a ranking. The mode and the median are given here as position parameters. Typically, no mean value can be calculated for ordinal scales. In this paper, the mean value is included. However, not for interpretation as an average value but rather to make a trend visible (Statista, 2022).

Table 1: Focus groups' information

Focus group	Number of workshops	Number of participants	Proportion
Manufacturing companies' employees	8	69	59 %
Work council representatives	3	32	27 %
Future qualified employees (FQE)	2	16	14 %

The simulation game is evaluated by 117 participants using the survey questionnaire. Table 1 visualizes the number of participants in the different focus groups. The collected data is further presented and analysed in the next section.

4. Study Results

As described in section 3, there were two categories of statements to collect feedback. The first group of statements was about the acceptance and reception of the technical content. The second group of statements addresses the execution and organization of the workshop - the letter E is added to the numbering of this group. Table 2 shows these two grouping statements.

Table 2: Study statements

Code	Statements
S1	Through the simulation game, I have understood what Industry 4.0 (digitalization) means and the principles behind it.
S2	The simulation game showed me the possible changes and opportunities caused by Industry 4.0.
S3	I believe that the simulation game has prepared me well for the future challenges of Industry 4.0.
S4	The simulation game concept helped me better assess my present and future situation.
S5	I realized that Industry 4.0 is based on already optimized processes (LEAN).
S6	The digitalised game round showed that Industry 4.0 makes processes more transparent.
S7	Digitalisation simplifies my work because the processes are structured with less paper.
S8	I have understood in which areas of my company Industry 4.0 has the most significant impact.
S9	The simulation game showed me how the variant-rich production could be supported by Industry 4.0.
S10	I will continue to practice the knowledge gained in the simulation game in the distant future.
S1E	The topic of the simulation game interested me.
S2E	The contents were explained in a comprehensible way.
S3E	The objectives of the simulation game were clearly defined.
S4E	The content structure of the simulation game was easily understandable.
S5E	I was motivated to think outside the box.
S6E	The simulation game encouraged my interest in the topic of Industry 4.0.
S7E	The content provided has an excellent relation to practice.
S8E	My expectations regarding the simulation game were fulfilled.
S9E	I have learned a lot from the simulation game.
S10E	The simulation game was well organized.
S11E	I was supervised well during the simulation game.
S12E	I can further recommend this simulation game.

Table 3 shows the recorded results for all statements in both categories. The coding of the response options to the statements corresponds precisely to the Likert scale given in section 3. The table shows the number of valid votes and the missing votes next to the codes for the respective statement. The mean, median, and mode are given as position parameters, while the standard deviation and variance are given as dispersion parameters. As already described, this is not an average in the sense of the arithmetic mean because this cannot be specified for ordinal scales. Instead, the aim is to be able to recognize a trend in the distribution of the answers. Thus, the standard deviation and the variance are not interpreted in the classical sense either. However, these were also applied because exemplary statements were selected for explanation with a high or low standard deviation.

Table 3: Study results

Code	Number of valid entries	Number of missing entries	Mean value	Median	Modus	Standard deviation	Variance
S1	116	1	1.86	2	2	0.768	0.59
S2	116	1	1.95	2	2	0.8	0.641
S3	116	1	2.47	2	2	0.774	0.599
S4	114	3	2.26	2	2	0.831	0.691
S5	115	2	1.82	2	2	0.79	0.624
S6	112	5	1.59	1	1	0.692	0.478
S7	116	1	1.84	2	1	0.913	0.834
S8	115	2	2.22	2	2	0.825	0.68
S9	116	1	1.84	2	2	0.802	0.643
S10	114	3	2.17	2	2 ^a	0.861	0.742
S1E	117	0	1.38	1	1	0.57	0.325
S2E	117	0	1.46	1	1	0.65	0.423
S3E	117	0	1.52	1	1	0.651	0.424
S4E	117	0	1.44	1	1	0.594	0.352
S5E	117	0	1.74	2	1	0.835	0.696
S6E	116	1	1.8	2	1	0.794	0.63
S7E	117	0	1.82	2	2	0.795	0.631
S8E	116	1	1.84	2	2	0.768	0.59
S9E	114	3	2.28	2	3	0.955	0.912
S10E	117	0	1.49	1	1	0.677	0.459
S11E	117	0	1.36	1	1	0.594	0.353
S12E	117	0	1.4	1	1	0.573	0.329

Exemplary evaluations of the statements follow to gain more insight into the focus groups' feedback. Therefore, Statements with excellent and poor average values and statements with high and low standard deviations were selected and presented below.

Table 4: Statement S11E results

S11E		Strongly agree	Agree	Neutral	Sum
Category	FQE	81.25%	18.75%	0.00%	100.00%
	Manufacturing companies' employees	68.12%	24.64%	7.25%	100.00%
	Work council representatives	68.75%	25.00%	6.25%	100.00%
Sum		70.09%	23.93%	5.98%	100.00%

The statement (with an excellent mean value of 1.36) results in Table 4 show that approximately 94 % of the participants believe that they were supervised well during the simulation game. Only 6 % of the participants (especially manufacturing companies' employees and work council representatives) found the supervision satisfactory during the simulation game. This proves that the supervision of the simulation, independent of different focus groups, was in order for the general population of simulation game participants.

Table 5: Statement S1E results

S1E		Strongly agree	Agree	Neutral	Sum
Category	FQE	60.87%	34.78%	4.35%	100.00%
	Manufacturing companies' employees	71.88%	21.88%	6.25%	100.00%
	Work council representatives	65.81%	29.91%	4.27%	100.00%
Sum		65.81%	29.91%	4.27%	100.00%

Table 5 illustrates the results of the statement S1E (with an excellent mean value of 1.38). According to the results, approximately 96 % of the participants were interested in the topic of the simulation game. Only 4 % of the participants did not have much interest in the simulation game topic. This indicates that Industry 4.0 is an exciting topic for the general population of simulation game participants.

Table 6: Statement S3 results

S3		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Sum
Category	FQE	18.75%	50.00%	25.00%	6.25%	0.00%	100.00%
	Manufacturing companies' employees	7.35%	38.24%	44.12%	8.82%	1.47%	100.00%
	Work council representatives	6.25%	50.00%	43.75%	0.00%	0.00%	100.00%
Sum		8.62%	43.10%	41.38%	6.03%	0.86%	100.00%

The results of the S3 statement with a poor mean value of 2.47 were presented in Table 6. It is observed that about half of the manufacturing companies' employees and the work council representatives were satisfied that the simulation game has prepared them well for the future challenges of Industry 4.0. On the other hand, according to the statement's results, the simulation game helped prepare the FQE for the future Industry 4.0 challenges. It shows that they benefit more from the simulation game because they do not see the challenges in the same way as the more qualified employees in this simulation game's focus group.

Table 7: Statement S4 results

S4		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Sum
Category	FQE	62,50%	31,25%	6,25%	0,00%	0,00%	100,00%
	Manufacturing companies' employees	11,94%	41,79%	40,30%	4,48%	1,49%	100,00%
	Work council representatives	9,68%	48,39%	38,71%	3,23%	0,00%	100,00%
Sum		18,42%	42,11%	35,09%	3,51%	0,88%	100,00%

Statement S4 with a poor mean value of 2.26 (see Table 7), describes that the simulation game helped the participants to better assess their current and future situation regarding Industry 4.0. Two trends are observed here. While the FQEs answered this very positively, the response of the experienced employees for this statement was between 'agree' and 'neutral'. An interpretation can be that inexperienced participants learned a lot from the simulation game and answered this statement more positively than other focus groups. Nevertheless, in general, more than the majority of the simulation participants think they have a better assessment of their current and future situation after the simulation.

Table 8: Statement S7 results

S7		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Sum
Category	FQE	75,00%	18,75%	0,00%	6,25%	0,00%	100,00%
	Manufacturing companies' employees	50,00%	41,18%	7,35%	1,47%	0,00%	100,00%
	Work council representatives	12,50%	37,50%	34,38%	12,50%	3,13%	100,00%
Sum		43,10%	37,07%	13,79%	5,17%	0,86%	100,00%

Table 8 indicates the results of statement S7, which has the highest standard deviation. This high standard deviation was caused by the different opinions of the participants about the statement. On one side, after the simulation, most of the work council representatives have expressed their opinion that digitalisation does not simplify their work because the processes are structured with less paper. On the other hand, more than 90% of FQE and manufacturing companies' employees had the opposite opinion. Their results show that digitalisation helps the processes be structured with less paper, simplifying their work.

Table 9: Statement S12E results

S12E		Strongly agree	Agree	Neutral	Sum
Category	FQE	87,50%	12,50%	0,00%	100,00%
	Manufacturing companies' employees	56,52%	36,23%	7,25%	100,00%
	Work council representatives	68,75%	31,25%	0,00%	100,00%
Sum		64,10%	31,62%	4,27%	100,00%

The statement S12E results with the lowest standard deviation are indicated in Table 9. More than 95 % of the participants recommend this simulation game to others. Furthermore, only some participants from the focus group “manufacturing companies’ employees” answered this statement with 'neutral'.

5. Summary and Outlook

This paper examines the mindsets of different focus groups concerning the ongoing challenges of digital transformation. First, the impact of the digital transformation in manufacturing and the human-centric approach are described. After that, the survey motivation is introduced. Then, the study design and focus groups are presented, and the response options for the respective statements are outlined. Furthermore, the simulation game’s study results of the focus groups are indicated and interpreted.

The summary describes only the findings of the simulation game’s study results with any assumptions of the authors. This is why the results presented in this paper cannot be considered representative of the entirety of the focus groups. The aggregated results, representations and statements shown here relate only to the sample that completed the survey.

To conclude the content of the simulation game from the questions, the primary distribution of the answers of the different focus groups was considered. In eight out of ten statements, the group of FQE most frequently choose the option 'strongly agree'. In the other two cases, the answer option was 'agree'. In the manufacturing companies' employees group, the answer 'agree' was selected as the most frequent response for each case in seven out of ten questions. Twice, the highest number of responses was for the answer 'strongly agree' and once for the answer 'neutral'. On the other hand, work council representatives choose the answer 'agree' as the most frequent response for nine of ten statements and 'neutral' once. The results show that compared to the other two groups the work council representatives evaluate the simulation game more critically. FQE responded most positively to the questions. This focus group was most likely to be confronted with new content in the simulation game because it could present content that had been discussed during the studies but had not yet been experienced in practice.

Next, the statement results of the focus group for the simulation games’ execution show that FQE chooses the option 'strongly agree' in eleven out of twelve statements. Only the FQE responded to the S9E statement with 'agree'. This shows that FQE evaluated the simulation game execution much better than other focus groups. On the other hand, the manufacturing companies’ employees selected the answer 'strongly agree' in eight out of twelve statements. Additionally, they answered three statements mostly with 'agree'; only in the S9E statement the most given answer was 'neutral'. The participants from the focus group work council representatives selected the answer 'strongly agree' mostly in nine out of twelve statements. They showed the same trend by answering survey statements as the manufacturing companies’ employees since they answered two statements mostly with the option 'agree' and the S9E statement with 'neutral'. These results indicate that manufacturing companies’ employees and work council representatives evaluated executing simulation positively. Only for the new learning content in the simulation game their opinions were more reserved than those of the FQE.

In the future, we will collect more data after the simulation executions to make the statements even more significant. It is planned to compare different mindsets of the focus groups in other countries. In addition, the simulation will be further developed, and an expansion with new elements has already been conceptualized (Himmelstoß *et al.*, 2021). After it is successfully implemented, we will collect feedback from participants and evaluate how it changes when new subject areas are addressed in the workshop.

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