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Gamification of Operational Tasks in Manufacturing

A Literature Review

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Abstract. Gamification is a growing topic of interest across all industries, including manufacturing. We conducted a literature review to determine the past and current research being conducted in the realm of gamification within manufacturing. We found that significant research is being performed, with growth in recent years. However, our analysis also found that the research is widespread, and not one group of researchers are focused on a niche area for gamification in manufacturing. Gamification in manufacturing research often focuses on three different research areas: knowledge acquisition, training, and operational tasks. Gamification research is conducted in equal parts of in-industry and in-lab settings. Literature reviews, empirical studies, and case studies are commonly used and published, and no specific methodology stands out as being preferred over the other. We found that conducting statistical hypothesis testing is feasible and appropriate when conducting an empirical or case study. Our paper summarizes the analysis by drawing additional conclusions and suggesting future research avenues for other researchers interested in how gamification is and can be incorporated within the manufacturing domain.

Keywords: Gamification, Manufacturing, Operations, Industry 4.0, Games.

1 Introduction

Gamification in manufacturing can often be categorized as focusing on two avenues: education or support for operations. Gamification is a hot and growing topic across many industries but has not yet been thoroughly discussed for operational tasks in manufacturing. Hence, this work aims to identify current research gaps in the field of gamification of operational tasks in manufacturing. It is believed that gamification can assist manufacturing facilities to improve workers' efficiency, motivation, and enjoyment [1]. With recent advancements in technology capabilities, it is feasible and desirable to implement gamification into current operating procedures. *Gamification*, "the use of game design elements in non-game contexts" [1], has been a topic of interest in engineering education research for many years, even before the 21st century. However, the term *gamification* itself was not clearly defined until 2010 [1]. Since

then, from 2010 and beyond, the use of the word “gamification” in research has grown continuously and significantly, with no evidence of the growth slowing down (see Fig. 1). Between 2000 and 2010, gamification was mentioned in more than 10, but less than 110, research papers annually. Initially focused on education, gamification has branched out into other sectors, including manufacturing. In recent years, we see a large number of publications focused on gamification. Since 2016, exceeding 10,000 papers per year. The histogram depicted in Fig. 1 aims to showcase the growth in overall interest without limiting the domain. The annual numbers are derived from Google Scholar (without accounting for patents and citations).

While we know that gamification has already touched the world of manufacturing, we are interested in determining how much and what has been done concerning gamification in this domain. More specifically, we are interested in the impact of gamification on operational tasks within manufacturing. In other words, we are interested in instances where shop-floor workers are directly interacting with gamification while performing manufacturing tasks. This research aimed to identify promising research gaps for future research opportunities related to manufacturing and gamification.

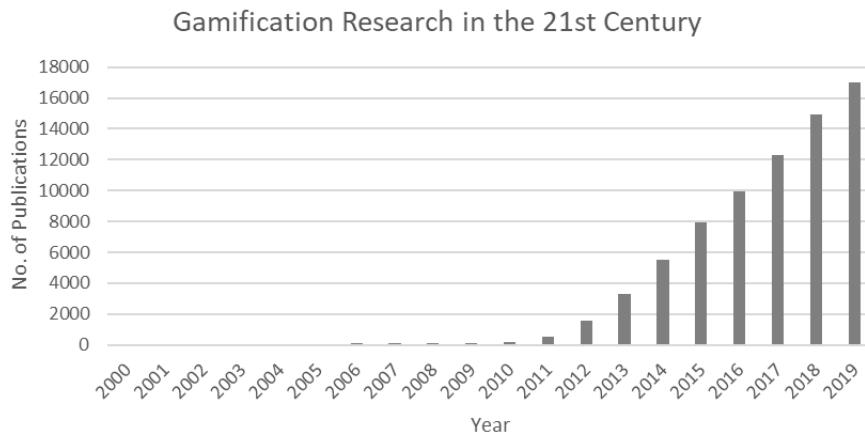


Fig. 1. Histogram: Number of Publications related to Gamification Research from 2000-2019

2 Research Methodology and Data Collection

We conducted a literature review to better understand the current state of gamification research within a manufacturing setting. The literature review began with a general search of gamification through two well-known and high-quality databases: Scopus and Web of Science. Since we were specifically focused on how gamification has been used in manufacturing, we added “manufacturing” as part of the search string. We decided on using “gamif*” in our search string to ensure we obtained all versions of “gamification” that are used today. With the search string “gamif* manufacturing” and restrictions to only include conference papers and journal articles, we obtained 46 results from Scopus and 32 results from Web of Science. The results were exported to

a spreadsheet for further analyses. After removing duplicates, our initial set of papers forming the basis of this study included 54 papers.

From here, we further reduced the number of papers by closely examining the papers' titles and abstracts. A relevancy score, on a scale from 1-10, one being completely unrelated and 10 being perfectly related to the scope of the research, was assigned to each paper. With at least a score of six, based on our scoring criteria, it was evident that these papers, at a minimum, simultaneously related to both aspects of our topics of interest, "gamification" and "manufacturing". After assigning a relevancy score, we chose to only include papers with a relevancy score of six or above. This resulted in a set of 23 papers remaining in the pool for further analysis.

Of these 23 papers, we were unable to obtain the full English versions of three papers. Therefore, 20 papers were read in their entirety. After reading the papers in detail, we decided to discard four additional papers as they did not fit the scope of the research. At this point, we established the relevant papers and no more papers were removed. The analysis is based on the final group of 16 relevant papers (see Table 1).

In addition to using a *quantitative approach* to analyze the results obtained, a *qualitative approach* was also adopted considering the emerging role of *gamification* in industrial settings. In this sense, a *narrative analysis* of the papers collected was conducted to explore multiple perspectives on the "gamification" topic, with particular focus on gamification usage to improve operational tasks. This complementary qualitative approach is fundamental for our review since it allows us to explore and analyze the trends of the inclusion of gamification in factory shop-floors.

3 Analysis of the Results

The results of this literature review are centered around the type of research methodology used, the research location, the research focus, the utilization of statistical hypothesis testing, and a qualitative analysis of overall content. The results, to the best of our ability, are descriptive and do not include any interpretation but rather factual statements derived and obtained from the literature. The results are critically discussed and interpreted in the following section.

3.1 Type of Research

Each paper was classified into at least one of the following categories: (i) literature review, (ii) empirical study, and/or (iii) case study. In some instances, a paper was classified across multiple categories. Papers were also classified based on their outcome, such as proposing a framework. For this purpose, a *framework* was understood to be a suggestion, or set of suggestions, of basic methods for the use of gamification.

A *literature review* was classified as a paper wherein the purpose of the paper was to examine previous research. An *empirical study* was classified as a paper wherein the research included results through a non-subjective medium, such as hypothesis testing or data collection. Meanwhile, a *case study* was classified as research where results were found through a subjective medium such as individual analysis, discus-

sions and/or interviews. This difference between “empirical studies” and “case studies” is supported by [2].

It was found that of the 16 papers included, there were five literature reviews, six empirical studies, and eight case studies. In addition to their main form of research, four of the 16 papers also included a proposed framework. Of these four papers that proposed frameworks, two conducted empirical studies, while the remaining two conducted literature reviews.

3.2 Location of Research

Papers were classified where the majority of the presented research was conducted, either in an industrial or lab setting. There are two papers which reported on work that was conducted in both settings. A paper was classified as “in-industry” if the research was conducted alongside a company and involved their employees. A paper was classified as “in-lab” if the research was conducted utilizing individuals not specifically associated with a company, such as students at a university lab.

3.3 Focus of Research

We found that all relevant papers could be broken into three main focus areas: knowledge acquisition (knwl. acq.), (ii) training, and (iii) operational tasks. The knowledge acquisition category differs from the training category in that *knowledge acquisition* focuses on gaining knowledge (either from employees or for employees), while *training* focuses on learning a skill or task. *Operational tasks* focus on day-to-day activities with which employees are already familiar. Again, some papers covered multiple categories. Of the 16 papers examined, six focused on knowledge acquisition, five focused on training, and seven focused on operational tasks.

3.4 Statistical Hypothesis Testing

Three papers conducted statistical hypothesis testing. Of these papers, two were empirical studies and the remaining one was a case study. In this work, we understand statistical hypothesis testing as the usage of formal hypotheses, such as H_0 and H_1 , to aid in drawing conclusions.

3.5 Overall Content Analysis

From the *empirical and case study* papers examined, there was only one which focused on a paper-based gamification scenario, and all others were digital-based scenarios. For the *training* focused papers, the gamification took place in a scenario off the production line, while the current training trend is incorporating gamification within the scope of work. There was one industry setting which was repeated in more than one article – the automotive industry.

Table 1. Results of Literature Review

Reference	Research Methodology				Research Location		Research Focus			Hypothesis
	Lit Review	Empirical Study	Case Study	Framework	Industry	Lab	Knwl. Acq.	Training	Operations	Statistical
[1]		•		•	•				•	•
[3]		•		•		•			•	
[4]			•			•			•	•
[5]		•			•	•	•			•
[6]	•		•		•					
[7]	•			•			•	•		
[8]	•			•	•				•	
[9]		•				•		•		
[10]		•			•		•			
[11]			•		•			•		
[12]			•			•		•		
[13]			•			•	•			
[14]		•	•		•	•			•	
[15]	•		•		•				•	
[16]			•		•		•			
[17]	•						•	•	•	

4 Discussion

4.1 Quantitative Observations

In our results, there are more papers reporting work set in an “industrial setting” than those set in a “lab setting”. While surprising at first, we believe this may be a bias included via the selection of our search string. Since our search string was small, we believe that we unintentionally pulled only a portion of the results related to gamification in manufacturing. Since we included “manufacturing” in the search term, many of the results are likely biased towards instances where the research was conducted at an actual manufacturing facility.

Of the papers classified with an “operational research” focus, three were conducted in a “lab setting”, while four were conducted in an “industrial setting”. This near-equal split between lab and industry setting indicates that gamification in manufacturing research is capable of producing significant results in either environment.

For the papers which utilized hypothesis testing, two conducted “empirical studies” while the other one conducted a “case study”. The case study which conducted hypothesis testing did not have numerical data to draw conclusions for the hypothesis but did appropriately establish multiple hypothesis statements to assist in drawing conclusions later. It is also important to mention that there were an additional four empirical studies which did not utilize hypothesis testing to draw their conclusions. These papers used basic statistical data such as mean, standard deviation, and percentage of participants (see papers: [3, 9, 10, and 14]). In these cases, hypothesis testing may have been beneficial to improve the confidence in the reported findings.

There are a few limitations of this study that need to be taken into consideration when reflecting on the results. First and foremost, like all literature-based studies, this research is limited by the search term used to gather the relevant papers. One might argue that there are complementary terms that should have been included. Potential terms that could have been included in the search include “serious games,” “production” and “operations”. It is important to note that “serious games” and “gamification” are not as closely related as often assumed.

4.2 Qualitative Observations

Reflecting on the analysis of the quantitative results obtained (see Table 1), and the qualitative analysis of the narrative of the empirical studies and case studies collected, it is possible to observe some coincidences between the rise of the exploration of gamification in manufacturing with the beginning of the Industry 4.0 era, emerging in 2010 and 2011, respectively. *Industry 4.0*, as a novel cyber-physical production paradigm, has challenged the current workforce with an accelerated pace of *knowledge acquisition* and skills development about the new collaborative robotics, intelligent automation, advanced manufacturing, and digitalization technologies. Furthermore, new and innovative visualizations are necessary to enable humans to interact with the

many new data-driven tools and interfaces. Among others, this forces operators to quickly go through the different learning curves of these modern technologies and their capabilities for their strategic implementation and immediate operationalization at the factory shop floor as a source of competitive advantage.

Nevertheless, the true source of competitive advantage relies on a knowledgeable and skilled workforce capable of a rapid technology adoption and mastering through “learning by doing”. Ideally, no human production resource diverts from the factory shop floor for training or disrupts value-creating production operations. This way, shop floor operators are able to continue to work and learn simultaneously while being trained on how to use these new production and production management technologies to improve the efficiency and effectiveness of their operational tasks. In this sense, from a socio-technical perspective, gamification could help to overcome some of the resistance to change when it comes to the rapid adoption of new technologies and their corresponding new working methods by employing motivational affordances such as points, badges, and leaderboards to drive the workforce to the desired goals and objectives [1]. Utilizing new digital technologies allows leveraging the opportunities of the new gamification paradigm in manufacturing. For example, using augmented reality devices as visualization tools to provide the shop floor operators with “digital assistance systems” (e.g., for assembly tasks) is empowering and, through “learning by doing,” can translate into higher job satisfaction and performance.

5 Conclusions and Future Work

The most important conclusion from this research is that manufacturing seems to be severely underrepresented within published gamification research. Given that in 2019 alone, more than 17,000 papers were published where gamification is referenced and that our research only included 16 publications which directly related to manufacturing and gamification, it is evident that only a very small portion of gamification research is related to the manufacturing industry. This minimal representation is in contrast to the very wide range of possible value-adding applications of gamification within the manufacturing field that are theoretically possible.

As aforementioned, the purpose of this paper was to identify research opportunities for future work for individuals interested in gamification in manufacturing. One reoccurring future research opportunity is identifying the long-term effects of gamification. It is unclear if the improvements witnessed in gamification research can be solely attributed to gamification as a technique or gamification as a new and novel tool. If the improvements are mostly related to employees working with a new gamification feature within an operational task, then over time the novelty of gamification will wear out and production will return to its pre-gamification state. Many papers mention limited sample sizes are a potential downfall of their research, so we need large scale studies focused on gamification of operational tasks within manufacturing.

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