An Analysis of an Augmented Reality Application to support Service Staff in Industrial Maintenance

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Abstract. Augmented Reality is an emerging technology and gains in importance. With AR, the physical world can be extended with virtual content. Especially AR-applications for industrial maintenance are experiencing an upswing. AR-technologies for maintenance aim to improve human performance by providing relevant information for a specific task. This information can be provided by sensor data from machines, software systems, or human experts. Currently, there are not many industry-ready AR-applications on the market. This lack raises the question if AR-applications can effectively support service staff in the field.

An experimental investigation was carried out to explore this field. Two industrial maintenance cases with different levels of difficulty were simulated, whereby service staff had to solve these real-life problems. Support from an expert was provided via an AR-application. In addition, the Affinity for Technology Interaction score was assessed in order to identify the target group for AR-applications.

The results clearly show that AR-applications can effectively support service staff in the field. The research also reveals that a high Affinity for Technology Interaction score of the service technician leads to a higher acceptance of the AR-application. The application offers many potentials, but there are still some limitations concerning the user interface and technological aspects.

Keywords: Augmented Reality, Expert Support, Affinity for Technology Interaction, Industrial Maintenance Support, Experiment, Empirical Study

1 Introduction

To keep up in the highly competitive market, companies have to improve their product quality and reduce their maintenance time. Technological developments are continually providing companies with new and innovative solutions to meet these challenges in a better way. Especially in the service sector, particularly in industrial maintenance, Augmented Reality (AR) technologies offer numerous application areas [1].

Maintenance tasks in the industrial environment are becoming increasingly complex and require more and more know-how, which service specialists have to acquire an expensive and time-consuming training [2, 3].

This causes enormous costs for companies. Training is therefore often provided only to selected service specialists. In the case of maintenance tasks, it is more common for the service technicians on-site to get stuck on a problem. They have to contact a more experienced and better-trained expert.

Communication usually takes place via a telephone call. In the industrial environment, complex issues are difficult to present and explain via purely verbal communication, which often leads to misunderstandings and ambiguities. As a result, in practice, the experienced expert is usually called in to solve the problem on-site. Especially in rural areas, the expert's trip causes a high expenditure of time and money for the company and, in turn, for the customers [4].

AR represents a way to provide expert support to service workers in the field. However, this technology may not be suitable for the entire service staff universally [5]. Therefore, the research question arises if an already existing metric as the Affinity for Technology Interaction (ATI) scale can be used to identify the target group of AR in an industrial setting quickly and accurately. To explore the eligibility of the ATI-scale as a predictor, an experimental setting was designed, including a questionnaire to collect data ATI scale data.

The next section provides a literature review followed by a description of the methodology. Section four presents the results of the empirical survey. The last section provides a summary, limitations, and ideas for further research.

2 Literature Review

In this section, the central terms and concepts relevant to the empirical study are presented. First, AR and its application in the industrial service sector are described, followed by Affinity for Technology Interaction. This chapter ends with the aim and the hypothesis for this contribution.

2.1 Augmented Reality

Augmented Reality (AR) is a technology that adds virtual content to the real world. AR creates an additional layer of information through computer-aided graphics, which is intended to simplify the user interaction in and with the physical world [6].

For this paper, AR is defined as "a set of human-computer interaction techniques that enriches user's real-world experience by embedding contextualized information into user's space in coexistence with real-world objects" [7].

Most AR-applications are available on mobile devices, like smartphones or tablet computers. In recent years, hands-free wearable devices, like smart glasses and displays that can be worn on the head, gained importance [8].

As depicted in figure 1, the Reality-Virtuality (RV) continuum can be used to integrate AR in a broader context [9].

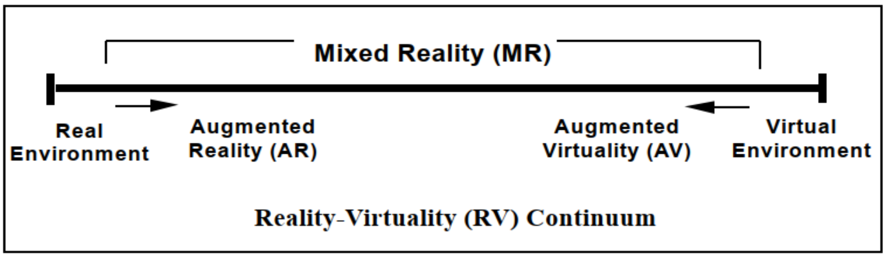

Figure 1. Reality-Virtuality Continuum [8]

The Reality-Virtuality continuum can be used to explain the difference between AR and Virtual Reality (VR). On the left side of the continuum is the real world, which consists exclusively of real objects. On the other side is the virtual environment, which consists solely of virtual and simulated objects. Between these two extremes, Mixed Reality (MR) is located. AR is a part of MR and is placed more on the left edge of the continuum. The basis of AR is the real environment with overlays of virtual objects or data.

VR, on the other hand, is entirely in the virtual environment. VR is computer-generated, three-dimensional, and interactive reality. In VR, the user is put into an immersive, virtual world and is cut off from the real world. When virtual reality is combined with parts of the real world, it is referred to as Augmented Virtuality (AV). An example would be a VR environment in which users can see their own hands [9].

AR is a very versatile technology that can be used in a wide variety of domains, e.g. in education [10–12], tourism [13–16], or marketing [17–19]. Visualizing information, receiving and following instructions, and interacting with products are the three central functions of AR-applications [8].

Currently, one of the most common uses of AR-systems are applications for instructing and training people. The potential use cases of AR-applications in this area are wide and varied. For example, there are promising experiments that deal with tennis training through real-time instructions via AR [20]. Another example is to use AR-applications to find the way out of buildings in an evacuation event [21].

AR has versatile use cases in the industrial sector. In the aviation industry, many activities are already supported by AR-systems. This includes the training of skilled workers or the support of staff in assembly and maintenance activities [22–24].

2.2 AR Support for Industrial Services

Research on AR-technologies for the industrial service sector focuses mainly on four categories: assembly and disassembly, repair, inspection or diagnosis, and training. The first category uses AR-applications virtual content to guide the service professional through the assembly or disassembly process. For repairs, AR is used to assist in the reconstruction or replacement of components. When inspecting and diagnosing equipment, AR-systems can assess the current condition of a product and analyze the causality of the defect. AR-applications for the training of service professionals provide a better understanding of maintenance activities [25].

In their research, Mourtzis et al. describe an AR-system that efficiently combines and integrates real-time data from various sensors implemented in machines to get an overview of the current condition of this machine. These results are displayed in an AR-application used by the machine operator [26].

Among the essential benefits of AR-applications in the industrial sector are the reduction of execution time and a resulting reduction in costs, and the increase in quality by reducing errors [27]. AR-applications contextualize information and present it understandably, leading service professionals to perform their tasks more efficiently. A better understanding of the job leads to fewer errors during execution and to an increased quality [7] as well as to a reduction of cost [28].

For complex tasks, purely audio-based support (e.g. via phone calls) often leads to ambiguities and misunderstandings. AR-applications provide a solution because they can extend communication with virtual real-time content that facilitates understanding and dissolves communication barriers [29].

2.3 Affinity for Technology Interaction

Increasing digitization means that interaction with new and sometimes complex technologies must be made low-threshold and straightforward. System developers try to solve this problem by developing systems that are user-friendly and intuitive. To that extend, user acceptance models can be applied. At the beginning of the 21st century, the Unified Theory of Acceptance and Use of Technology (UTAUT) was developed out of previous user acceptance models [30]. The fast changing world however demands for new models that allow facing current challenges.

The recent Affinity for Technology Interaction (ATI) describes the individually varying tendency of people’s interaction with technical systems. ATI is defined as “the tendency to actively engage in intensive technology interaction, as a key personal resource for coping with technology” [5]. The ATI scale was developed to measure this concept. The scale consists of nine items and uses a six-point Likert scale. The reliability and construct validity of the ATI scale as a measurement instrument has already been verified [5].

Further, Lezhnina and Kismihók conducted a multi-method psychometric evaluation of the ATI scale and described it as a valid, reliable, and recommendable instrument for human-technology interaction research [32].

We assume that the ATI-scale is a suitable predictor and helps to identify the right workforce, which should be provided with the AR tools in the first phase of the deployment. Thus, the central aim of this work is to explore if the ATI-scale is a suitable predictor to identify the right workforce for the first phase of AR deployment.

This leads to the hypothesis: The higher the ATI-score the better an AR-tool supports to solve problems in the field.

3 Methodology

An experimental setting was designed to collect data for the empirical study. The following section describes the design and execution of the experiment.

3.1 Design of the Experiment

The following situation was simulated as a scenario for the experiment: a service employee is on-site to maintain or repair a machine in a construction area. The service employee has to perform work for which the employee is not qualified. Consequently, the service employee has to contact a more experienced and better-trained specialist in the company. An AR-application is used for communication purposes. Within the distinct case of this experiment, PTC Chalk was applied.[1] The software allows experts to remotely assist technicians based on VR (see figure 2)

Figure 2. AR-application functionality[2]

To simulate the maintenance case as good as possible, the experiment was conducted in two separate rooms. The experienced expert was located in one room, while the service employee with the machine that has to be repaired was in the other room. The expert had a tablet, and the service employee used a regular smartphone, both with the AR-application installed.

In all runs of the experiment, the expert stayed, whereas the service staff changed. The expert's instructions for solving the problem were always the same. This ensured that the experiment was always carried out under consistent conditions.

One experiment consisted of two runs with different service cases. Each participant was given two maintenance cases (one easier and one more difficult) that had to be solved with the support of an expert and the AR-application.

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[1] https://www.ptc.com/en/products/vuforia/vuforia-chalk [last checked on 12th of April 2021]

[2] Image retrieved from: https://www.ptc.com/en/products/vuforia/vuforia-chalk [last checked on 12th of April 2021]

To be transparent and provide similar initial situations for all participants, they were informed about the study and the experiment's design. Furthermore, they received a short introduction to the AR-tool.

The experimental study was conducted at two different companies. The test subjects came from the service sector. Thus, the experiment must be classified as a quasi-experiment, since the assignment of participants was not randomized. Based on the objective of the research project, the participants were deliberately chosen from the service sector, as this allocation gives the results more relevance.

3.2 Used AR-Application

A commercial and professional tool was used in the experiment. This tool is an app, which runs on regular smartphones. A camera and an internet connection are required. The application has to be installed on the smartphone of the worker in the field and on the experts tablet.

This tool combines AR-technologies with real-time video communication functionalities. In a first step, the tool scans the environment (e.g. a machine) for which support is required. On the screen of the smartphone, marks (text, symbols, drawings, etc.) can be associated with objects of the environment (e.g. one specific component of a machine). These marks are stuck to these components. With that mechanism, the worker can move around in the environment, and marks are only displayed when the associated component is visible on the screen. Both the worker and the expert can draw marks. The session can be recorded (video and voice), or screenshots can be made. This helps to document all activities.

3.3 Data Collection

After the two runs of the experiment, each participant had to fill out a questionnaire printed on paper. The questions of the first section are related to personal data, like gender, age, highest educational attainment, current position in the company. In section two, the ATI-scale had to be filled out by the participants to measure the Affinity for Technology Interaction. The section asks if the AR-application supported the service employee without unnecessary burdens. They had to indicate if they would use the AR-tool again regarding the two different difficulty levels.

At the end of the questionnaire, an open-ended question was available. The participants were asked to provide further feedback and make personal remarks about the AR-application.

4 Results

Due to the Covid-19 pandemic, it was not possible to recruit more than 25 participants from two different companies for the experiment. From company one, seven and from company two 18 staff members participated.

The evaluation was not company-specific. The age of the subjects ranges from 16 to 47 years. The average age of the sample is 32.88 years, with a standard deviation of 8.67. The gender distribution is very unbalanced. There is only one female participant. The uneven gender distribution can be explained by the industry in which the experimental study was conducted. The proportion of men and women in technically focused industries is still very unevenly distributed. For mechatronics, energy, and electrical occupations, 89% of employees in Germany are male [33].

This uneven distribution is represented in the sample. The companies and participants have their focus in technical fields. Technicians, mechatronics engineers, and machine operators are significantly frequently represented in the sample. The vast majority of participants had an apprenticeship diploma or a master craftsman's diploma.

4.1 Affinity for Technology Interaction

Comparing the results of the two service cases showed that the AR-application provided better support in solving the more difficult problem. The support for the more manageable problem was rated less high.

As the following table 1 shows, for service case two, the more complicated use case, 20 participants indicated that the application facilitated problem-solving. For service case one, only 17 held this opinion.

Table 1. Support for both use cases

The AR-application supports solving the service case	Frequency use case one	Frequency use case two
Do not agree at all	1	0
Strongly disagree	0	0
Neutral	7	5
Strongly agree	8	10
Fully agree	9	10
Total	**25**	**25**

4.2 Evaluation of the Hypothesis

The following hypothesis was formulated: The higher the ATI-score the better an AR-tool supports solving problems in the field.

This hypothesis tests whether there is a correlation between the measured ATI-score and the degree of support provided by the AR-application in solving the problem. Spearman's bivariate correlation with a two-sided test for significance is used for evaluation. The results differ among the use cases. As shown in the following table 2, there is no significant correlation ($r = -.139$; $p > .05$) for the first use case.

Thus, there is no significant correlation between interaction-related technology affinity and the degree of support.

Table 2. Evaluation of hypothesis

	correlation
The AR-application supports solving service case one	-.139
The AR-application supports solving service case two	409*
n= 25; *p < ,05; **p < ,01	

The evaluation shows that there is a significant correlation ($r = .409$; $p < .05$) with a medium effect for the second, more difficult use case. Consequently, there is a significant positive correlation between the user's ATI-score and the degree of support that the AR-application offered.

It can be concluded that the more tech-savvy the service employee is, the more likely the AR-application is to provide support to solve challenging tasks. Conversely, however, we might deduce that users with a lower affinity for technology tend to perceive the application as less helpful in solving serious problems.

4.3 Analysis of the open-ended Questions

The results of the open-ended question are associated with four categories: user-interface design, additional functions, technical limitations, and other. The category other includes all other suggestions that could not be assigned to any of the other categories.

Most of the suggestions for improvement are related to technical limitations of the application. These include the reduction in image quality when the bandwidth of the Internet connection is low or the limited availability of the application on different end devices. The used AR-application is only available on smartphones or tablets, but not on laptops or personal computers. In the meantime, a newer version of the AR-application is already available, and it can be used on laptops or personal computers as well.

Most of the comments in the category technical limitations refer to the calibration of the AR-application. Before the application can be used, the environment must be scanned using the camera of the mobile device. This just takes some seconds. The smartphone or tablet has to be moved around slowly until all required objects for the service task are covered. Only when the scanning process is successful, symbols and graphical content (e.g. marks or symbols) can be drawn in.

If the environment changes significantly during the session or the user changes location, the AR-application no longer finds its way around, and the environment has to be rescanned. This recalibration bothered many participants.

The second most named suggestions can be associated with category user-interface design. Again, most of the recommendations relate to calibration. However, this is more about the wish for a dedicated button for manual recalibration than about the calibration function's general technical problem. The AR-application currently does not offer a way to restart the calibration manually. Only when the environment is no longer recognized, the AR-application prompts the user to rescan the environment.

One respondent describes that a remote zoom function would be a nice feature for the AR-application. Another suggestion refers to integrating a chat function, which can be used if it was too loud for voice communication. These suggestions are summarized in the category additional functions. Under the category other, there are further suggestions, like the wish for voice output in several languages.

5 Summary, Limitations and Further Research

84% of the participants agreed that the AR-application supported them to solve relatively simple service cases. In the case of the more complex services tasks, 88% of the service employees were of this opinion. 76% of the participants stated that they would use the application in their daily work. This can clearly be evaluated as a positive aspect of the AR-application, as employee acceptance is a critical success factor in implementing AR-technologies [34]. It can be concluded that the used AR-application support service staff in the field when further assistance by experts is required.

The future for AR-systems in the service sector is promising, and new technologies in particular, such as the 5G networks, offer new opportunities for future developments. However, system usability evaluations of new systems should take the user's interaction-related affinity for technology into account. This score has a significant influence on user support when solving especially more complex problems.

In turn, this results in the problem that users with a lower ATI-score tend to perceive the AR-application as less helpful in solving difficult problems. Consequently, when implementing AR-applications, it is essential to evaluate the technical affinity first. Staff with a lower ATI-value should receive intensive training.

The application offers many potentials but still has some limitations in terms of technology and user interface.

5.1 Limitations and Generalization

The sample size of 25 participants is very small and cannot be representative of the population. Further, only one female service employee participated, and only two cases were considered. Besides, the experiment was not conducted in a real world setting, but in an experimental one. Therefore, a generalization is rather difficult. Furthermore, the age distribution of the sample is uneven and is rather in the lower range with an average age of 32.88 years. Also, the average ATI-score of the participants is above average and is 4.82. However, the uneven distribution of the subjects' occupational orientation was deliberately chosen because the AR-application in this study is primarily relevant to individuals in technical occupations in the industrial sector.

Lastly, the biggest challenge in the experimental study was the international Covid-19 pandemic. This significantly delayed and complicated parts of the experimental study.

5.2 Further Research

One of the first activities would be to repeat this experiment with more participants from more companies. The gender distribution should be more balanced.

Since the technical development of AR-tools is growing rapidly, a newer version of the used AR-tool or AR-tools from different manufacturers could be used. In this study, a regular tablet and smartphone were used. From a technical perspective, it would be interesting to use a combination of AR-glasses and smartphones. Another approach could be to compare two settings, one group supported with an AR-application and a second group supported with regular voice support from experts.

References

References

1. Pace, F. de, Manuri, F., Sanna, A., Zappia, D.: A Comparison Between Two Different Approaches for a Collaborative Mixed-Virtual Environment in Industrial Maintenance. Front. Robot. AI (2019). https://doi.org/10.3389/frobt.2019.00018
2. Martinetti, A., Rajabalinejad, M., van Dongen, L.: Shaping the Future Maintenance Operations: Reflections on the Adoptions of Augmented Reality Through Problems and Opportunities. Procedia CIRP (2017). https://doi.org/10.1016/j.procir.2016.10.130
3. Palmarini, R., Erkoyuncu, J.A., Roy, R.: An Innovative Process to Select Augmented Reality (AR) Technology for Maintenance. Procedia CIRP (2017). https://doi.org/10.1016/j.procir.2016.10.001
4. Masoni, R., Ferrise, F., Bordegoni, M., Gattullo, M., Uva, A.E., Fiorentino, M., Carrabba, E., Di Donato, M.: Supporting Remote Maintenance in Industry 4.0 through Augmented Reality. Procedia Manufacturing (2017). https://doi.org/10.1016/j.promfg.2017.07.257
5. Franke, T., Attig, C., Wessel, D.: A Personal Resource for Technology Interaction: Development and Validation of the Affinity for Technology Interaction (ATI) Scale. International Journal of Human–Computer Interaction (2018). https://doi.org/10.1080/10447318.2018.1456150
6. Amin, D., Govilkar, S.: Comparative Study of Augmented Reality Sdk's. IJCSA (2015). https://doi.org/10.5121/ijcsa.2015.5102
7. Fernández del Amo, I., Erkoyuncu, J.A., Roy, R., Palmarini, R., Onoufriou, D.: A systematic review of Augmented Reality content-related techniques for knowledge transfer in maintenance applications. Computers in Industry (2018). https://doi.org/10.1016/j.compind.2018.08.007
8. Porter, M.E., Heppelmann, J.E.: Why Every Organization Needs an Augmented Reality Strategy. Harvard Business Review 95, 46–57 (2017)
9. Milgram, P., Takemura, H., Utsumi, A., Kishino, F.: Augmented reality: a class of displays on the reality-virtuality continuum. Proceedings of SPIE - The International Society for Optical Engineering (1994). https://doi.org/10.1117/12.197321
10. Ferrer-Torregrosa, J., Jiménez-Rodríguez, M.Á., Torralba-Estelles, J., Garzón-Farinós, F., Pérez-Bermejo, M., Fernández-Ehrling, N.: Distance learning ects and flipped classroom in the anatomy learning: comparative study of the use of

augmented reality, video and notes. BMC medical education (2016). https://doi.org/10.1186/s12909-016-0757-3
11. Garzón, J., Kinshuk, Baldiris, S., Gutiérrez, J., Pavón, J.: How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis. Educational Research Review (2020). https://doi.org/10.1016/j.edurev.2020.100334
12. Sahin, D., Yilmaz, R.M.: The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. Computers & Education (2020). https://doi.org/10.1016/j.compedu.2019.103710
13. Mesároš, P., Mandicák, T., Mesárošová, A., Hernandez, M.F., Kršák, B., Sidor, C., Štrba, L., Molokác, M.: Use of augmented reality and gamification techniques in tourism. E-Review of Tourism **13**, 366–381 (2016)
14. Cranmer, E.E., tom Dieck, M.C., Fountoulaki, P.: Exploring the value of augmented reality for tourism. Tourism Management Perspectives (2020). https://doi.org/10.1016/j.tmp.2020.100672
15. Jingen Liang, L., Elliot, S.: A systematic review of augmented reality tourism research: What is now and what is next? Tourism and Hospitality Research (2021). https://doi.org/10.1177/1467358420941913
16. Tsai, S.-p.: Augmented reality enhancing place satisfaction for heritage tourism marketing. Current Issues in Tourism (2020). https://doi.org/10.1080/13683500.2019.1598950
17. Altinay Ozdemir, M.: Virtual Reality (VR) and Augmented Reality (AR) Technologies for Accessibility and Marketing in the Tourism Industry. In: Korstanje, M., Eusébio, C., Teixeira, L., Carneiro, M.J. (eds.) ICT Tools and Applications for Accessible Tourism. Advances in Hospitality, Tourism, and the Services Industry, pp. 277–301. IGI Global (2021)
18. Huh, J.-H., Seo, Y.-S.: A Location-Based Solution for Social Network Service and Android Marketing Using Augmented Reality. In: Park, J.J., Fong, S.J., Pan, Y., Sung, Y. (eds.) Advances in Computer Science and Ubiquitous Computing, vol. 715. Lecture Notes in Electrical Engineering, pp. 569–573. Springer Singapore, Singapore (2021)
19. Chylinski, M., Heller, J., Hilken, T., Keeling, D.I., Mahr, D., Ruyter, K. de: Augmented Reality Marketing: A Technology-Enabled Approach to Situated Customer Experience. Australasian Marketing Journal (2020). https://doi.org/10.1016/j.ausmj.2020.04.004
20. Kim, Y., Hong, S., Kim, G.J.: Augmented reality-based remote coaching for fast-paced physical task. Virtual Reality (2018). https://doi.org/10.1007/s10055-017-0315-2
21. Lovreglio, R., Kinateder, M.: Augmented reality for pedestrian evacuation research: Promises and limitations. Safety Science (2020). https://doi.org/10.1016/j.ssci.2020.104750
22. Ceruti, A., Marzocca, P., Liverani, A., Bil, C.: Maintenance in aeronautics in an Industry 4.0 context: The role of Augmented Reality and Additive Manufacturing. Journal of Computational Design and Engineering (2019). https://doi.org/10.1016/j.jcde.2019.02.001

23. Safi, M., Chung, J., Pradhan, P.: Review of augmented reality in aerospace industry. AEAT (2019). https://doi.org/10.1108/AEAT-09-2018-0241
24. Eschen, H., Kötter, T., Rodeck, R., Harnisch, M., Schüppstuhl, T.: Augmented and Virtual Reality for Inspection and Maintenance Processes in the Aviation Industry. Procedia Manufacturing (2018). https://doi.org/10.1016/j.promfg.2018.01.022
25. Palmarini, R., Erkoyuncu, J.A., Roy, R., Torabmostaedi, H.: A systematic review of augmented reality applications in maintenance. Robotics and Computer-Integrated Manufacturing (2018). https://doi.org/10.1016/j.rcim.2017.06.002
26. Mourtzis, D., Vlachou, E., Zogopoulos, V., Fotini, X.: Integrated Production and Maintenance Scheduling Through Machine Monitoring and Augmented Reality: An Industry 4.0 Approach. In: Lödding, H., Riedel, R., Thoben, K.-D., Cieminski, G. von, Kiritsis, D. (eds.) Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing, vol. 513. IFIP Advances in Information and Communication Technology, vol. 513, pp. 354–362. Springer International Publishing, Cham (2017)
27. Souza Cardoso, L.F. de, Mariano, F.C.M.Q., Zorzal, E.R.: A survey of industrial augmented reality. Computers & Industrial Engineering (2020). https://doi.org/10.1016/j.cie.2019.106159
28. Mourtzis, D., Siatras, V., Angelopoulos, J.: Real-Time Remote Maintenance Support Based on Augmented Reality (AR). Applied Sciences (2020). https://doi.org/10.3390/app10051855
29. Fang, D., Xu, H., Yang, X., Bian, M.: An Augmented Reality-Based Method for Remote Collaborative Real-Time Assistance: from a System Perspective. Mobile Netw Appl (2019). https://doi.org/10.1007/s11036-019-01244-4
30. Venkatesh, Morris, Davis: User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly (2003). https://doi.org/10.2307/30036540
31. Wessel, D., Heine, M., Attig, C., Franke, T.: Affinity for technology interaction and fields of study. In: Preim, B., Nürnberger, A., Hansen, C. (eds.) Proceedings of the Conference on Mensch und Computer. MuC'20: Mensch und Computer 2020, Magdeburg Germany, 06 09 2020 09 09 2020, pp. 383–386. ACM, New York, NY, USA (09062020). https://doi.org/10.1145/3404983.3410020
32. Lezhnina, O., Kismihók, G.: A multi-method psychometric assessment of the affinity for technology interaction (ATI) scale. Computers in Human Behavior Reports (2020). https://doi.org/10.1016/j.chbr.2020.100004
33. Bundesagentur für Arbeit: Anteil von Frauen und Männern in verschiedenen Berufsgruppen in Deutschland am 30. Juni 2019 (sozialversicherungspflichtig und geringfügig Beschäftigte). https://de.statista.com/statistik/daten/studie/167555/umfrage/frauenanteil-in-verschiedenen-berufsgruppen-in-deutschland/ (2020). Accessed 30 December 2020
34. Sorko, S.R., Trattner, C., Komar, J.: Implementing AR/MR – Learning factories as protected learning space to rise the acceptance for Mixed and Augmented Reality devices in production. Procedia Manufacturing (2020). https://doi.org/10.1016/j.promfg.2020.04.037