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EDICIONES COMPLUTENSE

# Doing Industry 4.0 – participatory design on the shop floor in the view of engineering employees

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**Resumen.** La Industria 4.0 incorpora un grupo de tecnologías diversas. Implantarlas en las empresas requerirá una amplia participación. Las actuales formas de diseño participativo (métodos '*Agile'*, *Design Thinking*, innovación abierta…) suelen implicar más a los clientes pero no a los trabajadores de producción de las compañías. Los autores han investigado si la ingeniería de producción que implanta la Industria 4.0 quiere involucrar a sus colegas del taller y, en su caso, cómo lo harán. Se presentan resultados de entrevistas cualitativas, de una encuesta cuantitativa y de ordenamientos a partir del método Q de encuestas, realizados a alrededor de 230 empleados de ingeniería de una planta de automoción. Se invitó a los ingenieros que han participado a que expresaran sus puntos de vista, sus experiencias y visiones sobre cómo los trabajadores de producción podrían ser involucrados en la implantación de la Industria 4.0. Por un lado, los datos sugieren una actitud positiva hacia las experiencias de participación. Por otro lado, la participación es muy exigente: los entrevistados señalan una falta de tiempo y de oportunidades para desarrollarla. Requerirá más imaginación e iniciativa para romper con los procesos formales, a menudo limitados a ir alcanzado simples mejoras productivas.
**Palabras clave:** participación; ingeniería; innovación; Industria 4.0

## [es] Implantando la Industria 4.0. Diseño participativo desde la visión de los empleados de ingeniería

**Abstract.** Industry 4.0 features a cluster of diverse technologies. Implementing these in the enterprise will require a considerable amount of participation. Current forms of participatory design (Agile methods, design thinking, open innovation) more closely involve customers, but not generally the company's own production workers. We investigate if and how the production engineers who will implement Industry 4.0 want to involve their colleagues on the shop floor. We present results of qualitative interviews, a quantitative survey and Q-sorts conducted with around 230 engineering employees of an automotive plant. Participating engineers were invited to express their viewpoints, experiences and visions on how production workers could be involved in the implementation of Industry 4.0. On the one hand, the data suggest positive attitudes towards, and experiences of participation. On the other hand, participation is demanding: respondents report a lack of time and opportunities. It may require more imagination and initiative to break through existing formal processes often restricted to "catch-up" improvements.
**Keywords:** Participation; engineering; innovation; Industry 4.0.

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## 1. Participatory Design: Urgently Required – but Lacking? An Introduction[4]

The advent of Industry 4.0 has been heralded for some years. The supposed new paradigm includes a whole range of new technologies. These include new approaches in robotics, wearables, machine learning or additive processes, but above all the networking of everything physical in the production process. From the start, observers have challenged technical determinism and asked whether and to what extent the change taking place can be influenced (Kagermann, Wahlster and Helbig, 2013). It is widely believed that this is possible in general terms; old notions of technological determinism have fallen out of fashion. If Industry 4.0 thus affords or even requires some scope for design, the question arises: Who designs, and by which processes? This question is not purely normative, possibly even less so than in the phases of automation and digitization that have taken place in past decades. Instead participatory design is a functional necessity of digitization itself, because Industry 4.0 as and its technical complexities meet existing production facilities. Processes and work organization have to change, decisions about workplace requirements have to be made. To implement all this efficiently and effectively, a top-down approach may not be sufficient. Already in the complex production environments of today, the experiential knowledge of employees on the shop floor is important every time new automation technology is implemented.

Since industry 4.0 is more demanding, more complex and technologically more far-reaching yet than previous automation, we suggest that even more inclusion of the employees' experience knowledge could be necessary: Individual technical facets of digitization are only usable once they have been intentionally designed (for example, AI only works after learning and being "fed" data); new business models only develop when different technologies are connected to one another and to new forms of organization, service provision and consumption. None of this can be bought "ready-made"; in its current phase, digitization very much needs to be worked *on* at a social and organizational level – *before* innovations are deployed. The large number of new technical options allows, at least potentially, a qualitatively different form of production, but the steps to that goal seem to be proceeding more disruptively than the technological changes of past decades (Pfeiffer, 2017; Zysman & Kenney, 2017). This too suggests that, at an operational level, the processes and actors involved in designing this future might (perhaps necessarily) not be the same as before.

Outward, the implementation of Industry 4.0 is confronted with new limits on design options: digital infrastructures and smart algorithms, for example, may be partly inaccessible adaptations when they are under proprietary licensing or other intellectual property protection; processes of real technological development and

4 The analyses and conceptual work for this article were carried out as part of the joint project "Good agile project work in the digitized world (diGAP)". This research and development project is funded by the German Federal Ministry of Education and Research (BMBF) and the European Social Fund (ESF), and supervised by the Karlsruhe Project Management Agency (PTKA), within the framework of the funding programmes "Future of Work" and "Innovations for Tomorrow's Production, Service and Work".

economic formation are separated from their use and effects, and are carried out in other societies, under other labour laws, at other times, and by other actors. Path dependencies and ever-accelerating dynamics hamper and undermine established structures of operational and institutional design, which usually need time to adapt, to handle conflicts, and find consensus. This becomes apparent, for example, when the actors of the world of work complain about ever-lower capacities, about a lack of time and overly rapid technological progress, and about the excessive complexity and lack of transparency of the new technologies.

In short, designing Industry 4.0 may be both harder and more necessary.

Given this challenge, it may be promising to design 4.0 technologies, their forms of use and business models, in a much more participatory way than was customary in the retrospectively numbered industrial revolutions 1.0 to 3.0. Methods allowing the experience of prospective users to be incorporated into the design process earlier and more systematically are currently attracting much attention in the context of agile project management (Patton, 2015) and design thinking (Schmiedgen, 2011). The crowd, and collaborating prosumers, are also increasingly being included in processes of open innovation n (Wittke & Hanekop, 2011), and participation in the genesis of technology is regarded as one of the prominent applications of the "social innovation" concept (Murray, Caulier-Grice and Mulgan, 2010). These more recent approaches build on ideas of participation by future users, ideas which have long existed in other traditions of participation, and which more explicitly consider employees as users. Examples are computer-supported collaborative work (CSCW; Boulos-Rødje, Ellingsen, Bratteteig, Aanestad and Bjørn, 2015), action research (Reason & Bradbury, 2010), or workplace design (Rasmus, 2011).

Thus, there is no shortage of approaches and methods relating to participation. More and more companies are using agile methods, design thinking and open innovation to involve prospective end consumers. So far, however, virtually nothing is known about whether and to what extent employees on the shop floor are being given a greater role in the design of the 4.0 world, and whether this is actually happening in production – that is, on the level of skilled labour, which is central for the core processes of Industry 4.0.

Up to now, design decisions in production about new automation solutions and the related digitization have usually been made by engineering departments often organized according to a strict division of labour (e.g. between mechanical engineering and IT), mainly following academic methods and thus integrating employees on the shop floor only in the last step. These well-established processes of implementing individual automation solutions are reaching their limits in Industry 4.0. However, if industry 4.0 requires more participation, we need to: What do the experts in the engineering think about more participation and related design processes? How do those employed in this area perceive and put into practice the participation of the shop floor today, and how do they expect to engage production workers in the coming implementation of Industry 4.0?

The relevant studies on this topic dealing with manufacturing companies and, specifically, the relationship between skilled workers and engineers, are limited in number, mainly older, and therefore do not take into account Industry 4.0 (Asdonk, Bredeweg and Kowol, 1993; Bieber, 1997; Funken, 1994; Manske, 1995; Wolf, 2012). More recent studies relating to Industry 4.0 have either accompanied pilot implementations (Lingitz & Hold, 2015), or focused on the role of employee representation (Georg, Katenkamp, Guhlemann and Dechmann, 2017). Research has consistently shown that production workers in Germany are especially highly skilled, mainly because of the vocational education and training system (Aizenman, Jinjarak, Ngo and Noy, 2017; Heinz & Jochum, 2014; Nicklich & Fortwengel, 2017; Steedman, Hilary, 2014). Besides formal training, however, there is also valuable, domain-specific experiential knowledge on the shop floor, which proves especially useful in highly technologized environments, as shown by studies on the introduction of CNC technology (Böhle, 1994; Böhle & Milkau, 1988), as well as more recent studies on assembly work and robotics (Pfeiffer, 2016). This "living working capacity" (*Arbeitsvermögen*) is personal, physical and informal (Pfeiffer, 2014; Pfeiffer & Suphan, 2015), and shows its particular strength when it comes to dealing with complexity and working in digital environments (Böhle & Huchler, 2017). And what works well today could also prove to be a relevant resource for the future. It therefore seems an obvious step to incorporate this special knowledge and ability of employees on the shop floor into the design of future manufacturing.

In summary, participatory design is urgently required, promising methods and processes are available and shop floor employees have a lot to offer. But what is it really like in the companies? Are available resources appreciated and fully utilized in participatory processes? Is the future of manufacturing in Industry 4.0 even seen as deliberatively "designable"? And what views on Industry 4.0 and its participatory design can be found among those who have so far been largely responsible for the design of incremental innovation on the shop floor, that is, the engineers who, in large-scale production plants, make the actual decisions about machines, manufacturing technologies and the degree of automation?

This article presents the results of surveys of these engineers in a German automotive plant. The focus is on their views, experiences and ideas for the future regarding the participation of shop floor workers in the context of Industry 4.0. The data, gathered in 2016, consist of 13 qualitative interviews, group discussions and feedback workshops and from a quantitative online survey (N = 233), including a Q-sort. The method and the factory studied are presented in *section 2*, the empirical findings are set out in *section 3*, grouped according to the different survey methods, and are then discussed in *section 4*.

## 2. Method and factory studied

The automotive factory studied produces mainly smaller commercial vehicles; at the time of the survey it employed around 15,000 people. Structural data for the factory can be found in the employee study carried out by the metalworkers' union, IG Metall, in 2013:[5] more than a fifth of the workforce of this factory (N = 3232) was covered by this survey. According to the study, the vast majority of the respondents from this plant are male (87.6 %), with only 12.4 % female.[6] The mean age of the employees, according to the IGM study, is 40.97 years (SD = 10.79; n = 3072), and

[5] The data set (IG Metall, 2013) comprises 514,134 people from over 8400 companies.

[6] For the analysis, only respondents aged between 15 and 65 were included, to exclude any members who had taken part in the survey but who were retired or on work experience from school.

the average period of employment is 18.81 years (SD = 10.55; n = 2878). The longest stated period of service is 42 years.

Surveys were fielded during a short period of time in the spring and early summer of 2016. Total duration of the project from the kick-off to the last workshop on the findings was just under a year (late autumn 2015 to autumn 2016). The tight timeline was requested by the company, which wanted to quickly develop a production line for a new vehicle type, involving as many "4.0" components as possible. As the management and works committee expected strong employee participation in this development, the aim was to complete the survey in time to inform the format of such participation. The survey was funded by the local branch of the company, and the research questions and method were developed in several workshops in consultation with company management and the works committee. It was agreed that the following three thematic areas were central:

- the views of employees on Industry 4.0;
- their experiences, fears and wishes regarding participation in the design of work systems and new technologies;
- the potential of employees to participate in the design of Industry 4.0.

The findings were initially presented to the works committee and management in the summer of 2016. Further rounds of feedback took place in the fall of 2016, reaching several hundred employees in total: for example, the results were presented to around 120 engineering employees at a lunchtime event. Another event attracted 160 senior staff from the production area (plant management, master craftspeople in the participating areas, departmental managers); three feedback events were held for employees from the production area, each attracting about 300 participants. The discussions at these six feedback events, and at the four group discussions with the management and works committee at the beginning of the project, were recorded by hand. These notes were included in the analysis as additional qualitative material. As part of the project, all employees of the plant were given access to the key findings of the qualitative analysis, and the descriptive analyses of the quantitative survey, in the form of annotated presentation slides – instead of a detailed research report. In total, eight different slide decks were made available, consisting of around 300 slides.

Our own survey included 28 qualitative interviews, several workplace observations, group discussions and feedback workshops, as well as quantitative surveys with a total of 452 respondents from the areas of production (N = 219) and engineering (N = 233). This article will present the empirical findings from the survey of the engineers, in particular their views on the subject of participation. First, 13 qualitative interviews, each around 1 hour long, were conducted with engineering employees. In order to generate sufficient material for the development of the items for the online survey, only engineers who had already worked with Industry 4.0 technologies at the time of the survey were included in the qualitative study. The interview guidelines were loosely structured with the main aim of eliciting self-determined narratives. The survey method and the selection of the interviewees were based on approaches from the sociology of work: the company case study and the innovation process analysis (Wühr, Pfeiffer, and Schuett, 2015). Interviews were transcribed in full and subjected to content analysis (Mayring, 2007).

In addition, 270 engineering employees were selectively targeted with the quantitative online questionnaire (response rate 86 %; N = 233); the selection was objectively based on who was expected to be involved in the reconceptualization of the manufacturing automation systems in the foreseeable future. These respondents can be assigned to five engineering groups in accordance with their areas of work: “automation & IT” (14.2 % of the respondents), “industrial engineering” (19.3 %), “logistics & materials” (20.6 %), “body construction planning” (23.6 %) and “assembly planning” (22.3 %). The respondents are in the middle age range (17.7 % up to 30 years old, 42.2 % between 31 and 45; 33.6 % between 46 and 55, and only 6.5 % older). Contrary to what one might perhaps expect in engineering, the respondents are not primarily university educated. Only one third (29.9 %) gained their qualifications solely from university study, and a quarter (24.7 %) have both vocational and academic qualifications, but just under half the respondents have only vocational qualifications (further training as a master craftsperson or technician following their initial vocational training). Although the respondents are carrying out engineering activities, the qualification structure is much more diverse. From our point of view, this is a noteworthy finding in itself: engineers in the automotive factory under study work primarily with methods from the academic discipline of engineering – but mainly on the basis of vocationally acquired skills and qualifications.

With reference to age and qualification, the five engineering groups do not differ significantly. There are some small anomalies, however: for example, the group “automation & IT” is the only one to show a polarized age structure: 34.3 % of the employees are 30 and under, 12.5 % 56 or over – in each case these are much higher values than in the other four groups. It may be that the age structure also explains the unusual qualification structure in this group, which has the lowest percentage of employees with purely academic qualifications (12.9 %). The highest proportion of employees with purely vocational qualifications is found in the group “logistics & materials” (62.5 %).

## 3. Participation and Industry 4.0 today: Practice and viewpoints

In the following section, the findings based on the three steps of the study will not be presented in the same chronological order in which the company survey was carried out. While the survey began with qualitative investigations, this section will first give an insight into the descriptive analyses of the quantitative survey, in order to offer a better overview (section 3.1). The focus here is on the current general views of the respondents on participation and the situation regarding Industry 4.0. This will be followed by a brief examination of the qualitative interviews (section 3.2) to background the subjective assessments of participation past experiences of participation and Industry 4.0 in everyday engineering work. In addition, 25 statements will be extracted from the qualitative material and interpreted from the perspective of sociological futures studies; these statements will, lastly, form the basis for the Q-sort presented in the third subsection (section 3.3). All three stages of the survey involve asking engineering employees the same questions: what will the future be like with Industry 4.0, and how can/should production workers participate in its design? The triangulation of the three different empirical methods leads to overlap in the content presented, but also better tracks the structural facts and individual experiences of participation.

## 4. Current participatory practice and implementation of Industry 4.0 in figures

Since the survey was focused on Industry 4.0, the first matter of interest is how familiar respondents are with the topic. Overall, 18.5 % say that they are not only familiar with Industry 4.0, but also routinely work with these technologies. This applies by far the most to the group "automation & IT" (48.5 %). Only 0.9 % (4.2 % within the group "logistics & materials") state that they have not yet had any contact with Industry 4.0 (cf. Table 1, top right).

The quantitative questions relate to the current practice of participation experienced by the respondents, regarding the shop floor and in the case of decisions about automation. Three sets of questions were analysed for this article:

- Timing and nature of the participation: How often are employees on the shop floor actively included before the decision-making, asked before the final decision, or only informed after the decision has been made?
- Information channels towards the shop floor: How often is information conveyed in face to face communication with workers on the shop floor? How often does this occur via line managers or through formal procedures?
- Probable reasons for non-participation of the shop floor: Participation is not a one-way street, so respondents were also asked why they thought employees on the shop floor might not get involved. Here they could choose whether this was due to a lack of time, a lack of knowledge, or inadequate procedures.

Overall, it can be said that all three forms of participation are relatively common in engineering. The highest proportion of respondents (75.8 %) state that they often only inform workers after the decision, and the lowest proportion (66.7 % – still a high figure) actively involve shop floor workers in an early phase.

When it comes to channels of information towards the shop floor, line managers (71 % "often") and direct talks (65.8 % "often") score higher than procedures (45.5 %). If staff on the shop floor do not get involved in changes, 52.4 % of the engineering respondents attribute this to a lack of time, and 46.8 % to a lack of knowledge; it is least often ascribed to a lack of appropriate procedures (30.5 %).

Between the groups, there are hardly any significant differences in relation to the three complexes of questions. One noteworthy finding, however, is that it is employees in "automation & IT" who least often actively involve the shop floor before a decision is made (34.5 %), and those in "industrial engineering" who do so most often (81.8 %). In comparison to the other engineering groups, "automation & IT" less often convey information to the shop floor via line managers (55.2 % "often"), and much less often in the framework of procedures (15 % "often"). Moreover, employees in "automation & IT" see a lack of knowledge (60.6 %) and the absence of adequate procedures (42.4 %) as the main reasons why workers on the shop floor do not participate.

Table 1. Descriptive findings on engineering and participation

**Ideal-typical views on „Industry 4.0“ and participation**

Q principal component analysis, N = 233

49 % ($R^2$) of variance explained

weighted deviation (σ): 0 – 5

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Workers from the production line have **too little time to actively participate** in changes. | | | | |
| | | | When it comes to changes in the workplace, **if too many people** have a say **too early** this does **not produce a good outcome**. | Most employees are **too attached** to their usual work **to be open to innovations**. | Industry 4.0 will make work **less physically** strenuous. | | | |
| | | The form Industry 4.0 will take in the factory is solely the **decision of the management.** | Industry 4.0 will make work **more psychologically stressful.** | Industry 4.0 will make everything **more technologically complex and more vulnerable**. | The design of Industry 4.0 by the workers leads to **technically better solutions**. | When it comes to technological changes, I am **dependent on the knowledge of workers** on the production line. | | |
| | The end result of Industry 4.0 will be **factories without people**. | Most employees are **not interested in actively co-designing** their place of work. | Employees on the shop floor are **not qualified** to design Industry 4.0. | Industry 4.0 will make it possible to **eliminate fixed cycle times**. | Workers can **actively design** Industry 4.0 if they are **informed about its possibilities**. | When it comes to technological changes, the workers who are affected should already be **included in the process of selection and decision-making**. | Industry 4.0 will secure the factory's place in **global competition**. | |
| When it comes to technological changes, it is best to **only inform** the affected workers **once everything has been decided**. | Industry 4.0 gives so much support that **work becomes less attractive**. | The design of Industry 4.0 should be **left to IT experts.** | The jobs **most at risk** from Industry 4.0 are those of **employees with reduced capacities** due to age or disability. | When it comes to changes, all production line workers have enough opportunity to get involved at their team meetings. | Industry 4.0 will make work in manufacturing **more interesting**. | Industry 4.0 will **create new jobs** for well trained skilled workers. | Workers who gain **experience** every day in their workplace often have the **best ideas for improvements**. | When it comes to technological changes, **the earlier** workers are included in the process, **the higher the acceptance**. |

do not agree — neutral / ambivalent — agree

It has already been noted that not even a fifth of all the engineering respondents in the company studied actually deal with the implementation of Industry 4.0. But how much is this fifth (or just under) engaged in participatory processes with the shop floor, be it as a result of structural guidelines or informal, individual choice? 62.5 % of them do actively involve the shop floor before making a decision, and 73.2 % often convey information in direct conversations with employees on the shop floor (cf. Table 1, middle right). The correlation is merely descriptive and should not be overestimated. Furthermore, the nature of the enquiry does not reveal whether these comparatively high levels of participatory activity relate to Industry 4.0 measures, or to other engineering activities. In addition, the figures do not give a reliable indication of the direction of the correlations – so we cannot say whether very participation-oriented engineering employees are more likely to be recruited (or to self-select) for Industry 4.0 projects, or whether such projects are associated with greater participation requirements and stronger participation processes. In any case, it did not become clear in the qualitative surveys (individual interviews and group discussions) and feedback workshops whether previous practices of participation or individual openness towards participation are relevant when teams are being assembled to implement Industry 4.0 projects.

## 5. Participation: Yes, but only in small doses, please! A look at the qualitative interviews

Often the usefulness of shop floor participation is seen as dependent on matters of *time*, *personnel* and *content*. Participation is valued, but the forms in which it currently takes place are projected, largely unchanged, onto future needs and the design of more disruptive automation and digitization technologies. Here participation appears as a highly controlled process: it tends to be organized from the top down, and its content and timeline are mainly determined by the engineers and not the production workers. In the qualitative interviews, three ideas prove to predominate:

- Involvement should only take place relatively late in the innovation process, i.e. only in the launch phase in serial production, and within the framework of special workshops;
- Only a small number of employees should be involved in participation; they are chosen on the basis of their role (master craftspeople, team speakers) or their level of commitment;
- In terms of content, participation should be limited to questions of the handling and operability of new developments, and their susceptibility to failure.

Overall, the purpose of participation is mainly associated with two aspects: making use of *experience* which is close to the workplace and relevant to practice and securing *acceptance*. The following interview quote makes this very clear:

> "The [workers on the shop floor] have experience, I mean, they build, let's say, talking in [x]-minute cycles, [hundreds of] vehicles per shift, the workers, they're so familiar with it, they know the product inside-out, even if it's only the prede-

> cessor product, but it's never completely different. So, on the one hand there's that, the input. On the other hand, there's something that I think is also very important: the acceptance of the processes afterwards. That the systems that are created are also followed, because you don't just plan your process with a view to ergonomics and time, but also in terms of quality. And if you get the acceptance there, then you can be at least, say, 90 to 95 % sure that the work will be done in that way. If those people are on board at an early stage, and also, later on, get to know the new product at an early stage as key communicators, and then tell their team a few things about it, and so on – to ensure this broad acceptance. To come back to input again: it's the experience. It's simply lots of actions that these people carry out [hundreds of] time a day in some cases, which contribute a perspective that you can't simply get sitting at a desk" (A-06_25; assembly planning).

The experience of the workers is a functionally necessary input. The subsequent description in this and almost all the other interviews shows that the experience of the workers is also highly valued when it comes to anticipated faults and product quality. However, the engineers' ideas about participation mainly follow the instrumental and product-related goal of safeguarding the engineering process in practice. Or, to translate this into the world of software development, workers on the shop floor function as selected key users who are invited to the beta test. This also fits with the views on the mode of participation: engineers retain their authority over form, content, timing and personnel; the process is conceived of as "catch-up" optimization rather than future-oriented innovation. The following interview quotation, referring to a process of material provision that had just been changed at the time of the survey, illustrates this:

> "And we made it so simple that [the workers in production] actually don't have to come into contact with it at all, that is, they don't have to deal with the technology, hence we've only involved them in the development process [for the modified material feed system] to a limited extent, because it simply isn't necessary. First we made sure that we got the technology right, and then we looked at whether it was manageable for [the worker] down there, and then we intuitively decided that it's so easy now: the things he comes into contact with are things he's already familiar with now, and for the things he's not familiar with we have [the relevant department], the software which is behind it in the end" (B-05_89-92; automation & IT).

Overall, the participation of the shop floor within the framework of the existing procedures (CIP workshops and employee suggestion schemes) is in many cases regarded as well established and sufficient. In view of Industry 4.0, however, respondents see the need to develop an even broader concept of participation, involving, for example, greater collaboration across factories and companies. For this, they say, the state of knowledge and information about Industry 4.0 must be improved. Furthermore, interviewees frequently wished that both decision-makers and shop floor workers were more willing to embrace change. The main thing the engineers surveyed expect from their managers is more transparency about the strategies of the company and the facility with regard to Industry 4.0. They also hope to gain more scope for decision-making and/or resources for experimental projects, since the tight timeframes imposed by profitability requirements systematically hamper larger innovative leaps. The respondents see workers on the shop floor as having largely unfounded fears of Industry 4.0 as an impetus for rationalization; instead they emphasize the ergonomic opportunities.

As well as the quotes presented here, it was possible to extract twenty-five statements from the qualitative interviews and group discussions. The ideas in these statements were present throughout, though sometimes these ideas were *disagreed* with. These core statements were therefore selected for further study using the blow Q-sort (cf. section 3.3). In the research process, the choice of statements was closely based on empiricism and the prevailing everyday discourse in the company at the time of the study. In retrospect, however, these can readily be interpreted with a classic concept from sociological futures studies: In his book *The Game of the Future*, published in the early 1970s, Fred L. Polak makes a fundamental distinction between positive or negative images of the future on the one hand, and assessments of the (im)possibility of influencing the future on the other. His distinction between *essence optimism* or *essence pessimism* and *influence optimism* or *influence pessimism* (Polak, 1973, p. 17) has recently attracted new attention in the scholarly discourse and as a participatory method: Hayward and Candy (2017, p. 8) develop a corresponding fourfold table and divide it – based on their own experience – into a positive or negative view of the future (things are good and getting better/worse) and an assessment of the potential to influence this anticipated state (in simplified terms: I/we can/cannot act to make things better). This heuristic can be applied to 20 of the statements extracted from the qualitative material; another five relate to possible forms of participation:

*Digital essence optimism* (Industry 4.0 is seen as an opportunity to make production work better):

- Industry 4.0 will make work less physically strenuous.
- Industry 4.0 will make it possible to eliminate fixed cycle times.
- Industry 4.0 will secure the factory’s place in global competition.
- Industry 4.0 will make work in manufacturing more interesting.
- Industry 4.0 will create new jobs for well-trained skilled workers.

*Digital essence pessimism* (Industry 4.0 is seen as a risk, and its negative consequences for production work are emphasized):

- Industry 4.0 will make work more psychologically stressful.
- Industry 4.0 will make everything more technologically complex and more vulnerable.
- The final result of Industry 4.0 will be factories without people.
- The jobs most at risk from Industry 4.0 are those of employees with reduced capacities due to age or disability.
- Industry 4.0 gives so much support that work becomes less attractive.

*Participative influence pessimism* (focusing on what respondents perceive as existing obstacles to the participation of production workers, or sensible restrictions on this participation):

- Most employees are too attached to their usual work to be open to innovations.
- Most employees are not interested in actively co-designing their place of work.
- Employees on the shop floor are not qualified to design Industry 4.0.
- The form Industry 4.0 will take in the factory is solely the decision of the management.
- The design of Industry 4.0 should be left to IT experts.

*Participative influence optimism* (the experience of production workers is seen as an important or even indispensable resource for design (or for the design of Industry 4.0); if anything precludes more involvement, it is time pressure:

- Workers who gain experience every day in their workplace often have the best ideas for improvements.
- Workers can actively design Industry 4.0 if they are informed about its possibilities.
- The design of Industry 4.0 by the workers leads to technically better solutions.
- When it comes to technological changes, I am dependent on the knowledge of workers on the production line.
- Workers from the production line have too little time to actively participate in changes.

*Forms of participation* (views on forms of successful participation processes in the operational context)

- When it comes to changes in the workplace, if too many people have a say too early this does not produce a good outcome.
- When it comes to technological changes, the workers who are affected should already be included in the process of selection and decision-making.
- When it comes to technological changes, it is best to only inform the affected workers once everything has been decided.
- When it comes to changes, all production line workers have enough opportunity to get involved at their team meetings.
- When it comes to technological changes, the earlier workers are included in the process, the higher the acceptance.

## 6. Diversity of statements – consensus of views

Q methodology (Brown, 1980; Müller & Kals, 2004) is a method of survey and analysis for investigating human subjectivity, which has so far been little used in Germany. Q involves both quantitative steps (for data reduction) and qualitative approaches (for interpretation), and, as a “mixed method”, promises to combine the scalability of quantitative methods with the discursive holism and openness of an interview.

In contrast to traditional survey research, viewpoints are recorded here as spontaneous *rankings* of numerous items, common sorting patterns are extracted, and finally interpreted qualitatively in the form of empirically shared, ideal-typical sorts. Q operationalizes the subjectivity as an *ipsative* measure of evaluating all items *relative* to one another, not to some normative standard as is done in conventional surveys. This comparison of each item with all the other items has the added benefit that the ratings are also standardized across the subjects, since all participants have to evaluate the same items.

We conducted this step of the survey with the engineering employees online.

After a rough preliminary sorting into three "piles" (negative – undecided/neutral – positive), the participants ranked all the items according to the extent to which they agreed with them from left (disagreement) to right (agreement). At the end, participants could correct their categorization and enter open feedback on their highest and lowest-ranked item. Participants could express indifference between items by placing them on top of each other as ties.

Q also differs from classic survey research in the formulation of the items: items can be ambiguous, in everyday language, or associative, but should be *commensurable* for purposes of evaluation and sorting, and should invite a spontaneous, subjective reaction. Falsifiable statements or objective facts are therefore not suitable. The 25 items selected – or their general meaning – come from the qualitative interviews conducted with the employees from engineering. They are a substrate of a total of 97 statements identified as thematically relevant. This concourse, or universe of statements, was not derived from the general discourse on "Industry 4.0", but deliberately reflect discussions on this topic in the factory under study. Since the sorting took place online and at the workplace, and other questions were also asked, it would not have been reasonable to include more than 25 items. The items were selected by mutual agreement within the research team.

The ranking data reveal some common patterns in the subjective views of the engineering employees. Absolute rank correlations between sorters average to 0.41 (Spearman's ). Typical for some Q data, there are also less negative correlations than positive correlations, indicating that people do *not*, on the surface, hold polar opposite as beliefs.

A principal component analysis was then used to reduce the shared patterns to one principal component.[7] The one-component model, with a moderate explanatory power of 48.61 % of overall variance, suggests some agreement among respondents when it comes to the topic of Industry 4.0 and participation.[8] There also appear to be

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7 After a parallel analysis following Horn (1965) and Glorfeld (1995), using a Monte Carlo simulation adapted to Q data (Held, 2017), only the first principal component remains with a corrected eigenvalue greater than 1 (Kaiser-Guttman criterion). This strict standard for component extraction is especially indicated in the case of the present high-dimensional data with low sample sizes (HDLSS): with 233 participants but only 25 items, it must be assumed that there will be substantial random covariance. For technical reasons the parallel analysis was conducted (as usual) based on Pearson's coefficient, *not* Spearman's rank coefficient, which is otherwise used here and is better suited to Q. Even with a Spearman's correlation matrix, however, the eigenvalues drop sharply after the first component (scree criterion), so that a one-component solution seems to be the safer choice. The analysis was carried out with Pensieve software (Held, 2017) for the R statistics platform (R Core Team, 2012).

8 Strictly speaking, the above-mentioned parallel analysis sets only a *negative* standard: the remaining covariances outside the first principal component (residual matrices) *cannot* be distinguished with great probability ($p = 0.05$) from random patterns, and will therefore not be interpreted here, to be on the safe side. Such an atypical result for Q can be explained by the unsuitability of the items, the great homogeneity of the participants, and an unfavourable ratio of participants to items, in this case particularly the last two.

no striking differences *between* the groups of employees[9]: on average, all the groups have roughly the same loading on the first principal component.

The first component is also unipolar: there are almost all positive loadings, indicating that many participants all agreed on this factor, with few being diametrically opposed.

This simple structure of the viewpoints is only surprising at first glance, as all the respondents are engaged in very similar activities, face similar work requirements, and work in similar environments (work equipment, subject of work, organization of work). They work in the same factory, using the methods of engineering science to design and plan the work systems and technology on the shop floor. In this respect, the sample displays a high level of homogeneity – especially as the items used were, *firstly*, developed on the basis of the qualitative interviews conducted with the same group of employees, and, *secondly*, related to the respondents' professional activity. We would not expect similar homogeneity for items on topics outside the respondents' own everyday workplace (e.g. items on climate change or the refugee debate).

The extracted factor was then used to generate an "ideal-typical" ranking.[10] Figure 1.1 in the appendix presents this, with the items that were

rejected on the left-hand side and the items that attracted the most agreement on the right-hand side. The shading of the cells shows the dispersion of the items. Items with darker shading are *less* scattered, i.e. there is a high consensus about the position of the item among the participants who are well described by the factor.[11] Lighter cells are *more* scattered around the depicted mean value, so opinions about the position of the item vary even among those individuals with high loadings on this factor.

The "ideal-typical" viewpoint of the engineering employees illustrates a high level of acceptance of Industry 4.0 and participation. A wide dispersion only appears in the case of especially positive items on both topics, despite strong agreement *on average*. For the most part, items expressing great scepticism towards participation or criticism of technology are also clearly rejected, although there is considerable dispersion here too. These two things suggest that while the underlying attitude is generally positive about participation and optimistic about technology, there are also a few employees who contradict the exclusively positive positions, or who are at least ambivalent about the items that are hostile towards participation and critical of technology.[12] The broad acceptance of participation and Industry 4.0 may *not* extend to the most forceful statements; at the extremes, the optimistic view is not as reliably shared.

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9 The study is too underpowered for an inferential test of group differences in loadings; the *lack* of differences should therefore be regarded with caution as a cursory observation.

10 Here we use the loadings-weighted average of the raw data, also known as "regression scores" (Thompson, 2004).

11 This is the loadings-weighted standard deviation of the rankings in the raw data (cf. Held, 2017).

12 The great dispersion in the extreme items, combined with (in some cases) very low dispersion in the neutral centre, is an anomaly from the point of view of Q methodology. One would actually expect that the items in the extreme rankings would have *low* dispersion; after all, covariances in the extremes have a major influence on the principal component analysis. Perhaps what we are seeing here are the traces of a rare but fundamental disagreement, which would, overall, appear more clearly with an elaborate measuring instrument (more items) and corresponding rotation of the loadings.

Figure 1. Result of the Q principal component analysis

| | Timing and nature of shop floor participation | | | | Information channels towards the shop floor | | | | Reasons for non-participation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Never | Some-times | Often | | Never | Some-times | Often | | No | Yes | |
| | % | % | % | N | % | % | % | N | % | % | N |
| | Active inclusion before decision | | | | Face to face communication | | | | Lack of time | | |
| Automation & IT | 3,4 | 62,1 | 34,5 | 29 | 0,0 | 28,1 | 71,9 | 32 | 42,4 | 57,6 | 33 |
| Industrial Engineering | 0,0 | 18,2 | 81,8 | 33 | 0,0 | 28,1 | 71,9 | 32 | 37,8 | 62,2 | 45 |
| Logistics & materials | 2,3 | 27,9 | 69,8 | 43 | 0,0 | 25,0 | 75,0 | 44 | 47,9 | 52,1 | 48 |
| Body construction plar | 2,1 | 27,1 | 70,8 | 48 | 10,0 | 38,0 | 52,0 | 50 | 54,5 | 45,5 | 55 |
| Assembly planning | 0,0 | 31,2 | 68,8 | 48 | 2,3 | 34,1 | 63,6 | 44 | 51,9 | 48,1 | 52 |
| ***all*** | ***1,5*** | ***31,8*** | ***66,7*** | ***201*** | ***3,0*** | ***31,2*** | ***65,8*** | ***202*** | ***47,6*** | ***52,4*** | ***233*** |
| | Asking before final decision | | | | Information via line managers | | | | Lack of knowledge | | |
| Automation & IT | 3,4 | 44,8 | 51,7 | 29 | 6,9 | 37,9 | 55,2 | 29 | 39,4 | 60,6 | 33 |
| Industrial Engineering | 0,0 | 15,6 | 84,4 | 32 | 0,0 | 29,0 | 71,0 | 31 | 60,0 | 40,0 | 45 |
| Logistics & materials | 0,0 | 19,0 | 81,0 | 42 | 2,7 | 16,2 | 81,1 | 37 | 47,9 | 52,1 | 48 |
| Body construction plar | 0,0 | 22,9 | 77,1 | 48 | 2,0 | 28,0 | 70,0 | 50 | 58,2 | 41,8 | 55 |
| Assembly planning | 0,0 | 29,2 | 70,8 | 48 | 0,0 | 26,1 | 73,9 | 46 | 55,8 | 44,2 | 52 |
| ***all*** | ***0,5*** | ***25,6*** | ***73,9*** | ***199*** | ***2,1*** | ***26,9*** | ***71,0*** | ***193*** | ***53,2*** | ***46,8*** | ***233*** |
| | Information after final decision | | | | Information through formal procedures | | | | Inadequate procedures | | |
| Automation & IT | 7,1 | 10,7 | 82,1 | 28 | 45,0 | 40,0 | 15,0 | 20 | 57,6 | 42,4 | 33 |
| Industrial Engineering | 13,8 | 10,3 | 75,9 | 29 | 0,0 | 35,7 | 64,3 | 28 | 77,8 | 22,2 | 45 |
| Logistics & materials | 4,8 | 19,0 | 76,2 | 42 | 15,2 | 45,5 | 39,4 | 33 | 72,9 | 27,1 | 48 |
| Body construction plar | 6,2 | 18,8 | 75,0 | 48 | 7,7 | 48,7 | 43,6 | 39 | 70,9 | 29,1 | 55 |
| Assembly planning | 10,6 | 17,0 | 72,3 | 47 | 11,1 | 33,3 | 55,6 | 36 | 65,4 | 34,6 | 52 |
| **all** | **8,2** | **16,0** | **75,8** | **194** | **13,5** | **41,0** | **45,5** | **156** | **69,5** | **30,5** | **233** |

| | Familiarity with Industry 4.0 topics | | | | | |
|---|---|---|---|---|---|---|
| | Not yet heard of | Heard of, no idea | Only rough idea | Familiar, but not involved | Familiar and involved | |
| | % | % | % | % | % | N |
| Automation & IT | 0,0 | 6,1 | 27,3 | 18,2 | 48,5 | 33 |
| Industrial Engineering | 0,0 | 13,3 | 40,0 | 37,8 | 8,9 | 45 |
| Logistics & materials | 4,2 | 8,3 | 41,7 | 37,5 | 8,3 | 48 |
| Body construction plar | 0,0 | 12,7 | 54,5 | 12,7 | 20,0 | 55 |
| Assembly planning | 0,0 | 15,4 | 40,4 | 28,8 | 15,4 | 52 |
| ***all*** | ***0,9*** | ***11,6*** | ***42,1*** | ***27,0*** | ***18,5*** | ***233*** |

Praxis of participation / familiarity with Industry 4.0

| | Aktive inclusion | | | Direct information | | |
|---|---|---|---|---|---|---|
| | never/ seldom | often | | never/ seldom | often | |
| **Industry 4.(** | % | % | N | % | % | N |
| Not familiar | 32,3 | 67,7 | 161 | 36 | 64 | 161 |
| familiar | 37,5 | *62,5* | *40* | 26,8 | 73,2 | 41 |
| | ***33,3*** | ***66,7*** | ***201*** | ***34,2*** | ***65,8*** | ***202*** |

| | Q method: loadings | | |
|---|---|---|---|
| | Mean | SD | N |
| Automation & IT | 0,64 | 0,18 | 33 |
| Industrial Engineering | 0,70 | 0,14 | 45 |
| Logistics & materials | 0,61 | 0,20 | 48 |
| Body construction planning | 0,60 | 0,21 | 55 |
| Assembly planning | 0,63 | 0,21 | 52 |

Further evidence of a *cautious* optimism of this kind is offered by the consistently neutral or undecided view of the limits of participation, Industry 4.0, and the status quo (middle of Figure 1). Overall, participation of the shop floor is seen as offering considerable potential, and as something that workers are capable of, but it is linked to various conditions; for example, it takes time and space, and both these things are often lacking.

In terms of the sociology of work, the result can be plausibly explained by the respondents' homogeneous work experiences and activities. This interpretation is also validated by the insights gained from the 13 qualitative interviews. The consistency in the findings can therefore also be taken as an indication that the Q method is suitable for investigating qualitative subjectivity in the work context.

On the other hand, the differences for the engineering group "automation & IT", which become apparent in the individual quantitative surveys on forms of participation, pathways and obstacles to it, cannot be confirmed in the more complex and in-depth analysis of the Q method: none of the groups of employees shows substantially different loadings, and no other clear covariances with other variables can be observed. This suggests that differences resulting from roles and functions are more likely to become visible in the classic form of survey and descriptive analysis – for example, whether someone often takes part in participation processes or never does so is, in the work environment, not so much a consequence of individual will, but more a reflection of organizational structures and established processes. In contrast, the Q method shows the subjective overall attitude to all participation-oriented items regarding Industry 4.0. Beyond the respondents' different areas of activity, their viewpoints on this are largely shared. Furthermore, regardless of the participation which respondents currently experience and which organizational structures permit, most perceive a greater need for participation in Industry 4.0 implementations and see this as offering considerable potential. However, the current obstacles to participation (especially a lack of time and unsuitable procedures) are also regarded as limitations in the future, and there is no indication that engineers are developing ideas or initiatives for overcoming them.

## 7. Conclusion: More innovative forms of participation are desirable, but initiators are lacking

The respondents in engineering largely value the experience of workers on the shop floor and see their knowledge as essential for the good design of new automation and digitization solutions. At the same time, they often disregard the workers' knowledge about current developments in the context of Industry 4.0. Here too, however, there is a prevailing willingness to include the production level at an early stage. What is lacking, however, is adequate conditions for participation processes. Our empirical investigations, which cannot be presented here due to space restrictions, confirmed something that had long been known from other research findings: that innovation processes in the engineering departments of the manufacturing industry show a particularly high degree of organizational standardization (Pfeiffer, Schütt and Wühr 2010; Will-Zocholl, 2017). Thus, there is insufficient time and opportunity for an incremental design of the processes. This is all the truer given that the previous procedures (for example in the framework of CIP processes) do not seem suitable for innovative, future-oriented implementations. It is also striking that the engineering group that hardly has anything to do with actual production and logistics processes, but is mainly involved in automation and digitization technologies, is less likely to include the workers on the shop floor, and – perhaps for this very reason – is also less likely to perceive positive effects when participation has taken place. A somewhat more optimistic picture emerges among those respondents who are currently involved in actual Industry 4.0 implementations: they take a slightly more participatory approach than others in engineering.

Overall, however, the practices, ideas and expectations associated with participation are largely oriented towards existing procedures. The engineers' view is that these have worked well so far and could be utilized even better for participation in the context of Industry 4.0. It is doubtful, however, whether the innovative potential of a cluster of technologies requiring as much participatory design as Industry 4.0 can be sufficiently exploited in established participation processes based on incremental optimization. The things that are repeatedly emphasized and held up as ideals in the current discourse on digitization and Industry 4.0 – from the use of the crowd to open innovation, the inclusion of future users in agile processes or design thinking – all these things could also initiate innovation and revolutionize the forms of participation between engineers and the shop floor. It would be worth applying these new forms of participation not only externally (that is, in customer relations or marketing), but also internally (that is, among the employees who are directly adding value) – after all, production sites in Germany have particularly skilled workers compared to other countries, thanks to the dual system of vocational education and training. Empirically, it is certainly possible to find engineers who are willing to encourage more participation from skilled workers on this level. It is unlikely, however, that engineers will provide the impetus for a radical revision of existing participation formats – unless they are given more time and room to manoeuvre.

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