WORKING PAPER

Eurofound

Digitisation in the workplace

Case Study: Digital technologies at Bächer Bergmann (Köln)

Digitisation in the workplace

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Related report: *Digitisation in the workplace*

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Case summary

Bächer Bergmann is a small woodworking company in Cologne, Germany, specialising in digital-aided small-scale production of design elements for museums, churches and public fairs. They work on a project basis for individual stakeholders on unique designs (NACE: C.16).

As part of the company's core business Bächer Bergmann uses digital technologies to develop its niche in the woodworking sector. In comparison with traditional woodworking, digital technologies aid employees in carrying out their tasks more efficiently. The company is investigating new digital technologies primarily out of curiosity, to experiment what the technologies can be used for. The following technologies are discussed in this report:

- 3D Printing (TRL 8), which enabled the company to produce objects not available or very expensive on the market to fit project needs. In addition, it allowed overnight production, optimising the uptime of machinery and utilisation of employee time.
- Augmented reality (AR; TLR 8), which has assisted the handover of designers in the office and employees in the workshop by simplifying the visualisation of designs. Additionally, it allowed the employees in the workshop to understand the whole project to which their work would contribute. Virtual reality (VR) was tested in the same vein, but failed to deliver the expected results due to technology limitations at the time.

For Bächer Bergmann, 3D printing follows earlier digitisation technologies in the woodworking process: computer numerical control (CNC) milling (which is extractive rather than additive). Yet both 3D printing and CNC milling require a different approach to work organisation from the employees in the workshop as machines operate differently to humans. While humans undertake a procedure in a certain order, a machine is likely to be able to perform multiple steps at a time. Augmented reality increased the possibility for autonomous behaviour for workshop employees as they can go back to a visualisation of the product that they are working on without consulting designers in the office. However, during the interviews, one employee criticised this approach as it does not lend itself to learning and improvement. Going back to a colleague to clarify uncertainties can result in error detection in the design or make office employees aware of problems in their communication.

With the introduction of digital technologies, training needs arose that are not institutionalised as they are uncommon for the industry. Therefore, the company needed to build an internal knowledge base to train new employees on the machines in order to have sufficiently trained personnel. Due to a flat hierarchy and small company size an open and voluntary approach to this has proved itself up to today.

Introduction

Background and objectives

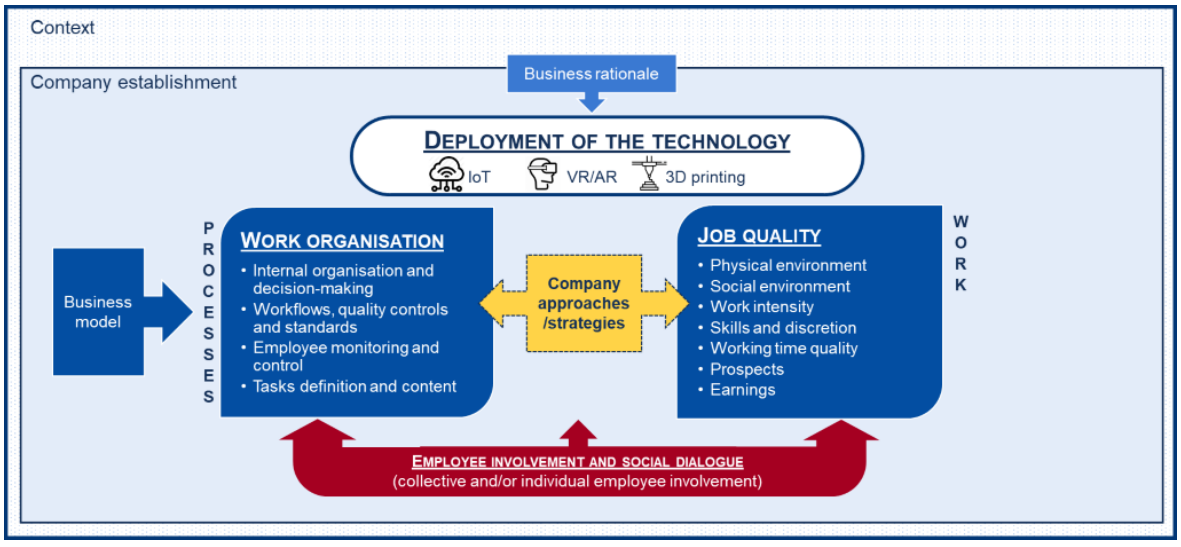
This working paper illustrates the case of Bächer Bergmann in Cologne (Germany) in relation to the introduction and deployment of 3D printing and augmented/virtual reality. The working paper explores the impact of these digital technologies on work organisation and job quality, as well as the extent of the employee involvement in the digitisation process.

This case study has been conducted in the context of Eurofound research on the impact of digitisation on the nature of work. This research is set against a conceptual framework elaborated by Eurofound (Eurofound, 2018), which differentiates between three vectors of change, of which one is digitisation and is associated with three digital technologies. These are additive manufacturing, the Internet of Things and Virtual and Augmented Reality.

Eurofound's conceptual framework on the digital age (Eurofound, 2018) proposes that the effect of digitisation is most direct on working conditions, as it involves a change in the work environment and nature of work processes. It also involves changes in tasks and occupations and has an indirect effect on employment conditions and industrial relations.

Based on this conceptual framework, Eurofound has developed an analytical model (reproduced in figure 1) that serves to guide the analysis of 9 case studies (including the Bächer Bergmann case) conducted for this research. According to this model, the nature of work consists of two core dimensions, namely work organisation and job quality. Employee participation and social dialogue is a cross-cutting dimension as it can both influence and be influenced by the way the technology is deployed in the workplace. Typically, the technology changes the establishment's business model, which in turn impacts work organisation and elements of job quality (partly depending on how the technology is applied in the workplace). Both contextual factors and establishment or company specificities may drive the digitisation efforts. These factors should be taken into account for a better understanding of what has either constrained or facilitated the digitisation process within each establishment.

Figure 1: Analytical model for this study



Source: Technopolis & Eurofound 2019

This case study draws primarily from qualitative interviews conducted at Bächer Bergmann with:

- one of the company's directors
- two designers
- one master craftsman
- one journeyman (worker, skilled in a given building trade or craft)

In addition, public information on the website of the establishment served as a basis for company information.

Reason for selecting this particular case

This particular case study provides insights into the introduction of several digital technologies at an SME. It illustrates a process in which change is embraced first and foremost out of curiosity. It also depicts a very open approach by employees to learning and expanding digital technologies by employees.

Report structure

In the following chapters further context will be provided by describing the establishment in more detail (chapter 1). The analysis will be illustrated by describing the process of the introduction and implementation of the technologies, including the role of social dialogue and employee involvement throughout the digitisation process (chapter 2). Next comes the impact of the three technologies on the business model, work organisation and job quality (chapter 3). The working paper ends with lessons learned drawn from this specific case and some takeaways.

1. Establishment profile

Type of entity and ownership structure

Bächer Bergman GmbH– Digital productions, is a small woodworking company in Cologne, Germany. It was formed in 2015 from the merger of Sebastian Bächer's GmbH and Georg Bergmann's UG. Both entrepreneurs knew each other from high-school, and Georg Bergmann started a woodworking company whereas Sebastian Bächer focused on digital technologies in craftmanship. After working alongside each other in a shared facility for seven years, the merger in 2015 left both as owners with equal shares of the new company. A GmbH ('*Gesellschaft mit beschränkter Haftung*') represents a limited company in Germany and is not publicly traded. As of today, their venture employs 20 people and is limited to one location.

Activities and geographic location

Bächer Bergman is located in Cologne and focuses on project work for German businesses or public entities. It rarely undertakes woodworking assignments from individuals. Main and recurring tasks are complex woodworking projects that require a small-scale series of products (e.g. interior fittings for a camper van series or transport boxes for cargo bikes) and interior building/ornamental work where design and quality play an important role. Examples of the latter are churches, shops and constructions for museums and fairs, where the company has found a niche on the German market. The company produces scenery, displays, furniture or entire rooms depending on the requirements of clients. The private customer market, according to one of the owners, has been taken up largely by larger players such as IKEA or MeinSchrank.de, making it challenging to compete for price at scale. While the company focusses on wood, other materials such as plastics also fall under the competences of the company when they better fit project requirements.

Size and workforce composition

As a small and specialist woodworking company, the firm currently employs 20 individuals, composed of:

- 2 managing directors
- 1 secretary
- 4 designers (drawing approvals, CAM interfaces for programming, work preparation (orders, etc.))
- 4 trainees
- 3 master craftsmen (manages projects in the workshop, according to the specifications of the designers)
- 6 journeymen

Designers are tasked with concept drawing, digital programming and work preparation (e.g. work orders), their task culminating in the handover of instructions to the shopfloor. From there, master craftsmen oversee and manage projects in the workshop according to the specifications received. Apart from the secretary, every employee has a background in woodworking. However, some employees have other degrees/backgrounds in addition to this (e.g. architecture). As a result, education levels in the company range from journeymen (vocational education) to employees with university degrees (bachelor and master). The majority of the employees are between 30 and 40

years old with four women working in the company. Only the secretary and two designers work part time, all other employees work full time at the company. Due to the company's size, the hierarchical structure is very flat and, on paper, only the two directors are considered to have a higher rank than other employees. However, during interviews with employees, it became apparent that general progression within the company is from the shopfloor to the office (e.g. design work). This suggests an implicit hierarchical structure that is based on work experience. Additionally, according to a director, in the far future, centralised external production might become a possibility. This would mean that the design of projects is done inhouse but then given to a larger external company that specialises on small-scale production. While this would increase the reliance on external suppliers, it reduces the cost of facilities significantly. Then a progression of employees towards design-oriented functions might be necessary as in-house activities will shift towards design rather than include the recurring woodworking tasks.

When it comes to remuneration, the directors aim to pay more than is common in the sector with extra benefits to ensure employee retention (such as flexitime agreements, communal staff meals and company outings). In addition, the company is located in the centre of Cologne, with the aim of making commuting easier for everyone working in the company. In recent years, the company has grown significantly, from seven employees at the start in 2015 to 20 in 2020.

Form of employee representation

Bächer Bergmann does not have an employee representation in the form of a works council. This lack of a works council is common in small companies in the craftsmanship sector in Germany. According to the *'Betriebsverfassungsgesetz'* ('Works Constitution Act'), employees in establishments with at least five workers have the right to form a works council. However, this is not mandatory and not always exercised in smaller companies. At Bächer Bergmann, the consensus between all employees interviewed was that the flat hierarchy lends itself more to direct communication than to the path through an institutionalised form of employee representation. If a problem occurs, this is either addressed directly with the parties involved (if necessary, with the support of colleagues or directors) or raised in a weekly roundtable meeting of all employees each Monday morning. In these meetings, all current discussion points are talked through and company directors inform the employees of new changes in the company, including digitisation efforts and what this means for the employees. Here, employees get the chance to raise concerns and discuss them right away with the company directors and each other. So far, this has worked well according to all interviewees.

However, German labour unions urge employees to form a works council even in smaller establishments. They argue that a works council might be considered unnecessary as long as operations are going well, but when things change, it might be too late to form one (IG Metall, 2017). At present, none of the employees at Bächer Bergmann belong to a trade union.

2. Digital technologies at Bächer Bergmann

Bächer Bergmann makes an interesting case in the context of this study not only because it highlights the unique topics that might affect SMEs when it comes to the adoption of digital technologies, but also because it provides examples of a successful implementation, a challenging implementation and a (so far) failed implementation. These relate to 3D printing, augmented reality (AR) and virtual reality (VR). In addition, a large part of the current business volume is made up of projects that involve computer numerical controlled (CNC) milling machinery. Similar to 3D Printing, a CNC machine works by receiving a digital, three-dimensional input from a computer program and shapes the material being used into this form. However, in contrast to 3D Printing, this is done by removing material via a multitude of rotary cutters working on different axes.

According to all interviewees, 3D printing is still regarded with suspicion by small woodworking companies in Germany. Due to its very similar process of operation from computer aided design to automatic processing, this report will also make references to CNC milling and take developments here into consideration when assessing 3D printing. All of the technologies introduced were due to the curiosity of the directors coupled with interest from employees. As the company has no inhouse capabilities to develop and advance new technologies, they rely on available technology from external suppliers that they can implement at a high technology readiness level (TRL). Therefore, both 3D printing and augmented reality operate on a TLR of 8-9.

Motivation for the introduction of the technology

In general, the introduction of new technologies is based on a mixture of 'child-like curiosity' and operating efficiency, according to both company director and one employee. In the case of 3D-printing, they reported no economic interest for the initial introduction, although projects soon opened up that were fully dedicated to 3D-printing. Once introduced, further exploration of the possibilities of the technology and remaining 'in the game' were the motivations for ongoing deploying 3D-printing. In addition, the company considered that the technology enabled quick and cheap access to parts that need replacing or are unavailable or expensive on the market. For augmented and virtual reality, the incentives were similar, but the angle differed. Here, one director of the company and one of the designers were introduced to the technology at a trade fair. Both saw the potential that such technology could have to simplify the process of knowledge transfer from the design office to the shopfloor. Traditionally, this was done with blueprints of workpieces. However, this required the ability to read the very technical aspects of such a description. In addition, employees needed to visualise final 3D objects from the 2D-drawings. Here, augmented and virtual reality were envisaged as a way to assist employees in the translation from concept to product and to facilitate communication between employees. On top of that, for large projects, employees on the shopfloor are likely to be involved in producing only a small part of a whole work. Therefore, by using augmented and virtual reality, employees could see and oversee the whole design. This engaged them in the full project and helped them to see which elements of their artefacts would be visible in the end and therefore what they needed to emphasise most.

Place in the workplace for the technology and its embeddedness

3D printing was initially only performed with a single 3D printer in-house. However, for three years, the company has been cooperating with an acquaintance in the same building who operates a 3D printing firm with eight 3D printers and two 3D scanners. Bächer Bergmann rents the equipment alongside their own 3D printer when needed, relying on personal support and collaboration for larger projects. With the possibility of creating complex forms that would not be possible with subtractive methods such as CNC milling, 3D printing is now embedded in the work process as a tool for both design as well as shopfloor employees. It allows designers to produce mock-up models and consider parts unavailable on the market while in the workshop, employees are able to print the necessary components for their work. As such, 3D printing has not replaced other production methods. In order to make use of it fully, apprentices (or existing employees) need to be trained in how to use it. Similar to CNC milling, the technology is not readily available in other woodworking companies of similar size and therefore does not only require training of apprentices but also frequently that of new employees joining the company from other firms. However, because of the exclusivity of the technology in the sector, the company is approached by customers that want specific projects related to 3D printing (e.g. a car in 1:1 scale that was made out of 3D-printed parts). For both CNC milling and 3D printing most projects involve a high degree of digital procedures, but some tasks cannot be easily automated (e.g. assembly or finishing touches).

Augmented reality is used on the shopfloor. The company does not work with AR glasses but rather uses tablets. A sheet with a QR code is placed on the floor of the workshop and employees can walk around it with a phone/tablet that acts as a lens, showing the object based on the position of the QR code. This 3D visualisation helps with the communication of designs and associated tasks for the shopfloor. The system relies on the same output data that the company's virtual CAD design tool (Rhino 3D CAD) produces. The software has an AR output plug-in available, allowing the company to visualise the design via AR.

For virtual reality, the idea was similar as with AR, but aimed at making it even easier for the employee to look at every angle of the product. However, due to difficulties with the technology explained later, this never successfully took off.

Timing of the introduction and progress thus far

Of the technologies employed at Bächer Bergmann, CNC milling is part of the core business model since the formation of the company in 2015. 3D printing followed shortly after and quickly emerged from the pilot phase towards regular use. However, the employees and management team see the technology as too fast moving to invest in their own facility at the moment. While demand increases and even with some government subsidies available for 3D adoption exist, it is still easier to make use of external facilities when using it on a larger scale. The in-house 3D printer is used frequently for smaller and more individual tasks.

For AR and VR, the introduction started in 2016 via a collaboration with Samsung. As part of a competition, Samsung supplied Smartphones and (smartphone connected) VR glasses as well as 360-degree video cameras to film for export into VR. This was aimed to assist employees in visualising the more abstract parts of a construction and to facilitate the communication between the design office and the shopfloor. Unfortunately, at the time, the company was unable to share the image between the VR application and an external screen. Therefore, the employees reported to be 'on their own' in

the virtual world, describing to the other members of the team what they saw without the ability to show them. As such, while the concept was appealing, the shared view via AR is preferred and the technology introduction of VR was put on hold. For augmented reality, the progress has slowed in recent years and employee motivation to engage in the technology has reduced when the technology did not provide the benefit in every scenario and the workers got busier with other projects. Here, the company management is waiting for the next step in technology development to further increase utilisation.

Initial expectations of the introduction of the technology

The initial expectations varied between technologies. For 3D printing, both employees and directors were in agreement that the technology would be an asset in the 'tool belt' of the company. It was envisaged that, with 3D printing, it would be possible to create more complex forms while at the same time being able to produce spare parts that needed replacing. The former came true while the latter pivoted from spare parts to unique project requirements. In the cases where individual parts needed are not available on the market or only at a high price or with significant delay, the company is able to print them in-house.

Expectations for virtual and augmented reality were fairly low in the beginning, mostly considered as a tool to facilitate the communication between project idea and execution. Here, management and employees voiced different, although aligned concerns. Management feared that augmented reality would be rejected because of the need to wear specific glasses. At the same time, employees questioned the need for AR for visualisation. Some stated that discussing the product via a PC/projector screen would be sufficient. As such, while management concerns might have not come true, employees remained hesitant to commit too much to the technology.

Initial strategy for the introduction of the technology and adjustments during its deployment

The introduction decision in respect of new technologies lies with the company directors directly. As such, an initial assessment is done top-down as not every new technology aligns well with the business plans of the company. Here, partnerships with external companies (e.g., Samsung), offering the technology for testing incentivised the management to try out the technology. Due to the size of the firm and flat hierarchy, no formal introduction strategy and monitoring of the process was developed. Management introduced the technology through one of the regular weekly meetings, where they explained potential benefits and encouraged employees to try the new technology in a work context or for private projects (e.g. home furniture or sculptures). Over time, employees unfamiliar with the technology were expected to ask for assistance from experienced employees in the firm who either tried it within the company or had experience with it from a private context. This very open and voluntary approach to technology introduction formed an organic piloting phase. While not formalised, the technology was first tested in-house. However, the pilot phase did not have a set end-date and instead organically moved into frequent use. When a technology was not used, it was not further pursued/invested in, as was the case with virtual reality. However, an employee voiced the opinion that this approach might have not been the most efficient. In their mind, a stricter hierarchy and implementation plan might have resulted in more active technology incorporation. This interesting point highlights how some technologies may be at risk of being

rejected by the workforce at the outset, thus making it difficult to exploit additional untapped potential which only comes to light once a pilot has taken place. This could be mitigated if the pilot is done in a less voluntary way, and includes mechanisms for consultation and reflection. This could ensure a sufficient level of testing to come to an objective result. However, in Bächer Bergmann's case of 3D printing, it worked out organically. As more employees picked up 3D printing, the variety of tasks completed with it grew. Here, successes were reported back to the team via the regular work meetings, showing what could be done with the assistance of the technology. When project offers from clients came around requesting 3D printing, the company applied the technology in a customer-facing context. Later, an external one-person company in the same location as Bächer Bergmann offered 3D printing services that the company relies on since as it fits their needs.

Role and involvement of employees before, during and after the technological change

At Bächer Bergmann, employees are always involved in technological change due to the company's focus on innovation. Owing to the firm's size, the feedback from employees is important and often immediate. In general, the introduction of new technologies is initiated top-down out of interest by the directors or project driven. Then, during a pilot phase, the engagement with the technology is voluntary and involves interested employees directly, without affecting employees who are not ready or willing to participate in the experience. This ensures that, up to the point where the technology is used for projects in the company, feedback from employees is gathered and only workers familiar with the technology are using it. As a result, the employees who engaged in the pilot develop a skill base present in the company. With CNC milling, 3D printing and AR all adopted at the company, this strategy also applies to new employees that are, depending on their role in the company, expected to be familiar with the technology. New employees are introduced to the existing technologies as they join the company. As there is little experience with these digitised technologies in the sector, existing employees train the new hires. As a consequence, as the workforce grows, the number of skilled employees grows alongside it. During the weekly general meetings, feedback on projects and tasks is collected, which also includes the uptake, discoveries and challenges of new technologies. From there, employees are encouraged to develop their knowledge of the technologies further or suggest new helpful technologies to the rest of the team when they come across one.

3. Impact of the technologies in the workplace

Changes to the business model

Before the formation of the new entity in 2015, digital technologies were not frequently used at Georg Bergmann's company. The capabilities and specialisation in CNC milling of Sebastian Bächer brought with it the ability to combine expertise and to work on more design-oriented assignments. This gave the new company its niche in the market. With 3D printing, the focus on digital design increased. The company can now efficiently create individual designs on a small scale (only few pieces) for their customers. As 3D printing adds to the tools available to designers and workers in the workshop, the company was able to increase their offer to customers as there was a reduced reliance on unavailable/very expensive parts needed for projects. Designs can be printed as envisaged, rather than adjusting the design to the limitations of the tools. As such, it is this not seen as a change to the business model. The first big change relates to the merger, which came about due to the recognition of the value the use of technology brought along, and opened the company to new opportunities. Since then, the business model is adapting in a way that allows new technologies to offer more value to customers through being able to create parts in house which would otherwise not be (economically) possible, a much more tailored service and more options for the creation and development of designs and products.

Impact on the work organisation

Internal organisation and decision-making

At Bächer Bergmann, the decision-making of technology introduction are not formerly regulated but driven by management and employees with an interest in the technology. Technology itself has not made changes in the decision-making or organisational processes of the company. Task-related decisions such as material use or planning have been subject to pre-defined conditions required by the structure or autonomously done by the workers in the workshop. However, as the experience with the machinery grew, considerations such as what steps in a process might become necessary/redundant based on the capabilities of the machine/tool needed special attention of the employees working with it. While before, some tasks needed an intermediate step (e.g. a corner of wood needed to be left on the workpiece in order to form a guide in a later step in the process), these can be skipped because of the digital precision of the machine. These new found processes were later passed on to other employees working with the machines. Otherwise, no changes have been occurring.

As an exception, augmented reality allows more autonomous behaviour for workshop employees as they can go back to a visualisation of the product that they are working on without consulting designers in the office. However, during the interviews, one employee criticised this approach as it does not lend itself to learning and improvement. Going back to a colleague to clarify uncertainties can result in error detection in the design or make office employees aware of problems in their communication. These opportunities are not present when an employee in the workshop consults a digital file via augmented reality.

Workflows, quality controls and standards

Digital technologies affected both workflows and quality control at Bächer Bergmann. This was most pronounced for 3D printing. Here, in contrast to traditional woodworking, almost all design work is done in advance at the computer and the majority of the production work can be carried out unsupervised. This also holds true for the CNC milling machine, but there, if something goes wrong, the effect is significantly worse, ideally demanding supervision. Additionally, as the technology makes exact reproduction easier, adapting a pilot design is simplified. As a result, trial-and-error approaches in design became more viable. In addition, as 3D printers can work overnight, employees can schedule their time more efficiently, making more use of their daytime hours. In addition, as the whole design is available digitally, it allows for easier pre-emptive design checks without material being spent.

In the case of augmented reality, employees have the opportunity to go back to a visualisation of their task, reducing the need to ask the designers for clarification. While this streamlines the workflow, as indicated above, it eliminates a point of interaction that might serve as quality control for the design of the project or the process of translating this design into practice.

Employee monitoring and control

Neither the application of 3D printing nor augmented reality lends itself to employee monitoring or control. While it is now possible for company directors to monitor the progress of an employee based on the time they take to finish a print-job, interviewees argued that this was possible previously by investigating the piece that the employee produced during their work. This form of monitoring and employee control was stated to be appreciated as a form of safety net and quality control. While cameras exist at the CNC milling machine and 3D printer, these are not used to monitor employees working with them but rather a way to check on the machine if it is working overnight.

Task definition and content

The addition of digital technologies, and in particular 3D printing and CNC milling, has enriched the task content of the workers in the workshop. In addition to their regular tasks, they now have the opportunity to write small programs for machines to carry out. While this is not mandatory and relies on the employee's initiative, it allows for simplifying previously difficult procedures such as cutting a perfect circle/globe out of a material, although requiring rudimentary coding skills that have to be studied on their own. In addition, in the context of CNC milling, employees working with the machines need to prepare materials, load and prepare the machine and monitor the milling process. While these tasks might be new for some employees and especially the ones coming from outside the company, CNC milling and 3D printing allow to shift task content from more repetitive tasks which are replaced by the machinery towards preparation of material, organisation of the process and finishing touches, which is highly appreciated by employees. In addition, this reduces the percentage of physically demanding tasks, which reduces the strain on employees compared to classic woodworking.

For augmented reality, task content was just marginally extended for designers and workshop employees as the hand over process from design to the workshop was also previously part of the task definitions for designers and workshop employees.

In general, one employee remarked that, while digital technologies might not increase his task definition significantly, without them, the overall scope of work would be limited in the future as the industry evolves. In order to remain competitive and do what they are used to (e.g. production of goods), they need to adjust to digital technologies. Otherwise, the task content might shrink to special private contracts such as door and window repairs.

Impact on job quality

Physical environment

Digital technologies had little impact on the physical environment at Bächer Bergmann. In particular, augmented reality did not change the physical environment although a tablet was added to the toolset. The impact of 3D printing introduced little in terms of risks. As air pollution from small particles needed consideration, the machines are housed in cases with an air filter to minimise the effect on employees. In contrast, a CNC milling machine, because of the high velocity of spinning milling drills and the tension on the materials, is a significant risk consideration if not properly used. These risks are recognised by the company. As a result, new employees working with the machine are tasked to follow an experienced employee around for a month of intensive training before being allowed to operate the machine for small tasks. Interestingly, although presenting a training need in order to be operated with low risk, the German apprenticeship framework does not provide for apprentices to be trained in CNC milling or other digital content such as 3D printing or augmented reality. According to an interviewee, the number of apprentices and companies training apprentices is in decline. As companies are reluctant to pay for inter-company training courses, which are required to teach digital skills if no machinery is in house, policy makers are concerned to make this aspect mandatory. The interviewee suggests that regulators fear that as a result, fewer workshops will train apprentices should this happen and are hesitant to include a digital aspect in the apprentice framework. While at Bächer Bergmann, most training is done in-house, they participated in a project with universities and the Chamber of Crafts in the DigiTS project (*DigiTS*, 2017), aiming to bring digital technologies such as 3D printing and CNC milling to apprentices. In their eyes, as the working environment will change more significantly in the future, apprentices are the group that needs to be prepared.

While 3D printing is very risk-free apart from dust that needs to be managed, CNC milling is heavy machinery. With the increased risk due to the prevalence of this machinery, the company holds annual risk-awareness trainings for all employees in-house. In addition, should an accident occur, it is discussed during the next week's general meeting and employees are made aware on the correct way to use the machine in order to avoid an incident in the future.

Social environment

Due to the size of the company and the project-based workload, the employees of the company reported a very high degree of social interaction. While this might be reduced when using AR to go back to a visualisation rather than to consult a colleague in the office, they argued that their share of social interactions is still high. For 3D printing and CNC milling, no decrease in social contact was observed. Rather, as most of the repetitive work (making several objects of the same shape) could be dedicated to 3D printers and CNC mills, it can be argued that the interaction rate of employees even increased.

Work intensity and working time

According to the interviews, 3D printing and CNC milling led to a decrease in work intensity. Rather than working the heavy material by hand to form it into shape, these tasks were sourced out to machines. However, in general the speed at which the work can be done has increased. While it is not the aim to match the speed of the machines at every project, some larger-scale projects require a faster working pace when a deadline nears. In contrast to that, employees are able to let the machine work overnight, therefore allowing employees to have a buffer when planning their workload, leading to reduced stress levels and mediating the negative impact of 3D printing on work intensity. Similarly, the possibilities of 3D printing to generate new complex parts means that employees do not have to limit themselves to parts available on the market. This makes the work frequently more straightforward and easier while also adding novelty to it and enables greater scope for learning on the job.

AR reduces the work intensity in the workshop as employees can go back to a visualisation, making sure that they are on the correct path. Similarly, it makes them less reliant on colleagues when it comes to working time arrangements as they do not need to wait for their availability for consultation, allowing them to work more autonomous.

Skills and discretion

Digital technologies in woodworking require a significant adjustment in skills as the need for training of new employees at Bächer Bergmann shows. In addition to the designers now needing to plan the whole design in advance, rather than throughout the development of the project, people on the shopfloor also need advanced skills. Most significantly, the operation of the machinery requires a particular way of thinking, as the way a carpenter might approach a process might not be the easiest for the machine according to one employee. For example, while a carpenter needs to consider extra margins in a work piece for later aiming positions, a machine could use the extra space to work on more material, as these visual guidelines are not necessary. In addition, while traditional skills such as the understanding of materials and a conscientious approach (e.g., careful planning and precise handling of materials) to work remain viable, new skills such as programming small tasks for the machine are added to the mix. However, as a result, the technology offers a wider range of solutions for producing artefacts, encompassing all steps from the initial design interpretation to the finished product.

Training in these skills is not institutionalised. As such, no course from a technology provider is planned as a standard training approach. While these do occur when requested, most training is done via in-house mentoring. For this, dedicated work time is made available for learning and people are encouraged to shadow a more experienced employee. In addition, they are given their own training projects to work on and practise. Lastly, machines are also made available outside working hours for employees to test and develop their own projects (e.g., building a backgammon game after a team meeting).

However, digital technologies not only require new skills but also shift or reduce the need for traditional skills. As such, the conscientiousness and precise work is shifted from the workshop to the designer, as the machines take over a large part of the very detailed work. Similarly, as AR and other tools make the presentation of designs easier, an employee might not need to be as good in being able to visualise blueprints.

Prospects and earnings

At Bächer Bergmann, earnings are not tied to the extent of use of digital technologies. However, in general, the company pays more than the average wage in the sector and has a strong focus on digital technologies. Both management and employees indicated that a typical progression within the company is from the workshop to the office, suggesting that the involvement with digital design tools and the understanding of machinery will offer progress in the long term. In general, employees mentioned that they gained fairly specialist and rare qualifications when learning how to work with the digital technologies (3D printing, AR and CNC milling) at Bächer Bergmann, offering them a better position on the job market when leaving the company.

Concluding remarks

- The merger to form BB started a process of change which also opened the door to exploring new digital technologies. These expanded the core business model of Bächer Bergmann, allowing the small company to find a niche and remain competitive in their market. 3D printing enables employees to create parts/artefacts that would otherwise be very expensive to obtain on the market and to utilise employee time more efficiently. AR facilitates the handover between designer and workshop employee, enabling the latter to put their work into the context of the whole project.
- While an organic approach has proven useful in small companies, a more hierarchical structure with a mandatory pilot might ensure that the technology survives initial unwillingness of employees to participate who later accept it as a positive change in hindsight.
- As shown with the case of VR, not all technologies are immediately applicable to the company. Therefore, offerings by other entities or government subsidies allow companies to test the potential for themselves, judging them based on performance and suitability for the company needs.
- Testing the capabilities of new technologies as they arise and involving employees on a voluntary basis has resulted in an engaged employee base at Bächer Bergmann that can transfer their knowledge to the next generation of employees. With the digitisation on the rise, this aspect becomes more important in the future, making it a relevant inclusion in apprenticeship programmes.
- The digital technologies introduced reduce heavy work, stress and margins of error for the employees. This, however, does require significant time for on-the-job training of technology skills that are not traditionally thought in woodworking. At the same time, due to the acquired skills their jobs remain viable in a shifting industry.
- As a small company in a very traditional sector, not all digital technologies are applicable to Bächer Bergmann. It is key for the company to remain flexible and innovative. Due to the flat hierarchy structure and small workforce size, a less formal and more organic approach is feasible for experimentation and introduction of new technologies rather than setting strict guidelines and formalised strategies.
- Although digital technologies such as 3D Printing are seen as drivers of the digital revolution in traditional SMEs and support initiatives and subsidies from the national government exist, small businesses need to take into careful consideration how much to invest in them and where it is better to test the capabilities externally. Keeping pace with the digital revolution is seen as necessary to ensure continuing business in the future. However, if the technology moves too fast, it may be better to partner with specialist companies as Bächer Bergmann did.
- As digital technologies require more skills, generating an interest in them in the workforce and encouraging employees to invest themselves in them helps to ensure that a sufficient knowledge base exists in the company. As the industry has limited institutionalised offerings for training, inhouse knowledge becomes important to induct new employees.
- Key challenges for SMEs in this relatively traditional sector include the speed of technology development, acceptance for the technology in the industry and a sufficient supply of

trained employees. Here, companies need to work together on awareness and capability building to ensure sufficient attention to these novel technologies. In particular, knowledge sharing and a coordinated approach to training and the progression from apprentice to journeyman to master tradesman when it comes to digital technologies should be encouraged.

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All Eurofound publications are available at www.eurofound.europa.eu

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Annex 1: Definitions and terms used in this report

Term	Explanation
Works council (*Betriebsrat*)	A works council is a intra-company organization representing workers that functions as a firm-level complement to trade unions.
CNC milling machine	Milling machines use rotary cutters to remove material by advancing a cutter into a work piece. Computer numerical control (CNC), allows milling machines to automatically create a form by automatically changing tools and angles based on a computer design.
Industry 4.0	Industry 4.0 is used to describe the fourth industrial revolution, transforming traditional manufacturing via the use of digital technologies. The main focus of industry 4.0 lies on the connection of machinery and computers, resulting in cyber-physical systems.
Internet of Things (IoT)	Networked sensors attached to outputs, inputs, components, materials or tools used in production. This also encompasses electronic monitoring systems and wearable computing devices used for different purposes including monitoring work processes and employee performance and ultimately guiding management decision-making.
Virtual and augmented reality (VR/AR)	Technology blending the digital and physical worlds by superimposing digital information over human perception of physical reality.

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