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Training needs and didactical requirements to embrace the digital transformation challenge by SMEs

Tiago da Custódia de Carvalho

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Supervised by
Ana Correia Simões, Ph.D.
Vasco Figueiredo Teles, Ph.D.

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Abstract

Previous studies show that digital transformation brings several benefits and challenges for companies. Between those challenges, the main one is the need for increased capacitation, from technical roles to management. Considering this, the main objective for this study is to identify the training needs and necessary didactical requirements of the manufacturing SMEs in Portugal, in face of digital transformation. Semi-structured interviews were conducted with industry experts and company professionals in the automotive and textile sectors. It was concluded that all workers, from technical roles to middle and top management, lack digital capabilities, and would benefit from training programs. The most desired areas for training are data science, virtualization skills, quality assurance, technical training, and soft skills. The preferred format is physical (or hybrid at most), during working hours and with a theoretical training before on-the-job learning. Both companies and experts believe in the value of involving external entities in the internal training of employees, with the three most referred entities being technology and interface centres, universities, and business associations.

Resumo

Estudos anteriores mostram que a transformação digital garante benefícios para as empresas, mas igualmente desafios. Entre esses desafios, o principal é a necessidade de maior capacitação, desde as funções mais técnicas até à gestão. Considerando isto, o principal objetivo deste estudo consiste em identificar as necessidades de formação e os requisitos didáticos das PME's industriais em Portugal, como consequência da transformação digital. Foram conduzidas entrevistas semiestruturadas com peritos da indústria e profissionais de empresas nos setores automóvel e têxtil. Concluiu-se que todos os trabalhadores, desde funções técnicas até gestão média e de topo, têm falta de competências digitais e beneficiariam de programas de formação. As áreas mais desejadas para formação seriam ciência de dados, ferramentas de virtualização, qualidade, formação técnica e *soft-skills*. O formato preferido seria físico (ou eventualmente híbrido), durante o horário de trabalho e com uma componente teórica prévia, antes de formação aplicada no local de trabalho. Tanto empresas como peritos acreditam no valor do envolvimento de entidades externas na formação interna de colaboradores, sendo algumas das entidades mais referidas os centros tecnológicos e de interface, as universidades e as associações empresariais.

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1. Introduction

Industry 4.0 (I4.0) – a term which encompasses, among other things, changes related to smart factories, cyber-physical systems and new systems in distribution, procurement and development of products and services (Lasi et al., 2014). Such changes have a major impact on employment in the future, particularly on the required set of skills for “*paving the way for the human capital of the Factories of the Future*” (Mavrikios et al., 2013) (p. 473).

The reskilling and upskilling challenges are not a new phenomenon – in fact, they have been studied by several authors in the past (ex. Agrawal et al., 2020; Dittrich, 2016; Escobari et al., 2019; Vallor, 2015). However, with the Industry 4.0 initiatives around the world, a digital transformation is due to take place in industrial environments, namely in small and medium enterprises (SME). This transformation will promote a shift in the necessary set of skills of job profiles in factories (Pontes et al. 2021).

In this context, several instruments exist to address the reskilling and upskilling challenges, with one of the most known being blended learning and online courses (Zou et al., 2020). One of the instruments that can be used to address these challenges are teaching and learning factories, environments which foster a closer relationship between enterprises and academia with goal of achieving real-life, relevant learning outcomes (Chrysosolouris et al., 2016). Several studies have analyzed teaching and learning factories as innovative environments for interdisciplinary learning (Abele et al., 2017) and new instruments for the application of didactical frameworks (Pittich et al., 2020), as well as its implementation and the difficulties associated with this form of vocational education (Roll & Ifenthaler, 2021). Similarly, other studies focused on virtual learning environments as a tool valued by academia and firms, given its efficacy and feasibility with low investment (Manesh et al., 2011; Moncada et al., 2020).

Given the Portuguese (and European) context, characterized by a strong incidence of industrial SMEs, the main objective for this study is to identify the training needs and necessary didactical requirements of the manufacturing SMEs in Portugal, based on the systematization of the struggles and the perception of industry experts and professionals regarding digital transformation.

The results of this study will allow SMEs to identify approaches that may be more adequate for the upskilling and reskilling of their workforce, allowing for a swift digital

qualification of workers in industrial context and, thus, contributing to a successful implementation of technologies, while following a sustainable and human-centric trend. This study also intends to provide improved understanding of the reskilling and upskilling process in Portuguese manufacturing SMEs.

This study begins with a literature review focusing the topics related to the research objective, followed by a presentation of the material and methods and the study results. Afterwards, a brief results discussion is presented, followed by a conclusion where the study main conclusions, limitations and next steps for future studies are presented.

2. Literature review

Given the scope of this study, defined in the previous section, the literature review will approach three main topics revolving around the digital transformation process. Firstly, a brief overview will be made of what digital transformation and Industry 4.0 are, as well as the benefits that it entails; secondly, an analysis of the main challenges associated with its implementation and described in the literature will be conducted; finally, focusing specifically on the reskilling and upskilling challenge, an outline of selected approaches to address this challenge will be presented.

Together, these three sections should allow for an understanding of previous studies' conclusions on digital transformation and the training challenges that derive from this phenomenon. This will lay the groundwork for the continuation of this study in its following stages, namely in the comparison between literature and the findings on the specific reality in Portuguese SMEs.

2.1. The digital transformation process

2.1.1. What is digital transformation and what benefits it entails

Despite the fact that no unique definition of Industry 4.0 exists, it is possible to relate it with the digital transformation phenomenon in an industrial environment. According to Benešová et al. (2018), Industry 4.0 is “*a term for a new era of intelligent manufacturing caused by development of digitalisation and robotics*” (p. 1) in which “*smart factories (...) [will be] connected by Cyber-physical systems*” (p. 1). Another view describes Industry 4.0 as a reality that “*encompasses adopting opportunities from end-to-end digitalisation with connected computers and increasingly autonomous automation systems equipped with intelligent machine learning algorithms that control the robotics without much input from humans*” (Surianarayanan & Menkhoff, 2020, p. 1). One additional option is to define Industry 4.0 by relating it with certain types of innovation and technologies that they perceive as fundamental for the occurrence of this digital transformation, such as previously referred cyber-physical systems, Big Data, Internet of Things (IoT), cloud computing, machine learning, 3D printing and augmented reality (Assante et al., 2019; El-Thalji et al., 2020; Reddy, 2019).

The consensus is clearer regarding the discussion of Industry 4.0 and digital transformation's benefits. From operational benefits, such as better control and streamlining of

processes, flexibility, quality and customer satisfaction, to financial gains, from a productivity and cost perspective, this transformation allows companies to reap some of the most sought benefits from a business perspective (Kumar et al., 2021; Mian et al., 2020). However, the impacts of Industry 4.0 are visible in several other areas – its potential for the enrichment of factory work, with a more interesting working environment, greater autonomy and opportunities for self-development, is recognized, as well as the opportunities it entails for sustainable development (Kaasinen, 2020; Mian et al., 2020).

2.1.2. Underlying challenges

Notwithstanding the numerous advantages, Industry 4.0 implementation has come with several challenges, some of which have been addressed through differentiated methodologies in different countries – from roadmaps adopted by the European Commission, to single national initiatives created by each Member State of the European Union (Assante et al., 2021).

Among the different challenges and barriers identified, it is possible to highlight a “*poor value-chain integration, cyber-security challenges, uncertainty about economic benefits, lack of adequate skills in workforce, high investment requirements, lack of infrastructure, jobs disruptions, challenges in data management and data quality, lack of secure standards and norms, and resistance to change*” (Kumar et al., 2021) (p.85).

Despite such distinct topics and the apparent predominance of automation among them, the real challenge is among people, since new technologies and work processes, as well as organizational changes, raise new demands on the workforce (Brezeanu & Lazarou, 2020). Such disruption in industries will necessarily require that firms and their staff are agile in responding to quickly developing trends, for these people to embrace continuous learning in a new environment (Francisco et al, 2020).

The mismatch between current employee skillset and necessary skills in this new reality demands a reskilling process for the staff, with the workforce facing no alternative to adapting to this workplace transformation, other than being laid off (Rangraz & Pareto, 2021). In an industrial environment, this represents a significant change – all roles requiring skilled and qualified professionals, even those commonly associated with low training, such as controlling or maintenance (Rangraz & Pareto, 2021; Sallati et al., 2019). Therefore, requires a combined effort in the labour market and in education, in order to develop not only technical

skills but also right-brained skills, such as creativity, problem solving and critical thinking (Brezeanu & Lazarou, 2020; Rangraz & Pareto, 2021).

On this topic, Mian et al. (2020) highlighted those same points, namely that the adoption of Industry 4.0 paradigm requires thinking, cognitive and computational skills among the workforce, but also added that a very significant part of this process relies on universities, which need to update their curricula and their infrastructure. Given the aforementioned requirements, it is safe to conclude that, in an industrial environment, a structured approach to the development of the workforce's skills and competences will be vital for the success of any digital transformation strategy (Woschank & Pacher, 2020). Despite an apparent focus only on the skills of what could be referred to as blue collar employees, numerous changes in the competences of managers have been taking place as well (Assante et al., 2019).

Some authors have studied the reskilling challenge applied to specific case studies. For example, in the food industry, it was concluded that current business models represent new demands from the workforce, which led the authors to generate a database of current and future professions and competences that could be used as a roadmap to guide the sector through upcoming changes due to Industry 4.0 (Akyazi et al., 2020). Another example, a case study of an electronics manufacturer in Malaysia, concluded that professionals in the future will be required to have a new set of technical skills to interpret large amounts of data and use them as a tool to make strategic decisions, as well as a number of methodological, social and personal competencies to thrive in this new context (Kannan & Garad, 2020).

Considering all the highlighted challenges by Kumar et al. (2021), some could be considered to have a greater impact on small and medium-sized enterprises (SMEs), namely high investment requirements and lack of infrastructure. Regarding this specific type of firms, while referring specifically to the adoption of Automation & Robotics equipment to enhance the competitiveness of businesses, Casalino et al. (2015) emphasizes that the provision of upskilling and employee training processes represents a major challenge to manufacturing SMEs, which lack the financial and human capital to properly address this issue. However, regardless of the size of their operations, ignoring the digital transformation wave is not an option: SMEs put their competitiveness in jeopardy if they choose not to digitalize and they are well aware of it, with more than half of them recognizing this fact (Azevedo & Almeida, 2021).

An additional obstacle that could be relevant for SMEs is related with the lack of

awareness, from decision-makers, of the potential of new digital solutions, with some of these renouncing digital transition due to the fact that they may not comprehend how the integration of said solutions would be possible within their business (Azevedo & Almeida, 2021) – this is why, as stated before, the competences of managers are crucial for the success of Industry 4.0 initiatives (Assante et al., 2019).

An expert survey was conducted by Surianarayanan & Menkhoff (2020) about the readiness of SMEs in Singapore to embrace Industry 4.0, which was based on the assumption that “*the adoption of smart manufacturing technologies such as advanced robotics, cyber-physical systems, or the Internet of Things (IoT) continues to be a challenge for Small and Medium Enterprise (SME) manufacturing firms in Singapore*” (p. 1). In this study, the authors also pinpointed adoption issues that included significant capital investment, developing technical skills, recruiting new talent, re-skilling of the workforce, training needs, and top management support. However, this did not seem to hinder the traditional manufacturing model’s evolution, and the gradual adoption of the adequate technologies remained a key factor for the success of initiatives in this field (Surianarayanan & Menkhoff, 2020). Some of the drivers that seemed to be encouraging SMEs to adopt Industry 4.0 initiatives are a strong training and financial support from the Government for the adoption of technology, shortage of skilled labour, need to improve productivity and efficiency, pressure to innovate dictated by competitors, and the impacts of the Covid-19 pandemic (Surianarayanan & Menkhoff, 2020).

In summary, there are numerous challenges to the implementation of Industry 4.0. The main one is related with the skills that this transformation demands on a workforce that will require increased capacitation, from technical roles to management. This effort shall fall not only upon universities, but also upon companies – SMEs in particular could face increased difficulties managing this issue, due to its limited human and financial resources.

2.1.3. Approaches to address the reskilling and upskilling challenge

Having identified the challenge, which is the capacitation of workers to deal with the transformational process that digitalization entails, firms need to understand possible approaches that may enable them to address it. In order to address this, it is important to understand the underlying didactical requirements of these reskilling and upskilling processes, i.e., the teaching methods that will result in the methodological design of the curriculum (Pittich et al., 2020).

According to Huda et al. (2021), who analyzed the use of computer-based learning media and augmented reality in the learning process in industrial revolution 4.0, didactical requirements are “*requirements relating to the process of finding concepts according to the applicable curriculum, showing individual differences so that good media can be used to measure student abilities*” (p.118). In the context of Industry 4.0, Pfeiffer et al. (2021) studied the “*alignment of didactical requirements with the technical design and architecture to build up a sustainable remote laboratory system for study, teaching and research*” (p.78), concluding on didactical requirements such as support theory practice transfer, support of self-regulated learning and support of integration in a learning management system. According to Schuster et al. (2016), in a study about the preparation for Industry 4.0 in engineering education, this transformation entails “*cross-linked production processes*”, where “*physical reality and virtuality increasingly melt together and international teams collaborate across the globe within immersive virtual environments*”. Considering this, the authors intended to understand which didactical method the students preferred. The results showed that “*students equally prefer realistic (e.g., factory simulations) and fictional scenarios (e.g. travelling through a factory from the product’s perspective. In the case of fictional scenarios, the main principle is to exceed the limits of time, space and physics (...) to be immersed by the virtual environment and to interact with it intuitively and naturally*” (Schuster et al., 2016, p. 481). Based on these two types of scenarios, two of the most cited specific approaches will be explained in further detail, given their match with the conclusions of Schuster et al. (2016).

One possible approach in line with the “*fictional scenarios*” is the use of **virtual learning environments (VLE)**, which according to Dillenbourg et al. (2002) is characterized by the following features:

- A designed information space;
- A social space where educational interactions occur, not restricted to distance education but also with a role in the enrichment of classroom activities;
- There is an explicit representation of the virtual space, with information varying from text to 3D immersive worlds;
- A space where students are not only active, but also actors: they co-construct the virtual space by interacting with each other;
- A space that integrates heterogeneous technologies and multiple pedagogical approaches and that usually overlaps with physical environments.

As noted by Moncada et al. (2020), academia has already recognized the value of VLEs,

with numerous schools across geographies implementing virtual learning environments due to its struggles with new challenges that Industry 4.0 presents for the workers of the future and it became clear that the integration of VLEs in engineering courses will be vital to properly capacitate the students and develop the necessary competencies. There are numerous advantages to VLEs: some include learning settings that would be hard to access or dangerous, as well as the possibility of each student learning at its own speed (Schuster et al., 2016).

The use of VLEs would also be favourable in corporate settings. Firms reap benefits from a workforce that is aware and prepared for new advancement, tools and technology that could help its performance in a competitive environment, which leads to the conclusion that employees should go beyond the fundamental education that they were provided by universities and should continue to develop professional skills and competencies. Given this, VLEs allow for this process with little to no need of equipment, instruments or travel (Manesh et al, 2011).

Another possible approach, more in line with the “*realistic scenarios*” presented by Schuster et al. (2016), to address the reskilling and upskilling challenges in a working environment is the use of **teaching and learning factories**, also referred to as ‘teaching factories’ or ‘learning factories’.

A teaching factory is a new model of education which focuses on developing skills and competencies of factory workers, from engineers to other technical staff, through a balance between the teaching processes and the challenges of modern factories, allowing for an environment that delivers a practical experience to the staff and allows them to prepare properly to the challenges that Industry 4.0 encompasses (Caldarola et al., 2018; Kipper et al., 2021). Such approach is an alternate method to capacitate professionals which brings the best of academic and professional backgrounds, since it allows for the sharing of corporate knowledge on real life processes and methods in academia, through a practical framework in the form of a factory concept (Sallati et al., 2019).

Specifically on the didactical requirements needed to address digital transformation, Sackey et al. (2017) specifies that “*to manage the impact of Industry 4.0 on industrial engineering (IE) education curriculum requirements, realistic teaching and learning infrastructure such as a learning factory are required*” (Sackey et al., 2017, p. 114). The advantages of teaching and learning factories have been proven, with this approach being recognized as the “*ideal learning concept for acquiring*

skills” (Block et al., 2018, p. 57).

For SMEs, there is a higher difficulty in becoming skilled in applications of Industry 4.0, since “*those companies usually don’t have the manpower to look ahead and beyond their own product and production range (...) and they usually don’t have the possibility to invest in emerging technologies (...) in order not to lose money by focusing on the wrong technologies*” (Faller & Feldmüller, 2015, p.88), which is why Faller & Feldmüller (2015) proposed training for SMEs through a learning factory to address the need for “further training in modern technologies and methods to optimize their production” (Faller & Feldmüller, 2015, p.91). SMEs generally have difficulties assessing the usefulness of Industry 4.0 technologies for increased performance and flexibility and teaching and learning factories could allow them to capture significant benefits from complex tools (Grube et al., 2019). Given the value of this approach, Caldarola et al. (2018) envisioned ManuLearning, a system that allows to enhance workforce capabilities in a digital transformation context, while also allowing for an evaluation of the “*technological maturity of SMEs*”.

2.2. Main conclusions from literature review

Having covered the three proposed sections of the literature review, it is relevant to summarize the main conclusion that have been drawn from this phase of the study.

Industry 4.0 represents numerous benefits for industrial companies (operational and financial) and for its workers. However, among a vast number of challenges that may arise, one of the most vital will be the reskilling and upskilling of the current workforce, in face of the changes that digital transformational will bring to industry and specifically to manufacturing firms.

In particular, SMEs have a number of predominant challenges they need to be especially alert to – high investment requirements, lack of infrastructure and lack of awareness, from decision-makers, of the potential of new digital solutions, who may therefore be more prone to renounce these initiatives.

Given this context, companies need to address the upskilling and reskilling challenge. Two of the most effective approaches are virtual learning environments (VLEs) and teaching and learning factories. VLEs allow for a swift training, both in academia and in a corporate setting, with negligible costs or investments required. On the other hand, teaching and learning factories allow to bring together teaching processes and challenges of modern factories, enabling a practical experience through a proven learning concept.

Figure 1 is presented below, with a recap of the objective for this study and the main findings of literature review

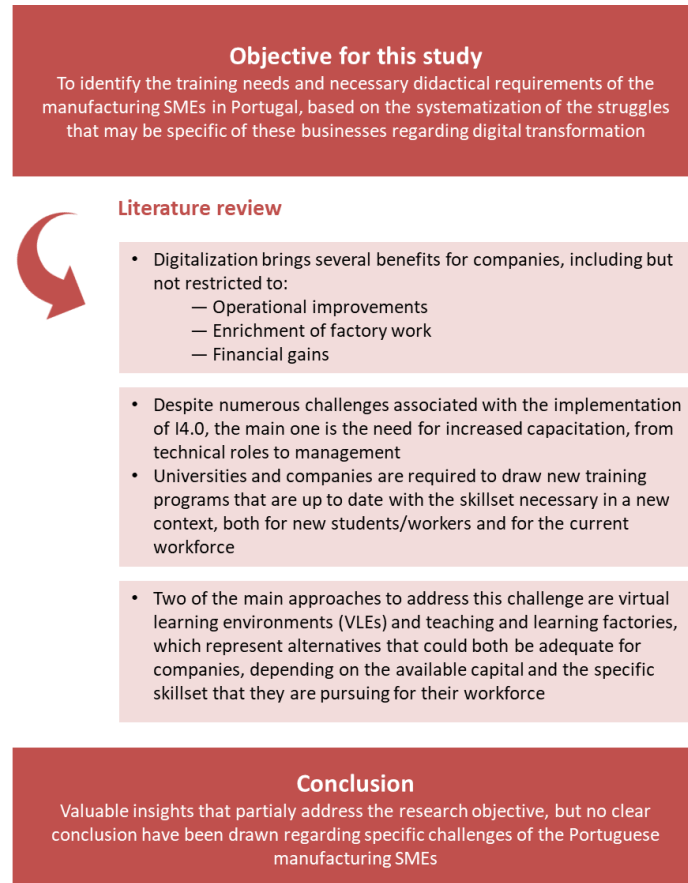


Figure 1 - Main findings from literature review

3. Methodology

3.1. Research design

The main objective of the present study is to identify the training needs and the necessary didactical requirements of the manufacturing SMEs in Portugal, based on the systematization of its specific business problems regarding digital transformation.

As Jackson et al. (2007) refers, the qualitative researcher's main purpose is the understanding, and not the explanation, of a phenomenon through a humanistic, interpretive approach. The proposed goal of understanding training needs and didactical requirements of a specific type of firm in Portugal will require a subjective understanding of the daily struggles of such companies, which may be different between distinct firms and could demand from the researcher an interpretive approach that is able to assess the context and compile the findings. Considering this, the research philosophy behind this study could be classified as Interpretivism, since this study will attempt to understand the context and the understanding of each person, instead of the mere physical phenomena – *“as different people of different cultural backgrounds, under different circumstances and at different times make different meanings, and so create and experience different social realities, interpretivists are critical of the positivist attempts to discover definite, universal ‘laws’ that apply to everybody”* (Saunders et al., 2016, p.140).

This will be an exploratory study, in the sense that its purpose will be to clarify the *“understanding of an issue, problem or phenomenon”* (Saunders et al., 2016, p.175), phenomenon which in this case is the training needs and didactical requirements deriving from digital transformation. Given the exploratory nature of the study, an option was made to conduct semi-structured interviews, as to enable the discussion of the relevant selected topics and to allow for some degree of comparability between different interviews, but with flexibility for the interviewee to suggest significant themes or include different elements that may influence its own reality. As Saunders et al. (2016) put it, there is a list of themes, but they may not be all covered at each interview. Several similar studies have followed this same method, such as Surianarayanan & Menkhoff (2020) and Jerman et al. (2020).

In the research sample, the main goal was to include key actors in digital transformations processes in manufacturing companies. A criterion-based convenience sampling technique was followed, i.e., based on a preliminary profile of professionals (their key involvement in

digital transformation) and companies (to be detailed onwards), the sampling procedure was based on the participants' availability and willingness to share their experiences.

A decision was made to collect data in 2 rounds of interviews. In the first round, with experts in the process of digital transformation and in close proximity with the Portuguese industrial companies. These 5 experts were selected by the researcher based on their holistic knowledge of the industrial sectors and experience in supporting companies in the process of digital transformation, allowing for an in-depth study of some trends and phenomena, a method similar to the one followed by Shmatko & Volkova (2020). In the second round of interviews, 8 professionals from companies were interviewed, in order to understand their particular experience with the phenomenon of digital transformation and the training challenges at their organization, through open-ended questions that would allow respondents to give answers according to their own interpretation of that reality. In total, 13 people were interviewed, with the sampling process ceasing at saturation.

All participants have filled out an informed consent, stating that they understood the objectives of this study and agreeing to participate and being recorded. It has been agreed that the researcher will not disclose the name of any expert, professional or company, attributing a code per expert and professional, which will be used to mention each one throughout the study.

Figure 2 - Summary of interview process

Semi-structured interviews	
<u>1st round</u> Experts in the process of digital transformation, in close proximity with Portuguese industrial companies	<u>2nd round</u> Professionals with particular experience with the phenomenon of digital transformation and the training challenges at their organization

3.2. Data collection

Companies should fit the following profile: be small or medium enterprises, with a geographical context limited to firms based in Portugal, with operations that encompass a

manufacturing activity and that are starting or have started recently a transformation related with some of Industry 4.0 characteristics, namely (but not restricted to) automation, artificial intelligence, smart factories and cyber-physical systems.

Table 1, below, summarizes the desired company profile.

Table 1 - Target profile of the companies to be studied

Size	Small and Medium Enterprises (SMEs), as defined in the Portuguese Legislation (Decreto-Lei n. ° 372/2007, 2007): • Employs less than 250 people; and • Its turnover does not exceed 50 million euros OR its total annual balance sheet does not exceed 43 million euros
Geographical scope	Companies based in Portugal
Operational scope	Companies conducting a manufacturing activity
Innovation scope	Companies that are starting or have started recently a transformation related with any Industry 4.0 topics

The first characteristics are directly related with the defined objective of this study, while start of a recent transformation intends to exclude from the collected data any inputs that may not be applicable today. The selected companies will be comparable in size, geography and sector, in order to allow for easier comparability of findings.

Given potentially relevant distinctions between players within this scope operating in different industries, it was decided that a focus on specific sectors would be necessary.

The selection of the two specific sectors was based on the experts' interviews, where it was pointed out that the automotive sector would be adequate, due to being a frontrunner in terms of automation, and the textile, clothing, leather and leather products sector was described as going through a very significant hurdle, due to a lack of specialized workforce. Since both these topics are aligned with the objective of the study, the researcher focused on those two sectors. The sampling process ceased at saturation.

The study resorted to interviews with two main types of profiles for company interviewees: middle management workers whose responsibilities are related with education and training among those firms, and executives to which the former report. This should allow to gather data from the people who are more knowledgeable in each firm about the topics of reskilling and upskilling.

Two preliminary interview guides with the main topics to address in interviews with experts and professionals were made. Below, Table 2 and Table 3 present these illustrative questions.

Table 2 - Preliminary guidelines for interviews with professionals in manufacturing companies

Getting to know the interviewee The main goal of this section is to understand the profile of the person to be interviewed, since its experience and personal context may influence his/her understanding of the phenomenon
Getting to know the company The main goal of this section is to understand the operational activity that the company conducts, in order to properly assess and compare the employee profile and the challenges that could arise with digital transformation
Understanding the transformation process The main goal for this section is to understand the transformation process, the challenges it entails and the interviewee's perception regarding the company's past, present and future path

Table 3 - Preliminary guidelines for interviews with experts

Which are the main technologies that Portuguese companies have been adopting, specially SMEs, in order to make their production more digital?
Where would these companies need more external support in regard to skills / competencies?
How can companies become more aware of the benefits of digitalization and overcome the hurdles that come with it?
In which sector would training needs for digital transformation be more critical?

For both experts and companies, concerns with confidential and sensitive information require that any referrals to a person, a company or an entity is made through a code. Considering this, a short summary of each company will also be included, describing

3.2.1. First round of interviews – Experts

Table 4, presented below, showcases the list of experts that were interviewed in an attempt to know the understand the Portuguese digital transformation environment, specifically for SMEs. Experts are attributed a number and will be referred to by an ID in the format “Exp-X”, with X being each expert’s attributed number.

Table 4 - Interviewed experts' profiles

Expert ID	Organization	Role	Duration
Exp-1	Research Centre	Board member of a re- search institute	1h18m
Exp-2	Research Centre	Senior consultant, sup- porting companies in the digital transfor- mation process	0h43m
Exp-3	Vocational School	Coordinator (technical area)	1h02m
Exp-4	Vocational School	Coordinator (technical area)	
Exp-5	Centre for technological support for the metal- mechanic industry	Director of the Centre	0h31m

3.2.2. Second round of interviews – Professionals at companies

Table 5, presented below, showcases the list of professionals / companies interviewed, according to the interview guide presented in Table 2. Professionals are referred to by an ID in the format “Prof-Y-Co”, with Y being the letter attributed to each of their companies, from A to H.

Table 5 - Profiles of companies and professionals

Company ID / Professional ID	Sector	Role of the interviewed professional	Duration
A-Co / Prof-A-Co	Automotive	Global Business Developer	0h53m
B-Co / Prof-B-Co	Automotive	Production Engineer	1h02m
C-Co / Prof-C-Co	Automotive	Engineering Director	0h43m
D-Co / Prof-D-Co	Textile	Executive Director	0h50m
E-Co / Prof-E-Co	Textile	Executive Director in charge of clothing and fashion products	0h47m
F-Co / Prof-F-Co	Textile	IT Department Manager	0h37m
G-Co / Prof-G-Co	Textile	CEO	0h53m
H-Co / Prof-H-Co	Textile	Account Manager; Human Resources and Quality Assurance responsible	0h50m

3.3 Data Analysis

The data analysis was made using NVIVO 12. After the interviews were conducted, recorded and transcribed, the content was analysed.

Due to the great number of topics that surround digital transformation and Industry 4.0, a decision was made to use Initial Coding as an approach to analyse and group each particular

topic, which is defined as segmenting qualitative data into parts, examining and comparing for resemblances and distinctions – this process is adequate for most qualitative studies and allows the researcher to capture analytical data for further exploration (Saldaña, 2021, p.81). Following what is proposed by Saldaña (2021), coding was an iterative process, with many of the initial codes being tentative and grouped or corrected as the analysis progressed. After a thorough understanding of each code and topic, these were grouped by category, in alignment with the research objective: Industry 4.0, Capacitation & Skills, SME Specific challenges, Addressing reskilling and upskilling, and Sector characteristics.

3.4. Research quality

In order to assess the quality of qualitative research, Korstjens & Moser (2018) states that there are 4 criteria: credibility, transferability, dependability, and confirmability.

Regarding credibility, the fact that interviews have been conducted with 13 different people, from industry experts to company professionals, shows that there has been “*prolonged engagement*” (Korstjens & Moser, 2018, p.121) with participants. The main purpose of the interviews with experts was also to understand and describe the context in which these companies operate, which constitutes a “*thick description*” (Korstjens & Moser, 2018, p.121), strategy meant to ensure transferability. Finally, as for dependability and confirmability, an “*audit trail*” (Korstjens & Moser, 2018, p.121), in the sense that all the steps have been described in this study and all records of the research path are being kept and accessible by the researcher, if necessary.

4. Findings

4.1. Preliminary notes

Due to the aim of this study, the presentation of the results of this study will not distinguish between the findings of the 1st round of interviews (experts) and the 2nd round of interviews (professionals at companies). Therefore, both pools of outputs are used to present the findings regarding the current digitalization environment among Portuguese SMEs, as well as their understanding of the phenomenon, challenges and strategies in place.

Following a process similar to the one made in the literature review section, and in order to properly comprehend the phenomena that lead up to training needs in the face of the digitalization process in manufacturing companies, the findings of this study are presented based on the following structure, from a broad context to a more specific one: firstly, the interviewees' understanding of the digital transformation process is presented (section 4.2); then, there is a focus on workers' capacitation, namely the distinct types of workers and the main areas for intervention (section 4.3); finally, a deep-dive in the approaches to address the reskilling and upskilling challenges is described, namely in terms of companies' current training methods, preferred formats for training and the role that external entities could assume in the draft of training programs (section 4.4).

Below, Table 6 summarizes the main findings that are thoroughly explored onwards.

Table 6 - Summary of main findings

Section	Subsection	Main findings
4.2. The digital transformation process	4.2.1. Perception of technological advancement	Distinct perception of relative technological advancement between textile (more positive) and automotive (more conservative)
	4.2.2. Important drivers for digital transformation	More prevalent drivers for digital transformation include productivity improvements, pressure from suppliers/clients (more prevalent in automotive vs. textile) and sustainability concerns
	4.2.3. Current challenges	Cultural mindset and resistance to change, data management and interoperability, absence of a plan for digital transformation, lack of guidance by external entities and

		specific challenges for the textile sector, due to the flexibility and pliability of the materials
	4.2.4. Specific concerns for SMEs	Limited funding, lack of structured processes, small number of human resources, with many people accumulating several job descriptions, and lack of in-house competencies towards innovation and R&D.
4.3. Workers' capacitation	4.3.1. Distinct profiles of workers	All workers, from technical roles to middle and top management, lack digital capabilities and would benefit from training programs
	4.3.2. Identified areas for intervention	Most desired areas for training are data science, virtualization skills, quality assurance, technical training, and soft skills
4.4. Addressing reskilling and upskilling	4.4.1. Current training methods	Most companies rely fully or partially on the equipment's manufacturer to deliver training to its workforce; one company is working with an automotive cluster to diagnose its training needs
	4.4.2. Preferred formats for training	The preferred format is physical (or hybrid at most), during working hours and with a theoretical training before on-the-job learning
	4.4.3. Role of different entities in training programs	Both companies and experts believe in the value of involving external entities in the internal training of employees, with the three most referred entities being technology and interface centers, universities, and business associations

4.2. The digital transformation process

Digitalization of industrial processes reaches far back beyond Industry 4.0, with the moulds sector being a precursor of this transformation, where a lot of product engineering through CAD and CAM happened (Exp-1). However, what was previously seen as a “nice-to-have” feature is now essential for competitiveness in all industrial sectors (Exp-1).

Both professionals (Prof-E-Co) and experts (Exp-1, Exp-3, Exp-4, Exp-5) seem to also agree that, despite digitalization having started before that the Covid-19 pandemic, the outbreak contributed greatly to the acceleration of the digital transformation trends – Prof-E-

Co points out that, due to difficulty in traveling to meet suppliers and develop garments, digital twin technology and virtual prototypes were highly accelerated.

In order to properly understand the phenomenon of digital transformation, which ultimately leads to the objective of this study, this section will be divided into 4 parts: perception of technological advancement, where it is analysed whether the interviewed professionals consider that their company is ahead, in line or behind the market; important drivers for digital transformation, in which will be presented the incentives or pressure factors that lead companies to embark on the journey of digitalization; current challenges, in which are presented the views of companies and experts regarding the biggest challenges and, therefore, the areas that they intend to tackle; finally, specific concerns for SMEs, in which will be presented factors that create more hurdles for SMEs in the digital transformation process, even though they may not be exclusive of these companies.

4.2.1. Perception of technological advancement

In all interviews with experts and professionals in companies, it became clear that the two sectors under analysis, automotive and textile, clothing, leather and leather products, are in very different stages of technological advancement. The automotive industry is a reference in digital transformation, since operational KPIs and integrated systems have been the norm for several years, due to the demands from OEMs and Tier 1 suppliers (Prof-A-Co). Most of the production chain is automated, with scarce human intervention (Prof-G-Co). Textile, clothing, leather and leather products, however, still require significant intervention, with Prof-G-Co pointing out that colour precision in textile dyeing process is still one of the steps where automation remained a challenge. Additionally, more than the area where a specific sector struggles, the key point is in the value added that each business contributes with to its product or service – companies whose core business revolves around added-value products are able to invest and dedicate resources to digitalization (Exp-2).

This difference between companies which add more value and companies which add less value could be influencing each company's perception of its technological advancement, in comparison with market peers. When asked how they ranked themselves compared to the market, automotive companies gave distinct, structured answers, with Prof-B-Co considering that they were now behind the market, after being a reference company in the past, Prof-A-Co considering they were in line with the market and Prof-B-Co considering they were ahead of the market. However, some of these companies felt the need to explain that, due to the fact that they were Tier 2 suppliers, they still fell behind OEMs and Tier 1 suppliers (Prof-

A-Co, Prof-B-Co). According to these inputs (Prof-A-Co, Prof-B-Co and Prof-C-Co), it is possible to perceive that the automotive players have very high benchmarks, and they are rarely confident that they exceed market performance regarding digital transformation.

This perception does not happen in textile, clothing, leather and leather products. Out of 5 interviewees, only one did not consider itself ahead of the market (Prof-E-Co). When asked to justify their positioning, the interviewees that assume they are ahead of the market pointed out very specific factors, or gave unstructured answers, such as “*other companies are always saying that they want the same weaving machines that we have*” (Prof-F-Co), “*we are a reference, but of course it can depend on the operating model of each company*” (Prof-D-Co) and “*we don’t know anyone in the industry who uses ProdSmart¹*” (Prof-H-Co), despite Prof-H-Co pointing out that they would be replacing ProdSmart with ProTextil², a software that they pointed out was used by competitors.

In summary, automotive is apparently well ahead of textile in the digital transformation process, but the perception of technological advancement of textile companies (relative to its peers) seems to be much more positive. Considering this, it is important to understand what the drivers for digital transformation are.

4.2.2. Important drivers for digital transformation

Despite recognizing digitalization’s importance, most interviewees in companies explicitly described not having a digital transformation plan (all except Prof-A-Co).

According to Prof-A-Co, A-Co was the most advanced company regarding this matter. They have drafted a plan and have been executing it, currently working with 2 partners to assess their needs in terms of management tools, engineering, quality assurance and project planning. This is leading to an update on their processes and to a strong investment in the development of ERP modules, which will allow for less human intervention in core and back-office day-to-day activities (e.g., human resources, finance).

According to the other interviewees in companies, the processes leading to digital transformation are not so positive. Some professionals referred that employees identify some flaws in the company’s processes and thus no structured process drove innovation and

¹ Manufacturing execution system that allows companies to “plan, assign, manage, track and analyze fabricating and manufacturing shop floor production with one software solution” (AutoDesk, n.d.)

² Production management software allowing for control over production planning and control, dyeing, lab processes, logistics, overall equipment effectiveness, quality management and dynamic analyses (InforCávado, n.d.)

digitalization, since people were too focused on the daily operations and don't have time to allocate to these matters (Prof-B-Co, Prof-F-Co). Prof-C-Co and Prof-D-Co's professionals both indicated that they had no structured plan for innovation, and presented some concerns regarding the unknown, foreseen path of the industry in the future. The only company that came close to A-Co's positioning was G-Co, defining its end-goal in terms of digitalization, but without specific initiatives or a step-plan, opting for remaining vigilant to new trends or technologies that can act as enablers (Prof-G-Co).

Given this, in these companies, most innovation in this regard was due to specific drivers that led management to pursue improvements.

Productivity is one of the drivers that is most pointed out by the participants (Exp-2, Exp-3, Exp-5), since it makes sense from a 'unit-economics' perspective. Regardless of their skillset, managers and workers usually understand what an improvement or a more advanced equipment is, since it alleviates the challenges in the shop floor and makes it easier to calculate a return on the investment (Exp-2). Exp-3 agrees with this perspective and points out that every improvement to processes that is easily quantifiable from a productivity and a return perspective will be easy to justify. Most companies embarking in the digital transformation challenge have an expectation of improving productivity, but the evaluation of the productivity improvement in processes is not necessarily a well-established procedure in SMEs (Exp-5). Among companies, an example of such an improvement is presented by Prof-H-Co. They plan on improving its shop floor software to improve the amount of production parameters that can be defined in the back-office, at a faster rate than it is currently possible. This will allow to control processes in a better way and improve the number of produced garments.

Another factor that can contribute to faster digital transformation is pressure from suppliers and customers (Prof-A-Co, Prof-C-Co, Prof-E-Co). This is a prevailing factor especially in the automotive sector, where companies are constantly challenged by clients in the form of their tailor-requests (Prof-A-Co). Additionally, Prof-C-Co mentions that clients are the only stakeholders that push them to become more digital. On the other hand, the only textile company professional mentioning this is Prof-E-Co, which could be a reflection of a sector where upstream companies seem to define progress:

*"Some clients clearly have dematerialization in their plans for fashion collections in the following years, but **they depend on the speed at which industrial companies make this movement (...).** There are many things that we believe will happen, but machinery/ **equipment suppliers will have***

to develop those technologies and only then can we take advantage of them” (Prof-E-Co)

There is also a belief that technological progress and decreasing costs will be driving transformation in each sector - as machines increase their processing power and their costs decrease, there are conditions for the massification of technologies adoption that were previously inaccessible for smaller companies (Exp-A).

Finally, sustainability could also be a key driver for digital transformation. As the importance of environmental impact and decarbonization grows, digital technologies could enable visibility of their processes (e.g., how much water is spent, how much clean energy do we use) (Exp-1) and encourage companies to pursue what Prof-G-Co points out as a strong traceability of their internal processes, a path G-Co chose to invest in in the last 6-7 years.

In summary, despite almost all interviewed professionals (except Prof-A-Co) stating that their company did not have a drafted digital transformation plan, these companies are still driven by three main factors: productivity, pressure from suppliers/clients (this one more prevalent in the automotive sector) and sustainability concerns. In the future, it is expected that decreasing costs will also represent a driver for this transformation – however, at this point, the required investment is one of the main challenges for companies. This study will now present the findings regarding the current challenges that companies face and whether training needs are included or not.

4.2.3. Current challenges

One of the main challenges reported in the digital transformation transition is cultural mindset and resistance to change (Prof-A-Co, Prof-D-Co, Prof-E-Co, Prof-G-Co). Some company professionals point out that they have employees with ten years of experience, and those employees usually put obstacles to working with new machines, platforms or software (Prof-A-Co, Prof-D-Co). Despite efforts in integrating these workers in the decision-making process regarding new equipment, there appears to exist resistance to change and conflicting interests between co-workers (Prof-D-Co). Prof-G-Co, for instance, reveals that these struggles happen more often when companies are dealing with operators, who believe that the new machine or process is wrong, and they are correct. A different perspective states that some workers having a fear of becoming redundant, preferring to do tedious tasks instead of allowing for automation (Exp-5). It seems that even fashion brands (the last agent in the

value chain of the textile sector) have this problem, with designers that are used to working with pen and paper not wanting to adopt new technologies (Prof-E-Co). Prof-C-Co and Prof-H-Co have more positive experiences, with Prof-C-Co describing an open-minded staff and Prof-H-Co revealing that the transition has been smooth and with a concern for intuitiveness in the front-end of the new systems on the shop floor.

As referred in section 4.2.3., most companies do not have a clear digital transformation plan, which increases the hurdles when navigating through this transition.

Another factor to account for regarding challenges is data management. Several of the interviewed company professionals have described installing sensors and cameras, namely Prof-B-Co, Prof-D-Co, Prof-F-Co, Prof-G-Co and Prof-H-Co. However, all interviewed experts and company professionals have alerted that, in order to properly capitalize on the gathered data, enterprises need to have fully implemented and integrated data systems. Prof-A-Co, for instance, points out that tracking of operational and logistical KPIs has been the norm for several years in the industry and in the company, however, they are still investing in their ERP system, in a pursuit to further digitalize processes and access more real-time information than they are currently able to. In the future, A-Co intends to continue investing, to further enhance its digital systems. Prof-B-Co points out that some of the machines acquired already come with data collection systems, but that they are “*isolated beings*” that, without integration with the other element of the production process, require that someone physically goes to the machine to collect data. All these data systems, in their varied forms (e.g., temperature, lead times for each task), are of utmost importance for Prof-C-Co, Prof-D-Co and Prof-H-Co. There is only one professional that does not recognize this threat at the same scale, saying that “*we have an ERP that has some years, (...) we have our eyes open and know that it has a limited lifespan, we will evaluate it in the future*” (Prof-F-Co). Exp-2’s opinion is in line with most companies, observing that especially most SMEs struggle with systems’ integration, and specifically ERP integration, given that the customization of these solutions falls out of the companies’ budget range and that leads to a gap between what the equipment is able to do and its actual performance. In an opposite example, Exp-3 notes the positive example seen in a small factory, where the management software had visibility over the the execution times for each task and was fully integrated with the production system, allowing for increased efficiency. Given this, despite being based on archaic tools, its integration led to better performance than comparable peers, with customization being the key. This is not the case in all companies, with some still storing valuable data in tools such as Microsoft Excel

or, in some cases, even in paper (Prof-B-Co). Prof-B-Co states that this maintains companies further from full data interoperability and from exploring the entire potential of its data.

Data also allows companies to pursue automation of quality control, but this entails similar challenges. Automation of quality control is still based on two different factors: automatic collection and processing through sensors and systems, such as software to analyse and report quality in cloud environment; but also human intervention, with the next step being based on intelligent cameras and artificial intelligence to quality control (Prof-D-Co). Prof-E-Co, for example, describes that, in a different business unit of the same Group, is already at the next level, defining algorithms based on speed, temperature and external conditions of the machine to find the best balance between speed and temperature, maximizing performance and minimizing defective products.

Another identified challenge is the lack of guidance from external institutions. Prof-C-Co, for instance, is creating an R&D area and has been visiting several other companies to understand the best way of structuring it. However, Prof-C-Co feels that institutions such as interface centers or other external consultants could streamline this process, helping to decide on recruitment, structure, funding, among other factors.

Finally, the textile sector faces enormous potential with digitalization. For instance, prototyping is fundamental for this industry, with companies producing thousands of physical prototypes (Prof-D-Co notes that it produces 10.000 prototypes per year). Digital twins could revolutionize this and shake the sector, with a strong impact on costs and waste being described by all interviewed textile companies. However, there is also a specific challenge for this sector, with automation in textile becoming a big challenge, due to the flexibility and pliability of the materials involved in production.

In summary, there are five main challenges that affect companies attempting to pursue digital transformation:

- Cultural mindset and resistance to change, with workers not feeling compelled to welcome new technologies in their day-to-day operations
- Data management and interoperability, in order to further digitalize processes
- Absence of a plan for digital transformation
- Lack of guidance by external entities
- Specific challenges for the textile sector, due to the flexibility and pliability of the materials

4.2.4. Specific concerns for SMEs

There are specific challenges that SMEs face that, due to its impact on smaller companies, should be highlighted in this section.

As expected, due to its size, one of the concerns that becomes inflated in SMEs is funding. As Prof-A-Co points out, despite all the European funding programs and the exceptional Portuguese Recovery and Resilience Plan (RRP), many small and medium enterprises are still equipped with machines and value chains that have limited digitalization potential. Given the limited financial resources of these companies, many times they choose low-risk investments, such as a well-known machine of which the return is well-known to the company, regardless of other investment alternatives that could provide higher returns, such as more disruptive machinery that could leverage the companies' productivity (Prof-B-Co).

Another challenge are SME's human resources, usually limited in number, with vast job descriptions and a necessary focus on the core business. Prof-D-Co refers that he is a Board member, also a Director in charge of digital transformation and constantly needs to resort to people from other departments to conclude its digitalization projects. An SME's focus on operations leads to some investment in the digitalization of the production process, but these companies usually fail at integrating this with the ERP, with a gap between production and management software that does not allow for real-time tracking (Exp-2). This would require customization from the ERP that does not come out of the box from ERP providers.

Another challenge for SMEs that was identified during these interviews is the lack of structured processes. Regardless of the sector, there is a pattern of SMEs having a hard time assessing its quality and processes performance, due to the fact that these processes are usually not well-established, especially for companies that do not have a relevant exposure to international markets or to the end of the value chain (since the requirements are much stricter in the international market and downstream in the value chain) (Exp-5).

Finally, the lack of in-house competencies of most SMEs was also pointed out (Exp-1, Exp-2, Exp-3). Companies with limited human resources usually don't have any innovation or R&D competencies (Exp-1), while some companies are usually run by older, less-educated managers that will be less sensitive to digitalization and transformation topics, since they built the companies' current way of working and have seen it succeeding (Exp-2). Exp-3 agrees and explains that top management usually does not have any notion of the state-of-the-art in terms of digitalization in its own sector.

In summary, the most impactful challenges for SMEs in the digital transformation process are as follows:

- Limited funding, leading to risk-averse positioning in terms of investments;
- Lack of structured processes, which hampers continuous improvement;
- Small number of human resources, with many people accumulating several job descriptions;
- Lack of in-house competencies towards innovation and R&D.

Therefore, regarding the digital transformation process itself, it has been concluded that companies have discrepancies between themselves in terms of perception of technological advancement (which may show that these perceptions are built by people in need of training). This may lead many of them not to have a clear digital transformation plan, but there are still some drivers that promote some digitalization initiatives. However, challenges for companies are still big, especially in terms of culture, data and lack of guidance; however, SMEs in particular face tougher hurdles, with lack of processes, as well as adequate human and financial resources. Considering the resistance to change and general lack of training pointed out, it is important to address training and capacitation topics.

4.3. Workers' capacitation

This study will now address the topic of workers' capacitation, i.e., which workers need training in areas connected with digital transformation and which specific areas are these.

4.3.1. Distinct profiles of workers

At this point, it is important to distinguish technical roles (e.g., operators in the shop floor) from top and middle management workers. All interviewed companies and experts recognize that technical roles, or blue-collar workers, will be needing reskilling and/or upskilling. However, some company professionals (Prof-A-Co, Prof-H-Co) and experts (Exp-1, Exp-2, Exp-5) also point out that white-collar workers, and specifically top management, also need to pursue training regarding the digital transformation process.

Prof-A-Co shared its belief that companies have a vision of digital transformation that is too technical but need to introduce a more holistic vision to its middle managers. This professional also believes that Portuguese managers are many times unable to properly plan these transformation processes, due to the lack of a step plan and proper resource allocation. A more agile mindset is also required from top management to navigate the digital

transformation era (Prof-H-Co).

All experts believe that the capacitation of white-collar workers in SMEs is one of the key drivers for success in this process. Exp-1 notes that we will be seeing the “*Erasmus generation*” reaching top management, substituting the current managers, self-made man with low qualifications that are less sensitive to digitalization. There is apparently a big contrast between the typical SMEs, with ageing CEOs, and new start-ups with young, qualified leaders (Exp-2). When faced with Portuguese SME top management that are self-made man and had operational roles, they usually have a focus on operations (e.g., “*delivering the order*”) and not on digitalization (Exp-5).

All in all, passing the fairly unanimous conclusion that blue-collar workers need training in the digital transformation area, it seems that top and middle management are also pointed out as lacking capabilities in these areas. It is now important to identify in which specific areas should all workers be trained in.

4.3.2. Identified areas for intervention

Each company points out different areas for intervention. An attempt will be made at naming those that are more frequent and pertinent, given the challenges those same companies indicated.

Firstly, a commentary was made (Exp-3) referring that technical training as it exists today will remain necessary, regardless of digital transformation. Exp-3 points out that, even at a stage where we have collaborative robots, there is still a need for maintenance, assembly and disassembly, all of which will require manual, physical competencies that should continue to deserve the companies’ attention regarding training. This will also put pressure on the educational systems, especially on vocational schools, to pursue training of young students that will enter the market in the future.

Secondly, there is a need for training employees and managers in data science, which is still mostly externally hired (e.g., consultants) and will need to be internalized. Prof-E-Co, for instance, foresees that professionals in the area of data science will be able to contribute greatly to the organization in the future and is optimistic about the future, since some of the most recently hired production workers already have some knowledge in this area.

Thirdly, virtualization skills for the development of digital twins and other applications, which currently are still very early-stage. Prof-E-Co points out that several technologies in

the textile sector that will allow for virtualization come from film and videogame industries. Therefore, there is still a gap in professionals that have virtualization skills and experience in the textile sector.

Next, in face of the change that is bound to happen in the area of quality assurance, proper quality assurance training will be essential, in order to properly prepare the workforce to use digital solutions that can speed up production processes and reduce waste (Prof-A-Co, Prof-B-Co, Prof-D-Co, Prof-E-Co, Prof-G-Co, Exp-3, Exp-4). Through effective sensorization and system integration, workers will be able to minimize waste and defective products – however, this will demand different skills from their current job description.

Finally, soft skills are pointed out as a necessity, for people to understand team dynamics and the impact of each team member in the global output. Prof-A-Co makes the point that, given all the mindset and culture challenges, soft-skills are an essential part of training towards digital transformation. Prof-C-Co suggests that soft-skills are important, but focuses on areas not necessarily related with digital transformation (such as time and conflict management), while Prof-D-Co notes that there should be training focused on intellectual curiosity, to overcome the obstacles that companies usually have with low-qualification workers.

In summary, there are three main areas strongly connected with digital transformation that professionals and experts believe should be addressed in terms of training: data science, virtualization skills and quality assurance. There are also, however, two areas that companies and experts still feel the need to highlight: technical training, which will continue to be necessary regardless of digital progress; and soft skills, crucial during a time of cultural change.

The conclusion for workers' capacitation is that all workers, from top management to operators, need to have training in areas related with digital transformation, and the most desired areas for training are data science, virtualization skills, quality assurance, technical training and soft skills. Having identified the training needs, it is time to understand how the reskilling and upskilling challenge should be addressed.

4.4. Addressing reskilling and upskilling

In terms of how to address reskilling and upskilling, after a clear summary of the training needs, this study will focus on the didactical requirements in terms of the design of such courses. Therefore, it is now of the upmost importance to understand the training methods of each company (4.4.1), the formats that professionals in charge of digital transformation feel are more beneficial for the learning process (4.4.2) and the role external entities can have

in these training initiatives (4.4.3).

4.4.1. Current training methods

Companies do not seem very confident in the current training programs to address the reskilling and upskilling challenge. Both Prof-A-Co and Prof-E-Co do not believe that there are currently any available training programs that could prepare workers for the current and upcoming transformation. Regarding the way each company is addressing this topic, a brief analysis over each company's approach will be made.

There are several companies that still rely, fully or partially, on equipment manufacturers to deliver training (B-Co, G-Co, H-Co). For example, B-Co's training is purely technical and usually delivered by the equipment's supplier. When they acquire new equipment, they also acquire a training package that is delivered by the supplier to all middle management. These trainings are usually holistic and not specific for the worker's job description, in order to have some overlap and understanding of the challenges among different co-workers (e.g., process workers understanding maintenance challenges). G-Co is another company relying on the equipment suppliers for the training of its workers. The company representative explained that they are now recording these trainings, to allow workers to see them later, but did not outline any additional measures for training or reskilling. H-Co also focuses mostly on technical trainings related with their current equipment and other topics, such as internal processes, environment and social responsibility.

Other companies (A-Co, E-Co, F-Co) rely on internal resources to deliver their training programs. A-Co uses classroom training, delivered by team leaders, to prepare its technical workers for using new equipment/technologies. They believe that they are not a reference in this matter and that the company needs to evolve in terms of training. E-Co provides technical training to its shop floor workers, namely in technical areas such as quality assurance and sustainability but does not have any reskilling program foreseen. F-Co delivers training, in accordance to the company's policy and the applicable law that dictates an annual minimum of 40 hours of training, but does not plan for a specific reskilling program.

D-Co is more flexible than other companies in their training method. When they define a specific new process, they deliver an internal training for everyone that intervenes in that specific process or operates that technology. They divide this between a first moment of classroom training and a second moment of learning-by-doing in their working environment. However, when the need arises, they also resort to equipment and software suppliers for external training.

C-Co has a different approach and resorts to Mobinov, an automotive cluster in Portugal. Despite not having delivered any specific training yet, Mobinov presented its training portfolio to C-Co and will be assisting the company on identifying groups of workers to attend these courses.

In summary, many of these companies (B-Co, G-Co, H-Co) still rely on the equipment's manufacturer to deliver training to its workforce, while others have internal resources delivering these sessions (A-Co, E-Co, F-Co) and one company remains flexible between these 2 models. However, C-Co is doing something different, working with an automotive cluster to diagnose its training needs. Considering this, it is important to understand if there are any preferences regarding the format of these training sessions.

4.4.2. Preferred formats for training

In terms of location of the training, no companies showed a preference for online training, with only two company professionals saying that a hybrid-model would be ideal (Prof-A-Co and Prof-D-Co). Of these, Prof-D-Co said *"I always prefer in-person, but hybrid might be best"*, showing that the option for the hybrid model might be due to workers' expectations, while Prof-A-Co points out that a hybrid model allows the worker understand its struggles in a calm environment (at the office or at home), having a chance to clarify them later with co-workers and coordinators.

Regarding the timing of training, there seems to be a generic preference for training courses during working hours. Prof-H-Co clearly states that workers prefer it this way, while Prof-D-Co had past struggled with workers forfeiting their trainings when they exceeded working hours.

Prof-D-Co and Prof-G-Co also have a clear preference for on-the-job training. According to Prof-G-Co, it is through experienced professionals that workers are able to develop a skillset and learn more efficiently. All the other companies seem to believe in a mixed format, with a theoretical training in classroom context, followed by what is known as *'learning-by-doing'*.

There were also mentions about the importance of demonstrating feasible use cases, in order to engage the workforce in the digital transformation. Exp-1 points out that these use cases should revolve around companies of the same sizing, even if they are from different sectors, instead of same-sector multinational groups.

Therefore, the preferred format is physical (or hybrid at most), during working hours and

with a theoretical training before on-the-job learning. With the workers, the desired topics and the preferred format defined, it is time to understand whether these companies believe that external entities should be involved in the training programs or not.

4.4.3. Role of different entities in training programs

An important part of the didactical requirements involves that parties that intervene in the training process (and with which role they do). According to all experts and companies' professionals, many stakeholders/external entities could have a significant role as an enabler of digital transformation in companies and among entire sectors. Below, ordered by decreasing number of references, a list of entities and a brief explanation of the rationale behind their potential intervention is provided:

- **Technology and Interface Centers** – 6 company professionals (Prof-A-Co, Prof-B-Co, Prof-D-Co, Prof-E-Co, Prof-G-Co, Prof-H-Co) and 3 experts (Exp-1, Exp-2, Exp-3) mentioned this entity. Both companies' professionals and experts seem to acknowledge technology and interface centers' unique position to address some of the identified training issues. On the one hand, as Prof-A-Co puts it, these centres are close enough to the companies to understand its needs, and close enough to academia to promote adjustments in its curricula, allowing for an easier integration of new professionals in digital companies. These centers are also the main drivers of many training programs, with Prof-E-Co pointing out that CITEVE³, a technology center for the textile sector, is even creating digital competences among its organization and can have a key role in reskilling and upskilling organizations. Exp-3 also believes that CITEVE has a prime position in terms of company knowledge, due to the consulting services rendered to many players in the sector, and could diagnose the main struggles in the digital transformation process. These centers are focused on the development of new projects, but based on the professionals' experience, these could also have a key role in the technical and execution support in digitalization initiatives (Prof-B-Co). Exp-2 trusts that the network that these centers have can help deliver courses for workers from many different companies where it would not be possible to deliver an exclusive course, due to few people interested in the contents. Finally, Exp-1, that

³ CITEVE is a “*Technological Institute which provides technological support and services to companies acting in the textile & clothing business*” (CITEVE - Sobre O CITEVE, n.d.)

is also a board member of one of these centers, understands that they are ahead of the market in terms of ‘*state-of-the-art*’ technology. This should lead them to support companies through labs and services, assuming that they receive proper funding from public entities.

- **Universities** – 4 company professionals (Prof-A-Co, Prof-C-Co, Prof-E-Co, Prof-G-Co) mentioned universities. As previously mentioned, Prof-A-Co believes that universities need to be closer to enterprises, in order to successfully adapt their courses and properly prepare students to enter a predominantly-digital labour market. Prof-E-Co points out that universities are, together with technology centers, the biggest enablers of digital transformation and reminds that proper education will be key for this transition. Prof-E-Co mentioned the company’s past experience, when a university had a ~10 year hiatus with no training in textile engineering. This led to no renovation in the workforce for a long time and lack of competencies, which created a significant problem for the company – this is the main reason that leads Prof-E-Co to have a strong belief on the importance of universities. Prof-G-Co does not necessarily believe that universities are equipped to diagnose company’s needs, but understands that they can have a key role in the following training courses.
- **Business associations** – 2 company professionals (Prof-A-Co, Prof-C-Co) and 2 experts (Exp-1, Exp-2) mentioned business associations. Prof-A-Co is a big believer in the importance of business associations and clusters as a network to promote shared experiences and collective problem solving in the automotive sector. Prof-C-Co’s experience with Mobinov in the identification of training needs also leads the company to believe in the importance of business associations in the upskilling challenge. Exp-1, a big believer in technology and interface centers, thinks that business associations are the biggest promoters of these centers and also take over its role when these do not exist (e.g., launching training centers and academies). Exp-2 also considers that business associations can show added-value opportunities for companies and assist them in their training process.
- **Vocational schools** – 3 company professionals (Prof-A-Co, Prof-E-Co, Prof-G-Co) mentioned vocational schools. Despite a potential key role in these processes, many companies seem to consider that vocational schools need to be restructured in order to fulfil this purpose. Prof-A-Co, based on its experience, thinks that

vocational schools need to be further developed and increase their offer, since public policies have neglected this area in the last decades (decreasing investment in these schools), but the need for it is increasingly clear. Prof-A-Co also states that, in partnership with business associations, vocational schools could have a key role in reskilling the current technicians, since the necessary skillset does not currently exist in the workforce. Prof-E-Co understands that vocational schools need to increase their focus in new technologies outside sector-specific needs, namely digital, data, virtual reality and algorithms. Prof-G-Co thinks that vocational schools could be relevant for the training and reskilling of blue-collar workers since they are more practical than other conventional training methods and can be more appealing to these profiles.

- **Training academies** – mentioned by 2 experts (Exp-3, Exp-4), these entities promote training courses for companies and individuals, aiming for qualifying or reconverting professionals. Exp-3 and Exp-4, both coordinators at a training academy, believe that they have and can continue to have an important role in training, reskilling and upskilling. Specifically, Exp-4 believes that training academies can help recruit undifferentiated profiles or select current company profiles, while training them to match the company's needs. However, Prof-E-Co, while recognizing these institutions' competence, describes a rough experience, with several people attending the training course and forfeiting it without ever joining the company.
- **Public-private partnerships** – mentioned by 1 company professional (Prof-A-Co), these would be established between the State and multinational groups. Prof-A-Co thinks that, given several reference companies in Portugal in regard to digital transformation, public-private partnerships could serve the purpose of promoting collaboration between multinational groups with established processes and SMEs, since many of these processes are standard.
- **Primary and secondary schools** – mentioned by 1 company professional (Prof-A-Co). Prof-A-Co believes that we need to look into our education system at its most upstream levels to properly face the digitalization challenge. Significant work should be done in primary and secondary schools to ensure teachers are qualified and able to prepare the desired professionals of the future

- **Government** – mentioned by 1 company professional (Prof-D-Co). Following a low demand for training programs among its workforce, D-Co made available a 12.000€ scholarship for each employee for training. However, only 2-3% of its workforce accesses it every year. Given this, Prof-D-Co believes that the Government should pursue other ways to incentivize training, namely tax benefits

It is clear that both companies and experts in some of these entities want the involvement of external entities in the internal training of employees, the three most referred entities to be part of this are technology and interface centers, universities, and business associations, which goes to show that the connection between academia and the corporate world is valued by both parties.

In summary, in terms of didactical design and approaches to address the reskilling and upskilling challenges, there are a few relevant notes. Currently, most companies rely fully or partially on the equipment's manufacturer to deliver training to its workforce, while others have their internal resources delivering the training programs and only one company works with an external party, a sector cluster, to diagnose its training needs. The preferred format for future training programs is physical (or hybrid, at most), during working hours, and with a theoretical training before on-the-job-learning. Both companies and experts seem to believe in the value of involving external entities in the internal training of employees, with the three most referred entities being technology and interface centers, universities, and business associations.

5. Discussion

Both the analyzed literature and the current study are aligned in terms of benefits of digitalization. Previous studies recognized significant benefits for companies, with the main ones being operational improvements (Kumar et al., 2021; Mian et al., 2020), enrichment of factory work (Kaasinen, 2020) and financial gains (Kumar et al., 2021). All in all, it is safe to say that the results of this study validate these premises. Due to the fact that all companies except A-Co lacked a digital transformation plan, the discussions with experts and professionals were primarily focused on the drivers that led digitalization initiatives, rather than particular advantages. One of the main drivers is productivity (Exp-2, Exp-3, Exp-5), which can be easily related with the afore-mentioned operational and financial improvements (Kumar et al., 2021; Mian et al., 2020). None of the professionals seemed to mention enrichment of factory work as a driver or as an advantage, as pointed out by Kaasinen (2020). However, the need to stay at-par with suppliers and customers that was identified by some professionals (Prof-A-Co, Prof-C-Co, Prof-E-Co) should reflect as an advantage, in the sense of being a more attractive partner stakeholders in the industry. The fact that an expert (Exp-1) and a professional (Prof-G-Co) recognize that advantages of digitalization for successful visibility and traceability, which can allow for additional sustainability compliance.

As for the challenges that arise from digital transformation, as highlighted in the literature review section, some of the most prevalent are integration concerns in the value-chain, cyber-security, unclear economic and financial benefits, absence of adequate skills, sizeable investment requirements, absence of infrastructure, jobs disruptions, data management and quality, no secure standards and norms, and resistance to change (Kumar et al, 2021). There is a high degree of match between these and the challenges mentioned by experts and professionals: cultural mindset and resistance to change (Prof-A-Co, Prof-D-Co, Prof-E-Co, Prof-G-Co), data management and interoperability (Prof-A-Co, Prof-B-Co, Prof-D-Co, Prof-F-Co, Prof-G-Co, Prof-H-Co), absence of a plan for digital transformation (Prof-B-Co, Prof-C-Co, Prof-D-Co, Prof-E-Co, Prof-F-Co, Prof-G-Co, Prof-H-Co), lack of guidance by external entities (Prof-C-Co). Even when considering specific concerns for SMEs, it is still possible to identify the match when looking through the findings: limited funding, leading to risk-averse positioning in terms of investment (Prof-A-Co, Prof-B-Co), lack of structured processes (Exp-5), small number of human resources (Exp-2, Prof-D-Co) and lack of in-house competences towards innovation and R&D (Exp-1, Exp-2, Exp-3).

Specifically, regarding workers' capacitation, company professionals (Prof-A-Co, Prof-H-Co) and experts (Exp-1, Exp-2, Exp-5) specifically highlighted the necessary capacitation of all workers, including white-collar workers (e.g., top management), who they (Prof-A-Co, Exp-1, Exp-2) felt were sometimes forgotten when discussing reskilling challenges under the digital transformation phenomenon. This was also something previously foreseen in literature by Surianarayanan & Menkhoff (2020), who indicated top management support as one of the main adoption issues in regard to smart manufacturing technologies.

In terms of identified areas for intervention, the match between literature review and findings is not as close. Due to the highly vast nature of Industry 4.0, literature review is fairly extensive on its definition and on the technologies it presents as being encompassed by I4.0 (Assante et al., 2019; El-Thalji et al., 2020; Reddy, 2019; Surianarayanan & Menkhoff, 2020). Interviewed experts and company professionals focused on 5 main areas, that were likely to display higher proximity with the analysed sectors: **data science, virtualization skills, quality assurance, technical training, and soft skills**. These last two areas in particular are not necessarily reflected in the literature as specific Industry 4.0 concerns, which could be attributable to specific characteristics or context of the Portuguese SMEs.

Previous studies (Manesh et al, 2011; Mian et al., 2020) also pointed out that universities and companies were bound to draw new training programs, updating their existing curricula and bringing them up to date with the necessary skillset for this new context. The results of this study do not contradict, while not contradicting those conclusions, go beyond these two stakeholders and bring several other entities to the equation. The most relevant ones are technology and interface centers, business associations and vocational schools. Technology and interface centers could make use of their prime position as a bridge between academia and the corporate world; business associations could leverage their role as a network of companies with similar activities and interests, capitalizing on its aggregate size to pursue more ambitious challenges. Finally, vocational schools are in need of deep restructuring in Portugal, in order to correct the mismatch between current and needed skills, but remain key and a pre-requisite for facing this transition.

Regarding the ways to address the reskilling and upskilling challenge, the approaches that this study lists seem to be less ambitious than those identified in previous studies (Block et al., 2018; Caldarola et al., 2018; Kipper et al., 2021; Manesh et al, 2011; Moncada et al., 2020; Sackey et al., 2017; Sallati et al., 2019; Schuster et al., 2016), possibly due to the nature of the analyzed companies (small and medium enterprises). Two of the main approaches to training

programs presented in the literature were virtual learning environments and teaching and learning factories. In this study, companies were divided between wanting hybrid training programs, which could tend (at least partially) towards the virtual learning environments that were described in the literature review, and those who believed strongly in physical learning, be it in a classroom or in the workplace, following a learning-by-doing approach. Despite the match between learning-by-doing and teaching and learning factories, the fact is that most companies that believed in this approach also believed that training does not work as well outside of the workplace and that learning comes from the sharing of knowledge between experienced and unexperienced workers.

6. Conclusions

The digital transformation phenomenon is not homogenous, standing at different stages of execution between distinct sectors, geographies, company sizes, innovation contexts, among other variables. However, it is possible to conclude that it will eventually reach a widespread stage of maturity – therefore, regardless of the considered sector, companies need to be alert to something that can be an opportunity, if capitalized, or a threat, if they fall behind their competitors.

Currently, the most prevalent drivers for digital transformation include productivity improvements, pressure from suppliers/clients (more prevalent in automotive vs. textile) and sustainability concerns. There are, however, many challenges that need to be addressed. These challenges span across different dimensions, such as organizational, technological and cultural. Among these challenges, it is possible to highlight cultural mindset and resistance to change, data management and interoperability, absence of a plan for digital transformation, lack of guidance by external entities and specific challenges for the textile sector, due to the flexibility and pliability of the materials. Specifically for SMEs, some challenges become more inflated: limited funding, lack of structured processes, small number of human resources, with many people accumulating several job functions, and lack of in-house competencies in R&D and innovation.

Workers' capacitation in the future should encompass all employees (from blue-collar workers to top management) and be focused primarily on data science, virtualization skills, quality assurance, technical training, and soft skills. At this point, most companies rely fully or partially on the equipment's manufacturer to deliver training to its workforce, with fewer companies opting for more customized approaches. The preferred format for future training programs is physical (or hybrid at most), during working hours and with a theoretical training before on-the-job learning. Both companies and experts believe in the value of involving external entities in the internal training of employees, with the three most referred entities being technology and interface centers, universities, and business associations

This study indicates a summary of main training needs and some didactical requirements from Portuguese SMEs in the automotive and textile sectors, which may open the doors for a clear definition of training programs for these companies in the future. In addition, it was demonstrated that both companies and external parties (namely technology and interface centers) are willing to collaborate and recognize the value of a partnership to draft and deliver

training programs in the context of digital transformation.

The findings of this study encompass some limitations. Firstly, there is a limited size to the sample of company professionals and experts interviewed (13 people). Secondly, the sampling procedure was based on the participants' availability and willingness to share their experiences. These two factors may lead to a sample bias or to a sample that is not considered representative of the population being studied (Portuguese SMEs in automotive and textile sectors).

Future studies could focus on the definition of specific frameworks and training programs, matching the identified training needs and didactical requirements and building curricula that properly address companies and workers' needs. For instance, a possible case study regarding a collaboration between companies and one of the types of external entities mentioned in the study (e.g., technology and interface centers, universities, business associations) would certainly be helpful for analysing the efficacy of partnerships, as well as showcasing successful cases to other companies and entities.

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Annex

Detailed guidelines for company professionals' interviews:

Getting to know the interviewee The main goal of this section is to understand the profile of the person to be interviewed, since its experience and personal context may influence his/her understanding of the phenomenon	Illustrative questions (not restrictive): • What are your role and main responsibilities within the company? • What is your previous academic and professional experience?
Getting to know the company The main goal of this section is to understand the operational activity that the company conducts, in order to properly assess and compare the employee profile and the challenges that could arise with digital transformation	Illustrative questions (not restrictive): • What is the main operational activity of the company? • What are the profiles of employees that the company hires for the various stages of the supply chain? And for administrative roles?
Understanding the transformation process The main goal for this section is to understand the transformation process, the challenges it entails and the interviewee's perception regarding the company's past, present and future path	Illustrative questions (not restrictive): • How would you evaluate the technological advancement of the company, in comparison with its industry peers? • What steps has the company been taking to pursue digital transformation? • Does the company recognize added value in the pursuit for digital transformation? • Who would you say is the main enabler of the digital transformation process in the company?

	• Do you identify reskilling and upskilling challenges in your company related with the digital transformation process? Please identify these across functional areas and hierarchical levels • Describe the steps to recruit new employees for the processes where digital transformation is happening, indicating the main challenges faced • How do internal employees see digital transformation and the need for reskilling and upskilling? • What are the actions taken by the company to address these challenges? • What are the educational/didactical programs in place to address these challenges? Who do you think should be involved in the planning of such a program (government agencies; companies; academia)? • What didactical contents do you see as useful in such a program for your company? And for the manufacturing industry? What format do you believe is more adequate, considering the skillset to be promoted? (e.g. virtual, classroom, simulation, hybrid, on-the-job training)
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