RESEARCH REPORT

Eurofound

Future of manufacturing

Company initiatives to align apprenticeships to advanced manufacturing

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European Foundation for the Improvement of Living and Working Conditions

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The European Foundation for the Improvement of Living and Working Conditions (Eurofound) is a tripartite European Union Agency whose role is to provide knowledge in the area of social, employment and work-related policies. Eurofound was established in 1975 by Council Regulation (EEC) No. 1365/75 to contribute to the planning and design of better living and working conditions in Europe.

European Foundation for the Improvement of Living and Working Conditions

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List of abbreviations

BEng	Bachelor of Engineering
CAD	computer-aided design
CAM	computer-aided manufacturing
CNC	computerised numerical control
EQF	European Qualifications Framework
ESM	efficient and sustainable manufacturing
EURES	European Employment Services
HR	human resources
IBEC	Irish Business and Employers Confederation
ICT	information and communications technology
IoT	internet of things
IRT	Jules Verne Technological Research Institute
IVET	initial vocational education and training
JVMA	Jules Verne Manufacturing Academy
MAMF	Mechanical Automation and Maintenance Fitting
ME	manufacturing engineer
MT	manufacturing technician
NQF	national qualifications framework
SMEs	small and medium enterprises
VET	vocational education and training

See Annex 2 for a list of organisation names and acronyms.

Executive summary

Introduction

Advanced manufacturing covers various aspects related to the application of new and cutting-edge technologies to improve efficiencies and production processes. This technological change inevitably requires an adaptation of vocational training programmes and practices in initial, further and higher vocational education and training (VET).

Apprenticeships combining alternating periods at the workplace and in training institutions are well suited to provide young people with an entry point into the labour market and supply enterprises with skilled workers.

Building on the analysis of national apprenticeship systems with a special focus on advanced manufacturing (Eurofound, 2018a), this report summarises the results of 14 case studies of good practices in the manufacturing sector in five EU Member States (Denmark, France, Germany, Ireland and Italy) and two countries outside Europe (Australia and the United States).

Selected against a common set of selection criteria, case studies focused on practices that aim at adjusting apprenticeship programmes and/or manufacturing practices in response to challenges emerging from advanced manufacturing technologies and related changes and requirements.

The 14 case studies were selected on the basis of their links to at least one out of four pre-defined selection criteria: a) modernisation of a specific occupation; b) creation of new occupations/emerging occupations; c) creation of company apprenticeship/training programmes; d) organisation of apprenticeships/training in (regional) clusters. Beyond that, the main entry criterion was to have strong links to advanced manufacturing technologies. Furthermore, all case studies were selected from a long list of good practice cases that was elaborated as a result of interviews and exchanges with stakeholders and VET experts nationwide.

The report looks into contextual factors, drivers and reasons to implement changes concerning initial and higher apprenticeship/VET programmes in manufacturing, as well as specific objectives and intended results, target groups, scopes of practice and relationships with regional and national VET and/or industrial policy programmes and initiatives. The report also highlights lessons learned, outcomes and impacts on the companies involved, regional production systems and apprenticeship training. Finally, the report draws conclusions concerning crucial success factors and the adjustment of apprenticeship training in light of advanced manufacturing.

As a postscript to the report, a reflection of the case study results has been included in light of the Council Recommendation for a European Framework for Quality and Effective Apprenticeships that was adopted after the completion of the research in March 2018.[1]

Policy context

Apprenticeship training and industrial policy in the age of advanced technologies have been addressed by various EU initiatives. As mentioned above, the Council Recommendation for a European Framework for Quality and Effective Apprenticeships was adopted in March 2018. This initiative is linked to the New Skills Agenda for Europe launched in 2016, and also relates to the right to quality and inclusive education, training and lifelong learning as defined in the European Pillar of Social Rights. The European framework builds on previous activities, namely the European Alliance for Apprenticeships (EAfA) launched in 2013. The Commission is also to launch demand-driven apprenticeship support services to facilitate the introduction, reform and improvement of apprenticeship systems. The official launch took place on 8 November 2018 in Vienna as part of the third European Vocational Skills Week, celebrating the five years of EAfA. The close links between industrial competitiveness, advanced technologies and digitisation of the economy on the one hand, and high-quality initial vocational education and training (IVET) on the other, was highlighted in the Commission's Communication on the Digital Education Action Plan adopted in January 2018, which emphasised the need to foster investments in skills and talent development in order to support a successful transition from traditional to advanced manufacturing.

Key findings

- Whereas all 14 case studies have strong links to advanced manufacturing and the dual pathway of apprenticeship, their specific focus, scope and objectives vary significantly. This variety is largely driven by regional and national contextual factors and respective challenges of apprenticeship training facing the seven countries. For example, national contexts vary between countries such as Denmark and Germany, in which dual apprenticeship is the dominant form of IVET, to countries such as the US, where apprenticeship training still is a minor VET pathway and apprenticeship practice is mainly company- and industry-driven.
- Despite this variety of national apprenticeship contexts, a number of similarities concerning major motivation and drivers to initiate practices at national, regional, local or company level exist. First, in all cases, apprenticeship training in manufacturing occupations is facing similar requirements and challenges concerning adjustments of curricula, modernisation of courses and programmes resulting from new disruptive technologies and respective requirements regarding skills, competencies and qualifications. Additional motivations and objectives relate to apprenticeship as an attractive pathway

1 The European Council adopted the Recommendation on 5 March 2018.

of VET in the manufacturing sector, links and more flexible pathways to higher education and career progression or improvements in the quality and efficacy of apprenticeship training to guarantee the provision of highly qualified personnel for the company and/or the local/regional labour market.

- Against a background of new requirements stemming from advanced manufacturing technologies and the need to master them, and because dual apprenticeship competes increasingly with academic pathways, the majority of cases have totally or partly addressed 'higher' apprenticeship or 'higher' VET programmes leading to a qualification standard of European Qualifications Framework (EQF) Level 6 or higher.
- Many of the higher VET programmes have been initiated solely by or with strong involvement from single large companies, thereby indicating new needs at company level resulting from advanced manufacturing technologies, processes or materials as well as new skills and competency requirements in managerial positions.
- In contrast, the focus of IVET programmes described in the case studies has been on modernising, complementing or extending existing occupational apprenticeship schemes. Apart from Ireland, where the development of a new initial apprenticeship programme is related to a reform aiming at the overall expansion of apprenticeship training, the focus of good practices clearly has been on adjustments, innovations and improvements that also aim to address general challenges facing the national apprenticeship systems.
- Apart from the two smaller countries in the sample covered by this study, an important result of the case study research relates to local and regional contextual factors. In particular, in Germany, France and Italy, proactive local and regional industrial policies aiming at strengthening the new technologies and the competitiveness and innovativeness of the manufacturing sector or specific industry clusters have been key promoters of new initiatives and good practices of companies (or networks of companies) and VET education institutions. Such regional and local networks have been much weaker in the US and Australia where individual companies in close cooperation with VET institutions or higher education have been the main promoters of innovative and new practices.
- Though the case studies reflect general patterns of financing of apprenticeship training in the seven countries, a quite striking result of the analysis is that public financing plays a crucial role for new initiatives and programmes that go beyond single company practice. The generally weak role of public support in the two non-European countries is also reflected by the fact that the four cases analysed in the US and Australia have all been initiated and implemented by single companies.
- The case study research confirmed results of the analysis of national apprenticeship systems in the seven countries concerning the involvement and role of stakeholders, in particular when it comes to social partners. Particularly strong differences exist in relation to the involvement of trade unions and bodies representing workers at company level in the two German cases.
- With regard to key success factors of adjusting and modernising apprenticeship programmes and practices in the context of advanced manufacturing, the study has highlighted in particular the firm commitment of key actors involved, including the top management to invest in VET training and apprenticeship, collaboration and sharing responsibilities in a multilevel network (in particular relevant for the European countries), at least the backing and support of change and adjustment processes by social partners; supportive national and regional framework, including a sound and reliable provision of financial and non-financial support.

Introduction

Scope of the research

This report is part of the study entitled *Policy developments and practices of apprenticeships in selected EU Member States and world competing regions* carried out in five EU countries (Denmark, Germany, France, Ireland and Italy) and two non-EU countries (Australia and the United States – US). The study is conducted in the frame of the pilot project 'The Future of Manufacturing in Europe' (FOME), proposed by the European Parliament and delegated to Eurofound by the European Commission (DG Internal Market, Industry, Entrepreneurship and SMEs).

This report builds on a first phase of the study that analysed apprenticeship systems in the selected countries and reviewed changes to the current systems following labour market shifts, changes in employment, career and mobility patterns and technological and structural change. In addition, seven country reports and one comparative analytical report have been elaborated.

In contrast to the national analysis that was carried out from a top-down perspective, this report provides a bottom-up assessment. It builds on 14 case studies that researched national, regional and company-based practices of adjusting apprenticeship relating to advanced manufacturing.

Case study selection criteria and methodology

The 14 case studies have been selected based on quality and selection criteria. Key selection criteria for analysing practices of adjusting apprenticeship training in the seven focus countries were national good and 'leading edge' practices concerning the adjustment and modernisation of occupational profiles and programmes in response to various challenges in the context of advanced manufacturing. In order to assess how changes driven by advanced manufacturing technologies are reflected in the local adaptation of dual apprenticeship practices in advanced manufacturing and highly technological industries, all selected cases are related to the following different forms of adaptation of apprenticeship in response to advanced manufacturing:

- modernisation of a specific occupation
- creation of new occupations/emerging occupations
- creation of company apprenticeship/training programmes
- organisation of apprenticeships/training in (regional) clusters

Table 1 maps the final sample of case studies against these selection criteria.

Table 1: Case studies overview

Title or description	Focus of case study			
	a	b	c	d
Innovative practices at Airbus Operations in Hamburg – Germany (Eurofound, 2019b)			x	x
Modernisation of dual apprenticeship training at ABB – Germany (Eurofound, 2019c)			x	x
Talent Tracks for gifted industrial apprentices – Denmark (Eurofound, 2019d)	x			x
Knowledge centres for robot technology and automation – Denmark (Eurofound, 2019e)	x			
Jules Verne Manufacturing Academy – France (Eurofound, 2019f)			x	x
Job and Qualification Campus in transport – France (Eurofound, 2019g)				x
'New' apprenticeships in the light of technological change – Ireland (Eurofound, 2019h)		x		
Modernisation of a designated craft apprenticeship – Ireland (Eurofound, 2019i)	x			
Bosch Industry 4.0 Talent Program – Italy (Eurofound, 2019j)		x	x	
Higher Apprenticeship in Advanced Manufacturing – Italy (Eurofound, 2019k)	x	x	x	
Siemens higher apprenticeship pilot programme – Australia (Eurofound, 2019l)	x		x	
Varley Group: Modernising apprenticeships – Australia (Eurofound, 2019m)	x			x
Adjusting apprenticeship at Oberg Industries – United States (Eurofound, 2019n)	x		x	
Mechatronics Apprenticeship Program of Festo Didactic – United States (Eurofound, 2019o)		x	x	x

Structure of the report

From a comparative point of view, Chapter 1 outlines the wider regional, sectoral and other contextual factors of the 14 cases studies in the seven countries. This chapter also looks at the relevance of dual apprenticeship from the micro perspective, namely companies and local actors involved in the cases.

Chapter 2 presents a comparative overview of the adjustments, innovations and changes made in the context of the case studies. It describes drivers, reasons and objectives, intended outcomes and results as well as scope and target groups. Given the complexity of these aspects, the chapter includes a number of comparative overview tables and works with examples of practices taken from the case studies.

Chapter 3 considers lessons learned about major aspects examined in the research, from project design and planning, the involvement of different actors and financing, to implementation aspects, skills of the personnel involved and difficulties experienced during implementation of the practices.

From a comparative perspective, Chapter 4 summarises outcomes and impacts of the good practice cases analysed with a focus on company and region. It also discusses impacts concerning attractiveness of apprenticeships and describes major success factors that emerge from the study. The final chapter summarises the main conclusions from the research and highlights the policy implications for European VET policy. Also included after the final chapter is a reflection of the cases in light of the European Framework for Quality and Effective Apprenticeships.

1 Contextual factors

1.1 Regional, sectoral, company-specific and other contextual factors

All the 14 analysed cases have strong links to advanced manufacturing and new technologies and focus on the dual pathway of apprenticeship at both the company and VET school level. At the same time, factors concerning economic and sector-specific contexts as well as the company-specific set-ups differ significantly.

Whereas all cases are located in the manufacturing sector, the specific scope of the cases analysed in our study ranges from medium-sized and/or family-owned companies such as Oberg in the US (Eurofound, 2019n) or the Varley Group in Australia (Eurofound, 2019m) to global players with several thousands of employees worldwide such as Airbus or ABB. Against the focus of the research on advanced manufacturing, it is also not surprising that nearly half of the case studies have a direct or indirect link to key players in this field, such as Siemens (Eurofound, 2019l), Bosch (Eurofound, 2019h), Festo (Eurofound, 2019o), ABB (Eurofound, 2019c) and Prima Industrie (Eurofound, 2019k).

The case studies that do not focus on a specific company differ significantly as far as scope is concerned. They rank from activities targeting the whole country and the manufacturing sector, such as the modernisation programmes of apprenticeship training in the two Irish cases, the development of new components/pathways such as the 'Talent Tracks' case (Eurofound, 2019d) or the development of new types of VET school knowledge centres (Eurofound, 2019e) in Denmark. By contrast, the two French and the two Italian case studies are characterised by a strong regional embeddedness. All four cases are located in manufacturing regions hosting companies that, as of late 2018, face the need to apply and respond to new requirements in the context of advanced manufacturing technologies and processes, such as the French regions of Loire-Atlantique and the Valenciennes employment basin in the Hauts-de-France (Eurofound, 2019f, 2019g) and the Italian regions of Lombardy and Piedmont (Eurofound, 2019h, 2019i) which are amongst the top five regions in Italy with regard to (high-tech) manufacturing output, employment and innovation.

However, the regional context is very important in the other countries as well, as highlighted in the Australian case of Varley (Eurofound, 2019m), which is located and strongly rooted in the traditional industrial Hunter region in New South Wales. Moreover, Hamburg, hosting the largest single manufacturing site of Airbus Operations in Germany, is one of the three most important civil aircraft construction sites worldwide (see Box 1).

Box 1: The aviation cluster in the Metropolitan Region of Hamburg

Hamburg is one of the world's three most important civil aircraft construction sites, together with Airbus in Toulouse and Boeing in Seattle. Hamburg has profited from the boom of aviation and aircraft manufacturing: more than 40,000 highly qualified specialists work in the Hanseatic city in the civil aviation industry. In addition to the two industry giants (Airbus with more than 12,000 employees and Lufthansa Technik with around 9,000), more than 300 suppliers and various technological and scientific institutions contribute to the regional know-how of the aviation sector.

Source: *Eurofound (2019b)*

In contrast to the 10 EU cases, the four US and Australian cases illustrate a variety of contexts: two of them are largely driven by practices of non-US or Australian companies (Festo and Siemens) and thus are only loosely linked to the regional economic system of manufacturing and the regional education and training system. Though clearly linked to advanced manufacturing, the main purpose of the apprenticeship activities developed by Festo in the US (Eurofound, 2019o) and Siemens in Australia (Eurofound, 2019l) has been to satisfy their own demand for qualified workers. And where there are regional and sectoral factors that have an influence in the two Australian cases (namely the apprenticeship system), the same cannot be said for the US.

1.2 Relevance of dual apprenticeship

The national analysis of apprenticeship systems and practices has already illustrated the wide variety of VET context factors in the seven countries covered by our study. These differences also become evident in the 14 cases and their specific country-driven characteristics. The relevance of initial dual apprenticeship training ranges from very limited, as in the US (see Box 2), to being the predominant form of IVET in the case of Denmark and Germany.

Box 2: Apprenticeships in the US

The US is well behind other countries in creating apprenticeships at scale and in developing a well-structured apprenticeship system. Non-military apprenticeships that are registered with the state and/or federal government accommodate only about 0.24% of the workforce, about 9–10 times lower than the average for Australia, Canada and England. Although this figure understates US apprenticeships because some companies do not register their programmes with a government agency, these unregistered apprenticeships barely affect the conclusion that the US is well behind other countries. Moreover, while apprenticeships are quite widespread in manufacturing in many countries, the US manufacturing sector employs only about 7–8% of all official/registered apprenticeships. One reason is the unsystematic nature of the US apprenticeship system. The governance structure is complex, with the federal government as the registration body for half of the 50 states (plus the District of Columbia) and state agencies registering programmes in the other half. Funding for the administration of the system is negligible, with only one or two people in some large industrial states responsible for auditing, marketing to employers and registering programmes. The system lacks national or even regional occupational frameworks to guide employers and regulators as to what constitutes sufficient quality to become a registered apprenticeship programme. As a result, each firm or small group of firms must establish their own framework and sometimes spend months or years getting their programme registered.

Source: *Eurofound (2019o)*

To a great extent these national context factors also determine the experience of good practices. In the US, it already might be regarded as an incidence of good practice in VET when a company decides to invest in apprenticeship and even more so when the company develops its own programmes that are targeted to specific needs.

However, in the other countries, the case studies are related to specific challenges facing the respective apprenticeship systems. Though all cases are related to the apprenticeship programmes in the manufacturing sector, it has been quite striking that some good practices analysed (namely those in France and Denmark; see Box 3) are primarily about improving the attractiveness of the apprenticeship pathway. This is because the dual IVET system has generally been considered less attractive for young learners and faces a shortfall in candidate numbers.

Box 3: France and Denmark and the need to make dual IVET more attractive

In practice, the system of dual training (*alternance*) in general and the apprenticeship system in particular are not always optimal. In some industrial sectors, for instance in engineering, there is a lack of candidates because of the general negative image of the occupations in this sector.

The original project was initiated in response to the concerns of a number of enterprises in the advanced manufacturing sector, in particular that the pool of workers with high-level skills in areas like robotics, computerised numerical control (CNC) programming, multitasking machines and computer-aided design (CAD)/computer-aided manufacturing (CAM) was being steadily eroded due to an ageing workforce, and that the supply of new workers with specialist skills in these areas was therefore inadequate to meet the requirements of the enterprises.

Source: *Eurofound (2019d, 2019f)*

However, it should be noted here that France and Denmark are certainly not the only countries where manufacturing companies face a lack of (qualified) candidates and face increasing problems to fill all available apprenticeship places. As highlighted already in the comparative national analysis (Eurofound, 2018a), attractiveness and increased competition for qualified and motivated young talent is a challenge in all the countries analysed in this study. Moreover, initiatives to promote dual VET pathways have not only been reported in the French and Danish case studies but also, for example, in the German cases of ABB and Airbus.

As the share of people that start training with higher education qualifications has increased in all countries covered by our study, dual apprenticeship is increasingly seen as competing with academic pathways. Against this, 'higher' apprenticeship or 'higher VET' has also been promoted in many countries to improve the attractiveness of the dual apprenticeship pathway. This is also reflected in this study: eight out of the 14 cases are totally or partly about higher apprenticeship/higher VET programmes leading to a qualification standard of EQF Level 6 or higher, many of them developed from the very beginning, as Table 2 illustrates.

However, attractiveness has not been the only motivation to develop or improve higher VET and apprenticeship pathways. Such programmes also reflect the increasingly complex demands concerning competencies and skills

of workers and employees with managerial functions in advanced manufacturing, such as, for example:

- the new Digital Industry Trainee Human Resources (HR) programme at ABB Germany (Eurofound, 2019c)
- the new Level I Master's course Industrial Internet of Things (IoT) Specialist developed in the context of the 'Industry 4.0 Talent Program' in Lombardy
- the new Level II Master's course in Additive and Advanced Manufacturing and Industrial Automation, developed in Piedmont by Polytechnic University of Turin in collaboration with the high-tech company Prima Industrie
- the EQF Level 6 Manufacturing Engineer (ME) apprenticeship in Ireland

In addition, the new programmes developed in France (Eurofound, 2019f) and at the Job and Qualification Campus in transport (Eurofound, 2019g) aim to offer higher VET degrees or career pathways that are attractive to young talent who also have the option of selecting an academic programme with no on-the-job component.

Table 2: Links between cases and higher apprenticeship

Case	Links
Innovative practices at Airbus – Germany (Eurofound, 2019b)	Modernisation of the Aeronautical Technician programme (EQF Level 6)
Modernisation of dual apprenticeship training at ABB – Germany (Eurofound, 2019c)	New ABB trainee programme Digital Industry Trainee HR – candidates are required to have already completed a Master's degree (EQF Level 7)
Talent Tracks – Denmark (Eurofound, 2019d)	No, but the practice develops some form of higher-level VET within IVET programmes
Knowledge centres – Denmark (Eurofound, 2019e)	No
Jules Verne Manufacturing Academy – France (Eurofound, 2019f)	New higher qualification pathways and postgraduate degrees in engineering (EQF levels 6–8)
Job and Qualification Campus – France (Eurofound, 2019g)	New programmes offering technological diplomas, VET, Master's and engineering degrees (EQF levels 5–8)
'New' apprenticeships – Ireland (Eurofound, 2019h)	New higher VET pathway Manufacturing Engineer which leads to the academic degree of a Bachelor of Engineering (BEng) in Manufacturing (EQF Level 6)
Modernisation of designated craft – Ireland (Eurofound, 2019i)	No
Bosch Industry 4.0 Talent Program – Italy (Eurofound, 2019j)	New dual study programme Industrial IoT Specialist offered to engineering graduates – involves a postgraduate Level I Master's course corresponding to EQF Level 7
Higher Apprenticeship in Advanced Manufacturing – Italy (Eurofound, 2019k)	New Level II Master's course in Additive and Advanced Manufacturing and Industrial Automation (EQF Level 8)
Siemens higher apprenticeship pilot programme – Australia (Eurofound, 2019l)	Higher dual VET programme on Advanced Manufacturing leading to Bachelor of Applied Technologies (EQF Level 6)
Varley Group: Modernising apprenticeships – Australia (Eurofound, 2019m)	No
Adjusting apprenticeship at Oberg Industries – United States (Eurofound, 2019n)	No
Mechatronics Apprenticeship Program of Festo Didactic – United States (Eurofound, 2019o)	No

Source: *Authors, based on the case study reports elaborated in the context of the study*

It should also be noted that the case studies provide no evidence that the demand for workers with higher VET degrees has increased more rapidly than the demand for IVET qualifications. Though recent national data have indicated a strong growth in higher VET programmes, it would be wrong to conclude that the traditional initial apprenticeship programmes have become less relevant. This is illustrated by the number of people taking up professional apprenticeships (Level I) and higher education and research apprenticeships (Level III) which lead to nationally recognised qualifications. In Lombardy, as documented in the case study report (Eurofound, 2019j), both types of apprenticeship have increased significantly, in particular from 2015 to 2017, but Level I apprenticeship enrolments have increased much more rapidly than Level III courses.

2 Adjustment, innovation and invention: Good practices of adjusting apprenticeship in advanced manufacturing

2.1 Key drivers and reasons for change in apprenticeship practice

2.1.1 Adjustment across countries and cases

There are a number of similarities between the good practices analysed in this study when it comes to drivers and reasons to adjust apprenticeship programmes, occupational curricula and learning environments in response to new skills and competency requirements stemming from advanced manufacturing. In contrast to the more systemic aspects (concerning the regulation of VET systems, number of occupations, roles and responsibilities of different actors involved in the system, financing, etc.) these similarities are quite striking.

According to a VET research and training institution interviewed for this study, the disruptive technologies that most affect advanced manufacturing are additive manufacturing, artificial intelligence, collaborative robotics and industrial automation. With regard to skills and occupations, the engineering professions are closely involved in technological change from design and exploitation to maintenance and safety services.

As highlighted by one company-level interview partner in Germany, the following needs and requirements are related to advanced manufacturing as regards initial and further training contents.

- Occupational profiles have to be examined and adjusted both at company level (reflecting sector- and company-specific requirements) and also at the level of general/national framework plans and occupational profiles.
- Both in-company and school-based VET have to focus on competencies as these are becoming more important in the context of advanced manufacturing, digitalisation and 'Industry 4.0'.
- Thus, the VET school parts of apprenticeship training also have to be adjusted, including the qualification of VET school teachers and trainers.

Similarly, according to a VET expert in Italy, the challenges introduced by changes in technologies in manufacturing sectors and the development of advanced manufacturing should also be addressed by companies. This can be done by building skills and defining professional development that combine specialist technical dimensions with managerial and organisational skills designed to integrate the design and development of a product or a technology into the whole value chain. The interview partner stressed that, at the current 'exploratory phase' of implementation of new advanced production technologies, there is a need for a '360-degree vision' that establishes a set of skills and competencies that companies need most. It is therefore a matter of defining no single technical or specialist skills but a mindset that interprets the concept of 'Industry 4.0' as an approach that concerns both production and interaction with the various dimensions of the market.

Referring to disruptive technologies such as 3D printing, virtual reality glasses, wearable computers, glasses, gloves or clothes, collaborative robotics and digital devices such as tablets, smartphones and computers, interview partners highlighted that having or developing the skills to manage these new digital tools in production processes is only one part of the adjustment process. What is also required, and what is more demanding, in a growing number of occupations – not just the traditional IT-related ones – are new competencies such as problem solving, autonomous learning, coding, modelling, technical mathematical thinking and algorithmic problem solving.

As highlighted by a French VET institution, advanced technologies and new production methods also have a significant impact on traditional industrial occupations and tasks. These are the engineering work processes that today require new skills due to new automated processes, such as cobotic welding, innovative metal machining or non-destructive testing of the quality of machined products. Collaborative robotics that is used in welding, for example, demands new skills of professional workers that otherwise have little contact with advanced technologies in their daily lives. Another example is sensors that measure the degradation of machines and tools and require new skills of workers in reading and understanding the measurements. More generally, the digitalisation of factories requires adapting the skills of a large number of workers and technicians.

Thus, company-level interviewees in particular in all case studies reinforced a result described in the national reports of this study. Rather than inventing totally new occupational profiles (in particular at the level of initial apprenticeship), the real challenge is to adjust existing occupational programmes that are relevant for advanced manufacturing and modernise VET training practice and 'cultures' inside and outside the company.

As stressed by company-level actors in particular, the digital transformation process in manufacturing requires a comprehensive adjustment of skills and competencies,

not only in the field of production-related occupations and work but also in commercial work (for example accounting, sourcing, sales, HR).

With regard to skills that will be required by apprentices and indeed all workers to collaborate across boundaries, the ABB Training Centre Berlin has conducted a project designed to develop a qualification concept for supplementary 'transversal' digital competencies (see Box 4). As a result of this comprehensive research, 36 knowledge and competency items were identified as being highly relevant in manufacturing and clustered into five groups:

- basic competencies concerning digitalisation (technical drivers, digital society)
- learning and working in the digital world (learning with digital media, digital-driven knowledge management, knowledge transfer)
- information and communications technology (ICT) competency (hardware, software)
- handling data (data security, data protection, data analysis and evaluation)
- systems and processes (work processes, added value, cross-company processes/networking)

Box 4: Advanced manufacturing impacts on all production-related occupations

In 2017, ABB Germany had about 730 apprentices (including dual students with an employment contract) of which about one-quarter were female apprentices (most of them in commercial apprenticeship occupations). Half of all apprentices were in a programme of IVET in technical occupations, around 14% were in an apprenticeship in commercial occupations and 36% of all apprentices were dual students at the Dual University of Applied Science or Master's students; most dual students were in courses leading to a Bachelor of Engineering (BEng). The most important occupational programmes, in the field of initial dual VET, were Mechatronics (91 apprentices in 2017), followed by Electrician in Industrial Maintenance (54) and Industrial Mechanics (49). Recently there has also been significant demand for dual students: in 2017, the dual programme leading to a BEng Electronics Technology was the top apprenticeship programme at ABB Germany (94 apprentices) and the Bachelor of Arts in Industry (40) was amongst the top five.

Source: *Eurofound (2019c)*

2.1.2 New occupational profiles mainly in further and higher VET

In the field of initial apprenticeship programmes, only in Ireland with its manufacturing technician (MT) can an example be seen of the development of a new occupational profile; the focus of practices was more on the adjustment of existing programmes and the inclusion of additional skills and competencies. There are a number of examples of new occupational profiles in higher VET or higher apprenticeship and the acquisition of additional specialised qualifications.

Examples here are the higher apprenticeship programme of Industrial IoT Specialist in Lombardy in Italy in the context of the Bosch 'Industry 4.0 Talent Program' and the establishment of Level II Master's courses in Industrial Automation at Polytechnic University of Turin in collaboration with regional high-tech companies such as Prima Industrie (see Box 5).

Box 5: Developing Master's courses addressing advanced technologies in Piedmont, Italy

The main motivation driving the activation of higher apprenticeship was the local industrial manufacturers' need for highly specialised personnel. In fact, traditional higher education courses are considered to be rather rigid in terms of educational planning and scheduling, unable to train workers to meet companies' needs, especially concerning technological advancements and transformations. Prima Industrie first collaborated with Polytechnic University of Turin in 2016 in the context of a Master's course in Industrial Automation. The motivation concerned the need for highly specialised personnel that could deal with the drivers of technological change, in particular the development of innovative trajectories in laser technologies which by then had reached a state of industrial maturation. In the same year, Prima Industrie also established the first Master's course in Additive Manufacturing, together with five other companies in the Turin area. In 2017, the course in Industrial Automation evolved into a new Master's in Manufacturing 4.0, with participation from six partner companies, including Prima Industrie.

Source: *Eurofound (2019k)*

The Italian example illustrates that higher VET courses seem better able to satisfy new requirements that are emerging from advanced manufacturing technologies and applications. Being much more specialised, they should be regarded as complementary and specialised qualifications that are offered to candidates who already have an initial vocational qualification.

In addition, in Germany, advanced manufacturing and new technologies have resulted in the development of new dual study courses leading to Bachelor or Master's degrees (see Box 6). The aviation cluster in Hamburg in particular has been quite active through collaboration of the various companies and universities in fields such as new materials, cabin design or additive manufacturing.

Box 6: Advanced manufacturing and dual study courses at Airbus Operations, Germany

Airbus Operations in Germany offers dual study courses in a wide variety of specialisations, reflecting the increasing need for highly qualified specialists mastering advanced technologies.

Bachelor of Engineering: There are 25 different dual study courses on offer in various fields, including: electronics technology; IT; communications technology; manufacturing systems engineering; laser and optotechnology; manufacturing technology and quality management; aeronautics technology; aeronautics systems manufacturing; aircraft construction, design and development; mechatronic systems engineering; cabin and cabin system technologies; lightweight construction and composite materials. Airbus also offers dual courses in industrial engineering with different specialisations.

Bachelor of Science: Airbus also offers 10 or more Bachelor of Science dual study courses in fields such as informatics; applied informatics; economic informatics; mobile informatics; network and software technologies; IT security; engineering defence systems; informatics engineering; production technology and management.

Source: *Eurofound (2019b)*

The Danish development and integration of 'Talent Tracks' (Eurofound, 2019d) into the IVET system can also be regarded as an example of 'higher apprenticeship', designed to raise standards and add content (for example advanced technologies such as 3D printing or robotics) for the most capable learners. However, it is not formally recognised as an example of 'higher VET', and so the qualification remains at EQF Level 5.

Other examples of higher apprenticeship/VET and the acquisition of additional specialised qualifications are found in Siemens Australia's 'higher apprenticeship pilot programme' on advanced manufacturing or Festo Didactic in the US that has developed an advanced manufacturing programme to train advanced technical skills in mechatronics. It should be noted that, in both cases, the main motivation behind the programmes is the companies' need for qualified personnel in a context where the national VET/apprenticeship system is deemed inadequate.

2.1.3 Other drivers and reasons for change

In France, Ireland and Denmark, good practices of initial apprenticeship training and further qualification have also been developed in response to weaknesses of the general apprenticeship training system in manufacturing, including a lack of attractiveness for young people and, in Ireland, a lack of suitable apprenticeship programmes.

In Denmark, a comprehensive VET reform in 2014 initiated a process of modernising the VET system, in particular the VET school infrastructure, and introduced new elements designed to make the system more attractive overall and reduce the high drop-out rates (see Box 7). 'Talent Tracks' was introduced to increase the retention rate, and Centres of Excellence (equipped with the latest technologies like the two Knowledge centres for robot technologies and automation) were established to improve the quality of learning. Both of these were initiated by the modernisation and improvements introduced in the 2014 reform. As highlighted in the Danish case study report, the Knowledge centres represent a response to rapid technological development which threatens to make elements of VET provision obsolete as individual vocational schools struggle to contain investment in new technology within their budgets.

Box 7: Denmark: Need to make apprenticeship attractive for 'gifted learners'

Over the past two decades, recruitment for IVET in Denmark has struggled to attract entrants. Gifted learners tend to favour upper secondary general education over VET due to the generally low opinion young people and their parents have of it. In addition, IVET has suffered from high drop-out rates – also amongst gifted learners – where at present only about half of those who enrol in an IVET programme actually complete it and obtain a qualification. Combined with an ageing workforce, where large numbers of skilled workers will reach retirement age in the coming years, companies in the advanced production sector in particular are worried about the availability of skilled workers in the future.

Source: *Eurofound (2019d)*

The French cases analysed in this study have some similarities to the Danish motivation to establish Knowledge centres to attract apprentices and provide further training and qualifications. However, in contrast to the Danish example, the French cases are strongly embedded in specific regional industrial environments (the Loire-Atlantique in the west of France and the Hauts-de-France in the north).

Both cases are related to advanced manufacturing technologies and aim to provide high-quality training and to improve the attractiveness of initial and higher apprenticeships in manufacturing (see Box 8).

Box 8: New approaches to apprenticeship training in advanced manufacturing in France

In 2015, the Technological Research Institute (IRT) launched the Jules Verne Manufacturing Academy (JVMA). It aims to train apprentices in advanced technologies from 2019 onwards. The school will have a capacity of 1,000 training places, half of which will be reserved for apprentices from local schools and the other half for students pursuing university curricula. The school aims to pool the technological equipment of the high-level IRT with a dozen dual training institutions. These institutions will be able to relocate their training within this school to benefit from its technological equipment. The new school and collaboration with the IRT and training institutions aim to improve the attractiveness of occupations within manufacturing.

Job and Qualification Campus (*Le Campus des métiers et qualifications*) is a national label awarded to secondary and higher education institutions that provide either initial or continuous training. These campuses form part of a national policy initiated by the Ministry of Education in 2013. Their aim is to improve the coordination between training offer and demand, and to adapt vocational training to the needs of companies. In practice, each campus targets a specific economic sector, generally at the level of an employment area. So far, 78 campuses have been launched in France, amongst them the Campus of the Rail and Automobile Industry (*FIAEM Campus* or *Campus des métiers et des qualifications du Ferroviaire, de l'Industrie Automobile et de l'Ecomobilité*) in the Hauts-de-France region that has been analysed in the context of this study. One of the main reasons for establishing this campus is to better link secondary education, apprenticeship, higher education and research. This should improve the attractiveness of apprenticeships amongst young people.

Source: *Eurofound (2019f, 2019g)*

Finally, the two case studies in Ireland are set in the specific contextual situation of a reform of the whole VET system. Following a comprehensive review process, the Irish government adopted a strategy to expand apprenticeships into new occupations in order to increase the overall number of occupation-specific apprenticeships. The expansion would be based on recommendations of employer-led consortia identifying occupations that are considered suitable for apprenticeship training (Department of Education and Skills, 2013). In manufacturing, two of these new apprenticeships (MT and ME) are closely linked and share the same curricula in the first two years. In Year 3, the curriculum is specific to MEs and opens a pathway towards 'higher' apprenticeship; after successful completion, MEs obtain a BEng in Manufacturing (Apprenticeship), an Irish NFQ Level 7 (EQF Level 6).

2.2 Objectives, expected results, target groups and scope of the practices analysed

The 14 cases differ significantly with regard to specific objectives, expected results, target groups and scopes. However, there are also similarities and common aspects that reflect challenges of the VET system and apprenticeship practices, both inside and outside the company. These aspects are highlighted briefly in the following section, based on synoptic tables.

2.2.1 Objectives and expected results

As Table 3 shows, practices analysed in this study range from very focused practices with specific objectives and goals (for example the 'Talent Tracks' programme in Denmark or the two Irish cases of developing new or modernising single apprenticeships) to more comprehensive activities that pursue a range of different objectives as in the two German cases or the French 'Job and Qualification Campus' that address different modes of transport (Eurofound, 2019g).

There are a number of similarities in objectives and expected results related to common challenges facing at least some countries, and these have been identified in the comparative national analysis (see Eurofound, 2018a).

Attractiveness and retention of apprenticeships in manufacturing: A number of practices in Germany, Denmark, France and Ireland (see Eurofound, 2019b, 2019d, 2019g, 2019i), as well as all four cases in Australia and the US, aim at making an apprenticeship in manufacturing more attractive, including for capable learners who may also be considering academic options. As described in the German and French case studies, increasing attractiveness of apprenticeship training will not be achieved by a single tool but by a bundle of measures that include, for example, new ways of learning, easing the transition into higher VET or apprenticeship courses and schools that have the latest technological equipment, technologies and pedagogical methods.

Improving the infrastructure and quality of VET schools and the skills of teaching personnel: These are objectives and expected outcomes of the majority of practices analysed in our study, seen in the cases of the ABB Training Centre Berlin (Eurofound, 2019c), the Hamburg Centre of Aviation Training or the Airbus Learning Factory (Eurofound, 2019b), the 'Knowledge centres for robot technology and automation' (Eurofound, 2019e), the JVMA (Eurofound, 2019f) and the 'Job and Qualification Campus' in the transport equipment sector (Eurofound, 2019g).

Improving and strengthening collaboration between companies, education, VET schools and VET research: As highlighted in the respective case studies, this objective is particularly relevant for those countries where collaboration has not worked well so far (late 2018), namely France, Italy, the US (generally) and Australia (in advanced manufacturing). The objective to foster collaboration between VET schools has also been highlighted in the Danish 'Talent Tracks' case (Eurofound, 2019d).

Table 3: Objectives and expected results

Case	Primary objective(s)/intended results	Further objectives and intended results
Innovative practices at Airbus – Germany (Eurofound, 2019b)	Prepare workers for technological change and new forms of working and learning in the context of 'Industry 4.0 – Factory of the Future Program' at Airbus Adjusting existing initial and further training programmes in aviation-related occupations in the Hamburg Aviation Cluster	Awareness raising of workers and management representatives Initiating pilot projects in fields of IVET, apprenticeship training and further qualifications Active integration and participation of employee interests in the process by own and collaborative projects with management Modernising existing and developing new higher VET and further qualification programmes/profiles (Hamburg Aviation Cluster) Retaining the competitiveness of the aviation cluster and extending global leadership with regard to specific skills and competencies
Modernisation of dual apprenticeship training at ABB – Germany (Eurofound, 2019c)	Adjusting apprenticeship, IVET and further VET provision at ABB in light of digitalisation and advanced manufacturing	Measures of awareness raising and implementing a new learning culture Modernisation of the ABB Training Centre Adjusting existing initial occupational apprenticeship programmes (in-company part) Developing 'Supplementary Qualifications for Digital Competencies' New higher VET trainee programme 'Digital Industry Trainee'
Talent Tracks – Denmark (Eurofound, 2019d)	Making apprenticeship more attractive for higher achievers	Increase retention rates Stimulate collaboration between regional VET schools and institutions
Knowledge centres – Denmark (Eurofound, 2019e)	Provide companies with new recruits trained in the latest methods and to the highest standards	Integrate new technologies in teaching at VET schools Develop and disseminate new learning and teaching methods Support VET teachers Develop and disseminate new learning and teaching methods Engage in collaborative projects with higher education institutions
Jules Verne Manufacturing Academy – France (Eurofound, 2019f)	Establish a VET school offering a broad range of occupational diplomas at initial and higher level that is based on high standards of technological equipment, learning and teaching methods	Strengthen collaboration between initial and further VET practice, VET intelligence/research institutions and business interests Develop skills to master advanced technologies, improve the competitiveness of local industry and create new business activities in the region
Job and Qualification Campus – France (Eurofound, 2019g)	Foster collaboration between regional companies, research centres and the education/VET system to improve the quality of training provision in initial and higher apprenticeships and VET in an industrial sector (transport)	Better articulation between schools and companies regarding school-to-work transitions and adjusting of training programmes Improve the quality of training at EQF Level 5 and complement it with higher education courses suitable for regional manufacturing companies in the different modes of transport Improve the attractiveness of industrial training apprenticeships and reduce drop-out rates

(*Continued*)

Table 3: Continued

Case	Primary objective(s)/intended results	Further objectives and intended results
		Reduce high drop-out rates from the regional/local VET system and improve the provision of well-qualified recruits to manufacturing companies Improve the skills and competencies of teachers in education and the VET system as regards new technologies and their application in the transport sector
'New' apprenticeships – Ireland (Eurofound, 2019h)	Develop a new occupational profile and apprenticeship pathway for MTs and MEs that reflects new skills requirements within advanced manufacturing	Improve competitiveness in the Irish manufacturing sector by providing companies with well-qualified recruits and workers Engage in collaborative projects with higher education institutions
Modernisation of designated craft – Ireland (Eurofound, 2019i)	Modernisation of Mechanical Automation and Maintenance Fitting that reflects new skills requirements within advanced manufacturing	Increase the supply of qualified tradespersons in sectors that are critical to manufacturing
Bosch Industry 4.0 Talent Program – Italy (Eurofound, 2019j)	Improve and foster the acquisition of skills and competencies of talented Bosch apprentices (future team leaders) in industrial automation, digitalisation and Industry 4.0	Strengthen the capacities and competencies of Bosch to implement Industry 4.0 projects in Italy
Higher Apprenticeship in Advanced Manufacturing – Italy (Eurofound, 2019k)	Develop new further training/higher apprenticeship pathways for workers in regional companies that provide skills and competencies for mastering advanced manufacturing technologies and new processes beyond the daily work routine	Strengthen the local industrial production system by improving contacts and networking amongst regional companies, VET institutions and higher education in the field of engineering
Siemens higher apprenticeship pilot programme – Australia (Eurofound, 2019l)	Establish a higher-level apprenticeship at diploma or associate degree level that meets the higher skills level demanded by advanced manufacturing and Industry 4.0	Support the regional advanced manufacturing industry (Siemens Australia and other companies in the Siemens supply chain)
Varley Group: Modernising apprenticeships – Australia (Eurofound, 2019m)	Develop a more multiskilled workforce for the company	Increase the ability to respond more quickly and effectively to new market demands Increase collaboration with schools, raise awareness and improve attractiveness of manufacturing apprenticeships
Adjusting apprenticeship at Oberg Industries – United States (Eurofound, 2019n)	Adjusting the company's in-house apprenticeship programmes in light of technical change and advanced manufacturing methods	Retaining the competitive advantage of the company which is essentially based on the quality of staff/apprenticeship programmes (the latter also opening up career paths into management and leader positions) Increase collaboration with high schools and community colleges to attract future applicants to apprenticeships and improve teaching methods
Mechatronics Apprenticeship Program of Festo Didactic – United States (Eurofound, 2019o)	Guarantee a highly qualified in-house workforce equipped with the right skills and competencies	Establish in-company career paths starting from initial apprenticeship to higher-level management positions

Source: *Authors, based on the case study reports elaborated in the context of the study*

Ease transition pathways and adjust existing pathways of higher VET and apprenticeship: This objective must be regarded as a further 'meta-theme' that characterises most of the good practices analysed in the case study research. As discussed earlier, the primary objective of the majority of the good practice cases is to develop and/or adjust higher VET and/or apprenticeship programmes, including the availability of access for upward pathways.

Strengthen the competitiveness and innovation capacity of advanced manufacturing production systems: Most cases in EU countries (all but Ireland) are linked to an identifiably proactive industrial policy

implemented by public authorities, often in collaboration with business organisations, social partners (Denmark, Germany, Italy) and companies. These cases (namely the Danish 'Knowledge centres for robot technology and automation', the Airbus Operations in Germany, and the two French and Italian cases) all aim to ultimately strengthen the competitiveness and innovativeness of the manufacturing sector by fostering a transition towards advanced manufacturing and specialisation, especially for the rail and automobile sector in Hauts-de-France and aviation in Hamburg.

The two Italian cases and the case of ABB illustrate that modern and innovative apprenticeship programmes are regarded as investments in the competitiveness of regional production and innovation systems. In these cases, the tactic of addressing not only the larger regional advanced manufacturers but also providing support for their suppliers (often SMEs) is noteworthy. The recently modernised and refurbished ABB Training Centre (AZB) in Berlin is a good example of collaborative training (*Verbundausbildung)* which matches the real needs of regional manufacturing SMEs. In October 2018, only 5% of a total of 800 apprentices were employed by ABB; 95% were apprentices from 140 collaborating firms.

Figure 1: ABB Training Centre Berlin – Network companies

Source: *ABB*

Providing companies with recruits that match their skills requirements: The extension of the Irish apprenticeship system (Eurofound, 2019h), the modernisation of manufacturing-related occupational programmes (Eurofound, 2019i) and the US and Australian practice cases should be seen against a background of increasing difficulties in finding recruits that match the skills requirements of manufacturing firms using advanced technologies. Thus, the practices analysed in our study are strongly driven by this objective and, in the case of the US (Eurofound 2019n, 2019o) and Varley Group in Australia (Eurofound, 2019m), are driven by single companies. It should also be stressed that in all three countries apprenticeship is regarded by the companies involved as the best way to develop a highly qualified and skilled workforce. Moreover, apprenticeship programmes in US manufacturing are shaped and adjusted by the companies themselves, given the fragmentary nature of the national apprenticeship and VET system.

2.2.2 Target groups

Table 4 highlights the different target groups that are addressed by the various practices analysed by the case studies. All courses target apprentices (including potential candidates). Furthermore, the practices that focus on the development/adjustment of higher apprenticeship/VET programmes also address students in higher education that may be linked to companies participating in the respective programme by an apprenticeship contract.

Although the target groups reflect the relatively broad character of the practices analysed (which also explains the multiple target groups of the two German cases), three aspects of the comparative evaluation are striking.

First, one would expect that for all those practices focusing on the adjustment and modernisation of initial apprenticeships, VET schools and in-company training personnel represent important target groups. However, this is not always the situation.

Second, in practices where new pathways of higher apprenticeship/VET in advanced manufacturing have been developed, one would expect that management and HR supervisors would also represent a target group. However, apart from the two German cases, this has only been highlighted in the 'Siemens higher apprenticeship pilot programme' Australian case.

Table 4: Target groups

Case	Apprentices	Students in higher education	Workers/ employees	Management	In-company trainers	VET school personnel
Innovative practices at Airbus – Germany (Eurofound, 2019b)	x	x	x	x	x	x
Modernisation of dual apprenticeship training at ABB – Germany (Eurofound, 2019c)	x	x	x	x	x	x
Talent Tracks – Denmark (Eurofound, 2019d)	x					x
Knowledge centres – Denmark (Eurofound, 2019e)	x				x	x
Jules Verne Manufacturing Academy – France (Eurofound, 2019f)	x	x				x
Job and Qualification Campus – France (Eurofound, 2019g)	x	x				
'New' apprenticeships – Ireland (Eurofound, 2019h)	x				x	x
Modernisation of designated craft – Ireland (Eurofound, 2019i)	x				x	x
Bosch Industry 4.0 Talent Program – Italy (Eurofound, 2019j)	x	x				
Higher Apprenticeship in Advanced Manufacturing – Italy (Eurofound, 2019k)	x	x				
Siemens higher apprenticeship pilot programme – Australia (Eurofound, 2019l)	x	x		x	x	x
Varley Group: Modernising apprenticeships – Australia (Eurofound, 2019m)	x					
Adjusting apprenticeship at Oberg Industries – United States (Eurofound, 2019n)	x					
Mechatronics Apprenticeship Program of Festo Didactic – United States (Eurofound, 2019o)	x				x	x

Source: *Authors, based on the case study reports elaborated in the context of the study*

Third, workers and employees together represent a target group. ABB and Airbus Operations in Germany are the only practices in our sample where workers (including older ones) are targeted by activities of awareness building, further training and qualification measures. Practices in this context are the 'Supplementary Qualifications for Digital Competencies in Initial and Further Training,' which targets not only apprentices but also VET personnel and qualified workers, that has been developed by the ABB Training Centre Berlin, or the projects that were developed jointly in 2017 by the Airbus Germany management and the company works council (namely the project of mapping and awareness-raising activities in all Airbus sites in Germany in the context of the 'Company Map Industry 4.0') (see Box 9). Another example would be the MT apprenticeship in Ireland (Eurofound, 2019h) where the majority of apprentices, whether by design or by chance, are older and already employed.

Box 9: Implementing Industry 4.0 and advanced manufacturing needs to address all workers and employees

ABB Germany, both as a driver of advanced manufacturing technologies and processes as well as an applicant of such technologies and processes, needs to adjust corporate practices in five broad fields of action: competencies, initial and further education and training, working environment, working time and places of work, and leadership. According to the head of HR, it is important to address all these strategic fields of practice in an integrated rather than an isolated way. Therefore, activities of awareness building amongst management and executive staff at all levels as regards digitalisation and Industry 4.0 have been an important focus of HR activities in recent years. Awareness workshops, knowledge transfer about advanced technologies and the development of analytical tools for identifying new requirements at the individual workplace/working environment have been conducted throughout the company.

Source: *Eurofound (2019c)*

2.2.3 Scope

It is evident from the previous section of this report that the scope of the practices analysed in the study varies significantly. It ranges from improving apprenticeship training for in-company apprentices in medium-sized companies (Oberg in the US, Varley in Australia) and a higher apprenticeship programme for only a few students (the Bosch Industry 4.0 Talent Program in Italy) to initiatives that cover (at least potentially) the entire advanced manufacturing sector in a country ('Talent Tracks' in Denmark). The scope also differs because some practices are quite narrow – modernising or inventing a single apprenticeship programme or profile – while others combine multiple activities, as in the German case studies.

As far as both ABB and Airbus are concerned, the modernisation and adjustment of apprenticeship training for advanced management is implemented on the management site not by site-specific HR and training departments but at the highest national HR management level. In both companies, these posts have been established to initiate, coordinate and manage comprehensive HR adjustment processes comprising many individual projects, including in the field of apprenticeship training (see Box 10).

Box 10: Implementing adjustment of apprenticeship training as a part of comprehensive HR reorientation in the context of advanced manufacturing

At the global group level, Airbus launched the project 'Industry 4.0 – Factory of the Future in the Aviation Business' in 2014. The initiative was implemented at the transnational level and across all Airbus divisions. It reflects the specificity of the aviation industry and the current situation of Airbus: it is struggling to keep up with strong and increasing demand. As highlighted by one interview partner, if Airbus were to stop selling new aircraft today, it would still take the company a good 10 years to deliver on its existing order book. As a result, Airbus must remain focused on its core business – manufacturing aircraft – but identify news ways of reengineering the way it manufactures aircraft in order to keep pace with technological change and new advanced manufacturing technologies and processes.

In Germany, national projects under the Industry 4.0 initiative are developed and bundled under the umbrella of 'Human Relations 4.0'. Airbus Germany launched HR 4.0 in January 2017 to complement the Factory of the Future project in the field of work and qualifications. According to the project manager and head of project activities, the key objectives are to analyse and learn more about the impact of advanced technologies and Industry 4.0 on employment and work, and to identify challenges and opportunities for workers at Airbus as early as possible and to assess how this should translate in terms of adjusting VET contents in initial as well as further qualification and skills development.

Airbus workers and their representation bodies (works council, metalworkers' trade union) are integrated in HR 4.0 projects. A framework agreement on the implementation of the HR 4.0 projects, including on joint interests and operational collaboration, was signed in 2017.

Source: *Eurofound (2019b)*

2.3 Links to regional and national programmes and initiatives in dual VET and industrial policy

As Table 5 shows, there is wide variety in the links between the 14 cases and regional and national public policy programmes fostering advanced manufacturing industrial policies and adjustments in the VET system. What is notable is that in the three EU countries with a strong regional/federal government (France, Germany, Italy) a number of industrial policy initiatives and (in Germany in particular) regional VET modernisation policies exist, including policies targeting specific sectors such as aviation in Hamburg. It should also be noted that in these three countries, regions in which case studies are located (Lombardy in Italy, Pays de la Loire in France and Baden-Württemberg in Germany) are partners in the European Vanguard Initiative (see Box 11). In particular, Lombardy is an active member of the initiative, one of the lead regions in the field of Efficient and Sustainable Manufacturing (ESM) and a co-leader in the field of high-performance production through 3D printing.

Box 11: The Vanguard Initiative

The Vanguard Initiative was founded in 2013 and established a network of European regions with the aim of fostering innovation, smart specialisation and industrial growth. By May 2018, 33 European regions had joined the initiative that works on the principle of 'leading by example'. In late 2018, the network was focusing on ESM, high-performance production through 3D printing, new nano-enabled products and, in bioeconomy, interregional cooperation on innovative use of non-food biomass.

Source: *Vanguard Initiative (n.d.)*

Although the level of national and regional policies in support of advanced manufacturing and VET/apprenticeship adjustment processes is unequal, it is much more developed than in the two non-European countries. No such initiatives exist in the US or Australia at either national or regional level, apart from funding support provided for the expansion of apprenticeship training in general (the Obama and Trump administrations have introduced initiatives to boost apprenticeships in the US) and for the modernisation of apprenticeship (Department of Education in Australia).

Table 5: Links to national and regional programmes and initiatives

	Industrial policy initiatives supporting the transition towards advanced manufacturing, Industry 4.0, digitalisation of industry, etc.		VET modernisation initiatives fostering adjustments to advanced manufacturing	
Case	**National**	**Regional/local**	**National**	**Regional/local**
Innovative practices at Airbus – Germany (Eurofound, 2019b)	National Aviation Strategy Platform Industrie 4.0	Hamburg Aviation Hamburg Platform Industrie 4.0	VET working group in Platform Industrie 4.0 National Programme VET 4.0	Hamburg Centre for Aviation Training Competence Centres, etc.
Modernisation of dual apprenticeship training at ABB – Germany (Eurofound, 2019c)	Platform Industrie 4.0	Federal state of Baden-Württemberg is a partner in the EU Vanguard Initiative	See above	Funding programme for VET schools, Berlin
Talent Tracks – Denmark (Eurofound, 2019d)	Confederation of Danish Industry initiative	No	VET reform 2014	No
Knowledge centres – Denmark (Eurofound, 2019e)	Confederation of Danish Industry initiative	No	VET reform 2014	No
Jules Verne Manufacturing Academy – France (Eurofound, 2019f)	Programme Investment for the Future	Pays de la Loire is a partner in the EU Vanguard Initiative	No	Yes, but mainly funding
Job and Qualification Campus – France (Eurofound, 2019g)	Programme Investment for the Future	No	Initiative of the Ministry of Education	Yes, but mainly funding
'New' apprenticeships – Ireland (Eurofound, 2019h)	Public funding programme initiated by Irish Business and Employers Confederation (IBEC)	No	Review of Apprenticeship Training in Ireland	No

(*Continued*)

Table 5: Continued

	Industrial policy initiatives supporting the transition towards advanced manufacturing, Industry 4.0, digitalisation of industry, etc.		VET modernisation initiatives fostering adjustments to advanced manufacturing	
Case	**National**	**Regional/local**	**National**	**Regional/local**
Modernisation of designated craft – Ireland (Eurofound, 2019i)	No	No	Review of Apprenticeship Training in Ireland	No
Bosch Industry 4.0 Talent Program – Italy (Eurofound, 2019j)	National Industry 4.0 Plan/Intelligent Factories	Lombardy Region is a partner in the EU Vanguard Initiative	No	No, apart from funding by the region
Higher Apprenticeship in Advanced Manufacturing – Italy (Eurofound, 2019k)	National Industry 4.0 Plan/Intelligent Factories	Yes, programme of the Piedmont Region	No	No, apart from funding by the region
Siemens higher apprenticeship pilot programme – Australia (Eurofound, 2019l)	No	No	No, apart from funding by the Department of Education	No
Varley Group: Modernising apprenticeships – Australia (Eurofound, 2019m)	No	No	No, apart from funding by the Department of Education	No
Adjusting apprenticeship at Oberg Industries – United States (Eurofound, 2019n)	No	No	No	No
Mechatronics Apprenticeship Program of Festo Didactic – United States (Eurofound, 2019o)	No	No	No	No

Source: *Authors, based on the case study reports elaborated in the context of the study*

3 Lessons learned from good practices

3.1 Project design, planning and implementation

Unsurprisingly, in those case studies that centred on a specific company, needs were defined primarily by the company itself, for example Siemens and Varley in Australia, Airbus in Germany, Bosch in Italy and Festo and Oberg Industries in the US – often in collaboration with training providers. In other cases, the 'Knowledge centres for robot technology and automation' and 'Talent Tracks' in Denmark (Eurofound, 2019d, 2019e) for example, the needs of industry in general were the focus as well as enterprises, mediated by the Confederation of Danish Industry. In Ireland, the employer association, the Irish MedTech Association, was responsible for conducting a skills survey of its members, which in turn led to the creation of the two new apprenticeships, MT and ME. In the Jules Verne case in France, a regional observatory of industrial skills was created specifically to identify needs and guide the training policy of the region.

In the 'Talent Tracks' case in Denmark, the emphasis was on the need for workers with certain skills: advanced and specialised skills in the advanced manufacturing industry, notably CNC, CAD/CAM and robotics. In the Bosch case in Italy (Eurofound, 2019j) there was a need for skills in the automation and digitalisation of the engineering component of production processes, and the company was looking for technical expertise in the fields of mechanical engineering, mechatronics and automation. Interestingly, in the Italian 'Higher Apprenticeship in Advanced Manufacturing' case, a need was identified for quite different skills linked to market aspects (interaction with suppliers and customers) and the organisation of production processes. In this particular case, managing interpersonal relations in the workplace and managing intercultural relations were other skills that were identified so that apprentices could interact with colleagues, customers and suppliers from different cultural backgrounds.

The analyses identified skills needed in several industrial professions and occupations, for example electricians, mechanics, engineers or maintenance workers at the IRT (Eurofound, 2019f). In Ireland, regarding the creation of new apprenticeships, the survey revealed a need for new occupations: MTs and engineers (Eurofound, 2019h). In the French 'Job and Qualification Campus' (Eurofound, 2019g), a need was identified for skilled technicians in mechanics and electronics, rail maintenance and signalling and, more generally, workers with digital skills in the rail and automobile industries. The main occupations were as follows: qualified mechanic maintenance workers, qualified workers in electronics and electricity, production engineers, welders (skilled workers, technicians and senior technicians), boilermakers (skilled workers, technicians and senior technicians), machinists (skilled workers, technicians and senior technicians), and maintenance technicians, unskilled workers in engineering and unskilled workers in electronics and electricity. In the US Oberg case, needs anticipation exercises led to the development of two new occupations: wire electrical discharge machining operators and ram electrical discharge machining operators.

3.2 Involvement of different actors

One of the undisputed strengths of apprenticeship training is the attention paid to the combination of learning based on practical and theoretical components which takes place in the workplace and in formal education institutions and is provided by a variety of different actors – companies, employer associations, trade unions, training providers and government agencies, as can be seen from Table 6.

Table 6: Involvement of different actors in selected case studies

Case	Company/ies	Employer association(s)	Trade union(s)	Training provider(s)	Government agency/ies
Innovative practices at Airbus – Germany (Eurofound, 2019b)	√	√	√	√	√
Modernisation of dual apprenticeship training at ABB – Germany (Eurofound, 2019c)	√	√	√	√	√
Talent Tracks – Denmark (Eurofound, 2019d)	√	√	√	√	√
Knowledge centres – Denmark (Eurofound, 2019e)	√	√	√	√	√
Jules Verne Manufacturing Academy – France (Eurofound, 2019f)	√	√		√	√

(*Continued*)

Table 6: Continued

Case	Company/ies	Employer association(s)	Trade union(s)	Training provider(s)	Government agency/ies
Job and Qualification Campus – France (Eurofound, 2019g)	√	√		√	
'New' apprenticeships – Ireland (Eurofound, 2019h)	√	√		√	
Modernisation of designated craft – Ireland (Eurofound, 2019i)	√	√	√	√	√
Bosch Industry 4.0 Talent Program – Italy (Eurofound, 2019j)	√	√	√	√	√
Higher Apprenticeship in Advanced Manufacturing – Italy (Eurofound, 2019k)	√	√		√	√
Siemens higher apprenticeship pilot programme – Australia (Eurofound, 2019l)	√	√		√	
Varley Group: Modernising apprenticeships – Australia (Eurofound, 2019m)	√	√		√	√
Adjusting apprenticeship at Oberg Industries – United States (Eurofound, 2019n)	√			√	
Mechatronics Apprenticeship Program of Festo Didactic – United States (Eurofound, 2019o)	√			√	

Source: *Authors, based on the case study reports elaborated in the context of the study*

Key actors are the companies. Indeed, without active participation from companies there would obviously be no apprenticeship training. Some case studies highlight one specific company, for example Siemens and Varley in Australia, ABB and Airbus in Germany, Bosch in Italy, Festo and Oberg Industries in the US. However, in other cases, in France and Ireland for example, individual companies, particularly if they are SMEs, are unable or unwilling to take on the considerable administrative and organisational responsibilities required to launch and manage apprenticeship programmes, so groups of companies have become involved.

These groups of companies are often coordinated by employer associations (apart from the US) which play an important role in supporting and recruiting individual companies, as well as participating in the design and implementation of apprenticeship programmes. Examples are the Irish MedTech Association in the MT/ME case, the Confederation of Engineering Industries and Occupations in the two French cases and the Australian Industry Group in the Varley case. Groups of companies are also represented in the trade committees, which are central to the development and implementation of apprenticeship strategy in Denmark.

In a minority of countries – Denmark, Germany and to a much lesser extent, Ireland and Italy – trade unions are closely involved in the design of apprenticeship programmes. In Denmark, the trade unions are members of the trade committees mentioned in the previous paragraph. The company-level works councils, in collaboration with IG Metall, the industrial union of metalworkers, are key actors in the 'Modernisation of dual apprenticeship training at ABB' (Eurofound, 2019c). Also, at Airbus, the works council plays a key role vis-à-vis the management in the adjustment of initial and further training in relation to digitalisation and Industry 4.0. The reasons for trade union absence may differ, but in the case of Siemens in Australia it is because apprentices are not covered by the Siemens Enterprise Bargaining Agreement, and in the French cases it reflects the marginal role played generally by trade unions in local education policies.

Unsurprisingly, training providers are omnipresent, either acting individually or in a consortium, and they are above all responsible for the off-the-job training. Community colleges are involved in the two US case studies. In Australia, Swinburne University has developed the apprenticeship programme for Siemens and accredits the course; it also participates in recruiting apprentices and is responsible for their pastoral care (Eurofound, 2019l). In Ireland, the Waterford and Wexford education and training boards and the Cork, Dublin and Limerick institutes of technology have participated in developing the curriculum for the Mechanical Automation and Maintenance Fitting (MAMF) apprenticeship (Eurofound, 2019i), and Galway/Mayo Institute of Technology has participated in developing the curriculum for the MT and ME apprenticeships (Eurofound, 2019h). In France, two universities, three engineering schools and three apprenticeship training centres collaborate in the IRT

(Eurofound, 2019f). In the Bosch 'Industry 4.0 Talent Program' (Eurofound, 2019j) there is a partnership featuring three technical universities from Turin, Milan and Bari. The Polytechnic University of Turin is also a partner with Skillab, a training company belonging to the Mechanical and Associated Mechatronics Companies and the Turin Industrial Union, which is a regional organisation within Confindustria, the General Confederation of Italian Industry and national employer association. In the other case, 'Higher Apprenticeship in Advanced Manufacturing' (Eurofound, 2019k), the Polytechnic University of Turin met with the companies to define curriculum content and training methods. Herningsholm Vocational School was initially the sole provider of off-the-job support for the training of industrial technicians in the 'Talent Tracks' programme (Eurofound, 2019d).

National and/or regional government agencies are often heavily involved, as follows: the Hunter Regional Development Agency in the Varney case in Australia; the German Federal Institute for Vocational Training in the ABB case; SOLAS, the Further Education and Skills Service in Ireland with statutory responsibility for the organisation and control of designated craft apprenticeships, including the MAMF apprenticeships; Lombardy and Piedmont regional governments in the two Italian case studies.

Although advantageous, this inclusion of a variety of actors has one particular potential weakness: there is a need to provide coordination and clear direction.

Some of the cases have clear coordination instruments. For example, in Denmark, sectoral trade committees, comprising representatives of social partners (employer associations and trade unions), have a central role in deciding the detailed content of training (the structure of training programmes, their objectives and assessment and the distribution of on- and off-the job training). They are also involved in the accreditation of companies.

In the French case, the 'Job and Qualification Campus' (Eurofound, 2019g) contains most of the actors that participated in the creation of the qualification: company representatives, employer associations, the chamber of commerce and industry, state, regional academic authorities and the regional council. It is administered by a strategic committee (comprising four representatives of the public authorities, two industrial representatives and the head of the vocational high school) which defines its political orientations, and a steering committee (comprising 21 members, including companies, educational institutions and local authorities) which ensures that these orientations are implemented.

3.3 Financing

Generally speaking, the costs for on-the-job training (apprentices' wages, mentors' time, equipment and, where appropriate, in-house training centres) are borne by companies and the costs for the off-the-job training (VET institutions' running costs and equipment) are borne by the public authorities.

In Germany, for example, this is the norm. In the 'Innovative practices at Airbus Operations in Hamburg' case (Eurofound, 2019b), funding for off-the-job training comes from the public authorities (the City of Hamburg, federal research funds and the EU programme Horizon 2020). In the 'Modernisation of dual apprenticeship training at ABB' case (Eurofound, 2019c), most of the financing of the modernisation and extension of the ABB Training Centre Berlin came from the Federal State of Berlin. In addition, ABB finances a series of promotion events with the aim of attracting young people to a career in the company.

This is also the norm in Denmark, France, Ireland and Italy, albeit with a difference. Approximately €29 million was earmarked by the Danish government for the Knowledge centres for the period 2017–2020, covering the costs of establishing and running the centres and the purchase of equipment. In addition, other funds have been made available to strengthen the quality of Danish (I)VET, and some of these funds may directly or indirectly benefit the activities of the Knowledge centres at a later stage. Although these funds are provided essentially by public authorities, they originate in part from companies' mandatory contributions to an 'Employer Reimbursement Scheme'. So not only do companies pay the on-the-job costs, but they also contribute to the off-the-job costs. Moreover, via the Danish Industry Foundation, companies contributed €2 million to the start-up costs of the 'Talent Tracks' initiative.

In Ireland, companies pay the on-the-job costs, but not wages for apprentices for the designated crafts, such as MAMF, during the off-the-job training periods; they are paid by the public authorities. However, this is not the situation for the 'new' apprenticeships, and companies pay the wages during both the on- and off-the-job training periods for apprenticeships such as MT and ME. In addition, companies in Ireland pay a mandatory levy to a National Training Fund, which finances off-the-job training amongst other things.

In France, the public authorities fund the off-the-job training. The IRT is funded by the state and the regional authorities, and by the city of Nantes which pays for other ancillary costs such as accommodation for apprentices. The projects of the 'Job and Qualification Campus' case have been funded by the regional authorities, and its operating budget and certain payroll expenses are funded by the Ministry of Education. However, the companies pay an 'apprenticeship tax', which contributes to part of these funds. They also pay the normal on-the-job training costs, but they are entitled to exemptions from and/or reductions in social security contributions.

In Italy, funding for off-the-job training comes from the regional authorities: Lombardy for the Bosch 'Industry 4.0 Talent Program', and Piedmont, which benefits from the European Social Fund, for the 'Higher Apprenticeship in Advanced Manufacturing' case. However, employers pay a payroll tax to inter-professional funds for training purposes. They also pay the on-the-job costs for apprentices, but they can claim a reduction in their social security contributions. They are also eligible for an incentive payment of €6,000 for employing each young person on a full-time higher apprenticeship contract.

In Australia, it is difficult to place precise overall figures on the cost of the apprenticeship programmes and the contributions provided by the different parties. In the Siemens case, it is known that the company provided Swinburne University with software to the value of approximately €87 million. Moreover, apprenticeships attract some form of financial incentive for both the training provider and the employer; training providers can claim approximately €8,300 for providing off-the-job training for certain apprenticeships and employers can claim approximately €2,500 from the Commonwealth (national) government for each apprentice.

There is one clear exception to this general rule: the US, where employers pay directly for both on- and off-the-job training. It has been calculated that a completed apprenticeship costs Oberg Industries approximately USD 250,000 (€212,000) per apprentice for the four-year programme, which clearly represents a significant investment. The costs include tuition and tools for the academic courses, costs of using equipment at the plant, wages of the apprentices and wages of the trainers/mentors during the time they undertake training and are away from their jobs. In the other US case, Festo pays the wages for the apprentices and their tuition, books and training material costs. In addition, it funds the equipment costs for the training centre to the tune of USD 1.3 million; it has also donated in-kind usage of 500m^2 of space within its facility and it provides one full-time apprenticeship supervisor, one full-time Master's instructor, an administrator and three part-time instructors that work full-time at other positions within the company.

3.4 Other forms of local, regional and/or national support and expertise

As discussed earlier, apprenticeship training draws on, and responds to, a broad network of different actors – companies, employer associations, trade unions, training providers and government agencies. However, there are other interested and supportive partners, particularly in the world of manufacturing and advanced manufacturing, but also more generally in terms of business evolution, pedagogical and technological expertise and broader educational development.

In Germany, training in the 'Innovative practices at Airbus Operations' case is associated with the Hamburg Aviation Cluster which comprises a network of companies, the two largest being Airbus and Lufthansa, and more than 300 smaller supplier companies in the aviation sector employing around 20,000 workers. This network also includes universities, employer associations and research institutes. Another significant actor is the Hamburg Centre of Applied Aeronautical Research (ZAL), which functions as an interface between academic and research institutions, the aviation sector and the City of Hamburg, and aims to secure and expand the civil aviation industry in Hamburg. In late 2018, the ZAL had three Centres of Competence: Aircraft Manufacturing and Maintenance, Repair and Overhaul; Cabin and Cabin Systems; and Digitalisation Technologies. Other partners include the German Research Center for Artificial Intelligence (DFKI) and the core partners German Academy of Science (acatech), Festo Learning Centre, Hamburg Centre of Aviation Training, the trade union IG Metall, the employer organisation Nordmetall and the Ruhr-Universität Bochum. As for the other German case study, ABB is an important member of networks that focus on the broad topic of digitalisation and its impact on work, such as the Platform Industry 4.0 initiative set up by the Federal Ministry for Economic Affairs and Energy and the Federal Ministry of Education and Research, and a joint metalworking and electronics sector social partners' initiative for the revision of industrial metal and electronics occupational profiles (the so-called 'Agile Procedure').

In France, the IRT – which has undertaken research into robotics/collaborative robotics and augmented reality, the numerical simulation of structures and processes and the innovative processing of composite and metals – is also associated with the Alliance for Future Industry, a national platform for the promotion of the industries of the future, which has undertaken an additive manufacturing research project and which comprises employer associations, chambers of commerce and research institutes.

In Denmark, the Knowledge centres are involved in networks, and Consortium No. 1, which comprises three vocational schools covering the southern part of Jutland and Funen and the surrounding islands (EUC Syd – Vocational Educational Centre South, SDE – Vocational Education College South Denmark and Herningsholm), is associated with the University of South Denmark, Odense Robotics, the Danish Technological Institute, the Lillebaelt Academy – University of Applied Science and UAS Denmark.

In Australia, Varley is a member of the Manufacturing Innovations cluster and the Lean Manufacturing cluster that are coordinated by the Ai Group (Hunter). These clusters enable SMEs, like Varley, to keep up to date with developments within a broader business and industrial environment and to gain insights into areas of possible growth and, hence, recruitment and workforce development.

A concern expressed in some case studies is the level of technological and pedagogical expertise of staff that is responsible for the off-the-job training. In the Knowledge centres, VET institutes in Denmark can call on the expertise of a network within the Danish Advanced Manufacturing Research Center which assists the Danish manufacturing industry with the implementation of new technology in its production processes, notably machining technologies, and which trains vocational teachers and trainers to incorporate the latest developments in new technology into their training programmes.

Varley is also involved in broader education development networks – for example, the STEM-Ship and P-TECH programmes – which aim to promote the study of science, technology, engineering and mathematics and ensure that secondary school students have the basic skills and pre-requisite qualifications to become apprentices in manufacturing and advanced manufacturing companies.

3.5 Implementing the programme/initiative

The case studies have one unifying theme: they are all very recent examples of stakeholders endeavouring to provide employers in the manufacturing and advanced manufacturing sector with skilled labour and to provide young people with a learning experience that will enable them to enter the labour market and start to develop a successful career. Implementation of the programme in each case is unique and bears witness to the different priorities in each particular context. Moreover, implementation is at different stages; in some cases apprenticeships are still going through the planning stage, in others apprentices have been recruited and are now starting their training. Some are revisions of previous experience, and many are starting from the very beginning. Some are aiming for higher apprenticeships at EQF levels 6, 7 and 8, others the more traditional levels (EQF Level 5 or lower). There are also, however, some similarities.

The preparation process is highlighted in a number of cases. The French 'Job and Qualification Campus' case was identified as a sector of excellence within a particular geographical area, and regional authorities identified the automobile and rail sectors as strategic elements of their industrial policy. In 2009, they developed the I-Trans competitiveness cluster as a partnership between companies, higher education and research institutions within the sector. Initially, there was no connection to apprenticeships, but it was expanded to include 14 vocational schools and apprenticeship centres. The Campus' goals are closely linked to those of the competitiveness cluster, which aim to support innovation in companies. In the other French case, the JVMA, launched in 2015, aims to train technicians and engineers on advanced manufacturing processes so that they are operational at the end of their training. The first stage was to collaborate with the 10 existing VET institutions in order to adapt their training and identify appropriate qualifications (20 in all), about 10 of which have been adapted or created. The second stage was to pool the technological equipment being used by the 10 partner institutions. However, with the partial withdrawal of funding from the region, the 10 VET institutions will not now relocate their training, but they will have access to the technological equipment of a new VET institution run by the Confederation of Engineering Industries and Occupations.

The Airbus works council, management and the IG Metall trade union have together initiated a project that is based on mapping changes in the overall working environment and in particular new qualification and skill demands at workplace and site level: the Company Map Industry and Work 4.0. There are three key aspects of this project.

- **Technology:** Which digital technologies are already applied today? Which technologies are likely to be applied in the future?
- **Employment and work:** How will digital technologies affect employment volumes? What will be the impact on competencies and skills demands? What requirements are there regarding changes in IVET and further qualification? How do digital technologies affect working conditions (burden, working hours, etc.)?
- **Organisation and processes:** What impact do digital technologies have on processes and practices within individual company departments and across departments?

In the US, the National Institute for Metalworking Skills sets industry skills standards and accredits training programmes that meet these quality requirements, but it did not have performance standards for operating electrical discharge machines, and so Oberg Industries developed its own occupational frameworks for wire electrical discharge machining and random-access memory electrical discharge machining operators and training programmes lasting four years. In the other case, Festo, the company took the occupational standard of the German Mechatronics Fitter apprenticeship which lasts 3.5 years and condensed it into a 2.5-year programme (the 'Mechatronics Apprenticeship Program 2') for US purposes. The programme began in 2016 with 11 apprentices, five of whom are employed by Festo.

In Australia, in the Siemens case, the government contracted Ai Group (Hunter), the employer association, to manage the training project. Swinburne University, the training provider, will carry out a formal evaluation of the programme, which will be released in 2019. In the Varley case, the emphasis is on multiskilling, and so the apprentices are required to spend extended periods of time on the job in different parts of the company.

In the Italian 'Higher Apprenticeship in Advanced Manufacturing' case (Eurofound, 2019k), the preparation process has been completed and has led to the creation of three fully fledged Master's programmes: Master's in Industrial Automation, Master's in Additive Manufacturing and Master's in Manufacturing 4.0. The Master's in Additive Manufacturing (EQF Level 8) is particularly specialised in advanced manufacturing and has modules in Design for Additive Manufacturing, Materials for Additive Manufacturing, Additive Manufacturing Systems, Advanced Sensors for the Control of Additive Manufacturing Systems, Integration of Additive Manufacturing Technologies with Conventional Processes for Part Finishing, Systems for the Evaluation of Products Made Using Additive Manufacturing, Production Management in Additive Manufacturing Systems, Supply Chain Management in Additive Manufacturing Systems, ICT Platforms for Facilitating the Integration of Additive Manufacturing in Traditional Manufacturing Processes and Managerial Training Processes. It has been launched and has recruited 10 students (with approximately 150 applicants for each place), four of whom are apprentices in Prima Industrie, a leading industrial group in the development, production and marketing of laser systems for industrial application, machinery for sheet metal processing and industrial laser sources and electronics. In the Bosch 'Industry 4.0 Talent Program' (Eurofound, 2019j), the process has led to the definition of a new occupational profile for a higher apprenticeship (EQF Level 7), an 'Industrial IoT Specialist', which will enable the company to become a leader and

point of reference in Italy for the design, development, in-house application and provision of industrial automation technologies. The training packages have been prepared. Eighteen apprentices have been recruited (out of a total of around 2,000 applicants) and training commenced in 2017.

Some of the cases highlight the benefits of the preparation process in terms of skills and competencies and the way they are brought together within a training curriculum or within a new or revised qualification. The 'Modernisation of dual apprenticeship training at ABB' case identified the transversal competencies that are required to deal with the digitalisation of production processes. They were clustered into five modules related to basic competencies concerning digitalisation, learning and working in the digital world, ICT competency, handling data and systems and processes. Each module contains a description of the knowledge, skills and personal competencies. These modules were piloted in 2017, and it is expected that they will be incorporated in a final supplementary qualification arrangement in 2018 to be used by ABB and other companies (Eurofound, 2019c).

In the 'Innovative practices at Airbus Operations in Hamburg' case, the Aeronautical Technician qualification has been reviewed and augmented to include the following: digital control and regulation of production processes; robotics and sensor technology; micro-controlled processes; construction (computer-aided three-dimensional interactive application V5), additive manufacturing and 3D printing; network technology and IT security and change management. This qualification has been placed on the German Qualifications Framework at Level 6 (EQF Level 6). The content of the course has been aligned with the standards published by the European Aviation Safety Agency, which means the technicians can obtain a Category B1 or Category B2 certification (Eurofound, 2019b).

In one of the Irish cases (Eurofound, 2019i), Modernisation of a designated craft apprenticeship, the curriculum was completely revised in 2016 to include in the off-the-job training new learning outcomes and new modules designed to ensure that apprentices have the knowledge, skills and competencies to deal with the skills challenges posed by developments in advanced manufacturing. Moreover, there is the introduction of soft skills training with modules on team leadership and communications. However, this emphasis is less pronounced in the on-the-job training. In the other Irish case, the creation of two new apprenticeships (MT and ME) which have been developed from the beginning, the new learning outcomes reflect the needs of manufacturing and advanced manufacturing, as do the modules for the off-the-job training. All three apprenticeships have been launched, two at EQF Level 5 and the ME apprenticeship at EQF Level 6; apprentices have been recruited and training commenced in 2017.

In Denmark, the 'Talent Tracks' initiative for industrial technicians was approved in 2011, and training has begun, albeit with only a few apprentices. The initial preparation process for the other case study, 'Knowledge centres', has been completed. Applications were considered for robot technology and automation, and two consortia were approved in late 2017. However, activities have only commenced on a very modest scale (Eurofound, 2019d).

3.6 Quality assurance mechanisms

Generally speaking, as highlighted in the German cases, the various elements of quality assurance in VET systems are not perceived as an overall holistic concept. They are based on traditional processes, procedures and regulations that are laid down in several laws and ancillary documents and practices. Quality assurance has nevertheless certain systemic and targeted features in most systems.

Systemic quality assurance in most countries is linked to the process of registration and accreditation. In the Irish cases, there is a long (albeit different, according to the type of apprenticeship under discussion) process of consultation with social partners (employer associations and trade unions, government agencies and training providers) and this consultation led to a proposal (including an occupational profile, a training standard, learning outcomes, a curriculum and assessment criteria and quality assurance guidelines) ultimately approved by Quality and Qualifications Ireland and thus recognised nationally. In Denmark, as shown in the 'Talent Tracks' case, the central element of systemic quality assurance is underpinned by the work of the trade committees which comprise representatives of social partners (employer associations and trade unions) and which define and develop the 'Talent Tracks' for industrial technicians. Every year, the trade committee assesses recent developments in technology and the market and, on the basis of that assessment, revises the content of the programme and proposes appropriate changes which are subsequently incorporated into the relevant Ministerial Order for the programme. The trade committees then develop the details of the relevant documentation including learning objectives covering theoretical instruction off the job and practical learning on the job. In Germany, the Vocational Training Act and the Craft Trade Regulation have established quality assurance mechanisms governing the development of training regulations and the organisation of their training and their supervision by the local chambers of commerce and industry.

Targeted quality assurance examines ways in which the apprenticeship programmes are being implemented. In the Italian cases, quality assurance mechanisms are based on the internal quality standards of the stakeholders involved, and, as far as the training institute is concerned, an external audit for certification. In the Danish 'Talent Tracks' case, the local trade committees monitor the delivery of the programme and may, within the overall limits prescribed by the Ministerial Order, adapt its contents to correspond better to conditions at the local and/or regional level. They are also responsible for accrediting local enterprises to take apprentices. The 'Modernisation of dual apprenticeship training at ABB' case demonstrates the roles played by the works councils, youth and apprenticeship representation bodies and employee representatives on the company supervisory board. The group works council recently agreed regulations on e-learning frameworks. Furthermore, the ABB works council agreed with the management a 'takeover guarantee' for apprentices. This means that each

apprentice knows that after the successful completion of the training they will receive a direct employment contract with the company. In the US case of Oberg Industries (Eurofound, 2019n), apprentices are required to demonstrate that they have achieved the standards set by the National Institute of Metalworking Skills, and their ability to produce quality parts that are acceptable to customers is also evaluated by in-company mentors. In the other US case, Festo, the company has hired a full-time Apprenticeship Program Supervisor and a full-time Master Instructor with German credentials to maintain the quality of the training at the Festo Training Centre. In addition, interestingly, the German American Chamber of Commerce in the Midwest audits and monitors the Festo 'Mechatronics Apprenticeship Program 2' to ensure that the training standards meet German occupational standards. In the French 'Job and Qualification Campus' case (Eurofound, 2019g) the most relevant criteria for evaluating the Campus activities are as follows: integration of young people into employment; adaptation of the training on offer; the permeability of the courses (bridges between the different programmes); improvement of the apprentices' level of qualification; the attractiveness of industrial sectors and the ability to meet companies' skills needs. In the French Jules Verne case, the training provider of the Confederation of Engineering Industries and Occupations is required to report the results of an ex post evaluation to the regional authorities and to the Ministry of Education. This evaluation highlights non-completion rates, completion rates and transition-to-work rates, and the results of the last survey were as follows (Eurofound, 2019f):

- completion rate: 86% (in the agreement with the region a target of 85% was set)
- non-completion rate: 5% (compared to 12% on average in the region and 20% nationwide)
- transition-to-work rate: between 80 and 85%

3.7 Skills of trainers and mentors

Generally speaking, the case studies show that provision for improving the skills of training and mentoring personnel is inconsistent.

Teachers and trainers responsible for off-the-job training are generally required to have certain initial qualifications to join the profession. For example, in Ireland, those teaching on the first period of off-the-job training are required to be qualified as a tradesperson, have five years 'post-apprenticeship experience and hold a recognised assessor qualification. For the two higher-level periods, they are required to hold a degree or its equivalent in the subject area or have qualified as a tradesperson, have three years' relevant postgraduate experience and hold a recognised assessor qualification.

Some practices explicitly include training personnel as a target group, as for example the ABB project of 'Supplementary Qualifications for Digital Competencies', and in France the Jules Verne case points out that teachers and trainers are contractually obliged to participate in in-service training, but opportunities for continuing training are limited. This general shortcoming is of particular concern given the rate of technological development, the move towards new forms of learning and the changing ways in which young people use new technology to access information. Interestingly, this has been recognised in the Danish 'Talent Tracks' case, and considerable resources have been mobilised to enable teachers and trainers to improve technological upskilling, training in new pedagogical methods and training using IT in a pedagogical context.

There are some examples of upskilling on-the-job in-company mentors. In the Irish MT/ME case, it was agreed that the in-company mentors would receive mentoring training organised by IBEC (Irish Business and Employers Confederation) and an introduction to Higher Certificate/BEng Programmes and mentor responsibilities, organised by the Galway-Mayo Institute of Technology. The US Oberg Industries case notes that in-company mentors are drawn from the most productive workers in operational roles, undergo training themselves and are required to gain a National Institute for Metalworking Skills certification for training. Another positive example may be the Bosch 'Industry 4.0 Talent Program' in Italy, where the corporate training scheme includes a module devoted to on-the-job mentoring.

3.8 Difficulties and challenges during implementation

Many of the case studies represent a recent response to the challenges facing employers and young people themselves in the labour market, and so for some, for example, the German ABB and the Danish 'Knowledge centres' case, it is too early to assess the impact, although there may be the gradual dawning of concerns.

For others, it is clear that many of the challenges are specific to the conditions that prevail in each country. It is possible that some of these conditions may be found in other countries but, if this is so, they are not the major preoccupations of the national stakeholders.

However, in terms of challenges shared by more than one country, some stand out: coordination, accreditation and/or registration, supply and demand of apprenticeship places and funding.

As discussed earlier, one of the undisputed strengths of apprenticeship training is its ability to respond to the needs of multiple stakeholders: companies, employer associations, trade unions, training providers, government agencies and others. However, coordination is a challenge and there are numerous examples of attempts made by stakeholders to come together to ensure that there is appropriate coherence and clarity concerning the implementation of apprenticeship strategies and programmes. Of course, coherence is not a given, and there are obvious competing tensions. As the French 'Job and Qualification Campus' case has shown, participation of the various partners is neither compulsory nor binding, and their priorities may well diverge. Moreover, even when they do not diverge fundamentally, there is a clear need, as shown by the Italian 'Higher Apprenticeship in

Advanced Manufacturing' case, to spend time and energy accommodating these differences. The Danish 'Knowledge centres' case (Eurofound, 2019e) notes that there are specific factors conditioning the successful implementation of an apprenticeship training strategy. In terms of intrinsic factors, the consortia are unable to maintain internal cohesion, they fail to coordinate their activities and their activities are focused around individual programmes rather than across divisions. In terms of extrinsic factors, other VET institutions do not benefit from the consortia-generated activities, and the stronger consortia use their assets to poach potential apprentices from other catchment areas.

Registration of the apprenticeship training programme is an issue in the US Oberg Industries case (Eurofound, 2019n) but, paradoxically, it is only marginally problematic because it is possible in the US to implement an apprenticeship without registration. More demanding is the question of accreditation of apprenticeship programmes. It was considered in the Australian Siemens case that obtaining the approval of the national VET regulator 'would have taken years'. In the end an alternative process was successfully tried, but this meant in those circumstances that all the programme preparation had to be concluded within a period of three months, a time period not necessarily conducive to producing the most carefully considered results. Long, if not very long, approval processes are the norm in many apprenticeship registration processes: two to three years in the two French cases, with the result that parts of apprenticeship curricula may be obsolete before apprentices have obtained their qualification. Moreover, stakeholders have little or no appetite to repeat the process of introducing revisions to the curricula, particularly if, as in the Irish 'New apprenticeships in the light of technological change' case, two different curricula are in operation simultaneously – the old 2009 version and the new 2016 version.

A number of case studies mention the supply and demand of apprenticeship places, a constant concern for many apprenticeship systems, not only those featuring in the two Australian cases and the Danish 'Talent Tracks' case (Eurofound, 2019d). Moreover, as has been highlighted in the Siemens Australia, Irish MT/ME and US Oberg Industries cases, many apprentices do not start their programmes with adequate basic skills, particularly in mathematics, and so, in the Australian case, have 'difficulty translating their mathematical knowledge into applied problems such as solving equations in electrical circuits'. The Oberg Industries case also mentions a lack of verbal and communication skills and resilience or perseverance required to complete the course.

Funding, or the reduction of funding at a critical time, is a challenge in the two French case studies and the Danish 'Talent Tracks' case, and possibly other cases too. In company-based programmes, such as Oberg, funding is not the issue, but cost, especially the cost of the time spent on apprenticeship-related activity in relation to the time lost in direct productive activity.

There are other more individualised challenges. For example, the meaning of the word 'talent' in the Danish 'Talent Tracks' case, and the lack of obvious incentives to take on this more demanding option. There are other challenges mentioned in individual case studies that may have a broader resonance: the quality of technological infrastructure in VET institutions, as in the German 'Innovative practices at Airbus Operations in Hamburg' case; the alignment of on- and off-the-job training, in the Italian Bosch 'Industry 4.0 Talent Program'; the lack of understanding and experience of industrial reality amongst teachers and trainers in VET institutions, in the Festo case; the relative lack of skills of in-company mentors in the Irish MAMF case and the potential geographical inaccessibility of the off-the-job training, in the two Irish cases (Eurofound, 2019h, 2019i).

4 Outcomes and impacts of good practices

4.1 Outcomes and impacts on companies and regions

It is hardly possible to identify measurable or even quantifiable outcomes of the analysed practices of this study. Due to the variety of practices – ranging from establishing new initial or higher apprenticeship programmes to comprehensive company and regional initiatives to foster advanced manufacturing – outcomes and impacts will differ. Furthermore, most of the analysed practices are very recent or still in a pilot or development state and thus it is too early to identify concrete outcomes or impacts. Against these restrictions, most of the outcomes and impacts highlighted by stakeholders involved or interpreted by the researchers on the basis of factual evidence are of a qualitative and often 'soft' nature.

And even if quantitative data on outcomes exist, they are not always easy to interpret. Here, the examples of the two Irish cases are noteworthy. With regard to the 'New apprenticeships' programme (Eurofound, 2019h), the first MT and ME apprentices were recruited in 2017 and began their training. According to SOLAS, the number of recruits (30 for the MT apprenticeship and 12 for the ME apprenticeship) are much lower than originally expected. Similarly, the number of those recruits that enrolled for the modernised MAMF apprenticeship in 2017 (126 new apprentices) is significantly lower than those expected by the SOLAS Skills and Labour Research Unit (175). It is not clear how to interpret these figures; they may result from a lack of supply of places but may also result from a lack of demand, and equally they could mean that the skills anticipation exercises need reconsideration.

In any case, the outcomes and impacts of the practices should be interpreted in a broader way, focusing mainly on qualitative impacts on the directly and indirectly involved companies, on the regional production system and on the VET system itself.

4.1.1 Impacts on companies and apprenticeship training

The analysed cases of good practices that have been initiated by single companies (ABB, Airbus, Bosch, Festo, Oberg, Varley, Prima Industrie) clearly show that initiatives to modernise, adjust or expand apprenticeship programmes and practices are regarded as a key element of the competitiveness and ability of the relevant companies to successfully adopt advanced manufacturing technologies and production processes. Apart from that, apprenticeships have been highlighted by company representatives as a key source of recruiting and developing a workforce that has the right skills. Interestingly, this has been particularly emphasised by the top-level management of the US Oberg case (Eurofound, 2019n). Oberg Industries sees the apprenticeship programme as absolutely vital to their competitive position in their industry sector. Apprenticeships are not only a tool for hiring and training workers to perform well in their job and career but a mechanism by which Oberg responds effectively to changing customer requirements. The apprenticeship programme not only develops talent that can flexibly adjust to new tasks but also improves the attractiveness of jobs at the company.

While initial apprenticeships for companies in Denmark and Germany constitute the single most important route into work and into a skilled workforce for young people, and also an important route for young people in France, Ireland and Italy, it is also interesting to reflect on the impact of higher apprenticeship and dual academic programmes on managing advanced manufacturing technologies and processes. The cases of Bosch in Italy, Festo in the US, Siemens in Australia and the two German cases strongly illustrate that suitable higher VET pathways are regarded as an important source to develop highly skilled specialists that are crucial for the respective business model or the transformation towards advanced manufacturing.

As stressed in the case of the Bosch 'Industry 4.0 Talent Program', this higher apprenticeship course is regarded as a crucial element of the ability of the company to position itself as a leader in the development and provision of production processes and technologies that fall within Industry 4.0 in Italy. Quite similar assessments have been made as regards the Siemens Higher Apprenticeship Pilot Programme on Advanced Manufacturing and the Festo Didactics apprenticeship programme in the US.

Also, the modernisation of initial and further VET training at ABB and Airbus and the development of new higher VET pathways such as ABB's Digital Industry Trainee programme are regarded as important elements in developing a workforce and future management personnel that have the right skills for the advanced manufacturing environment.

It should be noted that the good practices developed and implemented by single companies also have a positive outcome for the company in that they contribute positively to the image of the company as a forerunner of advanced manufacturing technology, teaching and dual VET training innovation in digitalisation of manufacturing and Industry 4.0. The Bosch 'Industry 4.0 Talent Program' is very attractive (2,000 applications for 15 places) and also the modernised ABB Training Centre Berlin has had a positive impact on the image of the company.

The higher apprenticeship programmes in Italy, but also the development of (further) training and competency centres in advanced manufacturing technologies and their application as analysed in Denmark, France and Germany,

are also reported to have a positive impact on the regional business structure, in particular SMEs.

As highlighted in the case of the 'Higher Apprenticeship in Advanced Manufacturing' (Eurofound, 2019k) by a representative of Polytechnic University of Turin, SMEs in the advanced manufacturing sector suffer most from the shortage of skilled personnel. They find it more difficult than large companies to recruit highly specialised personnel because graduate students tend to prefer employment in large companies. In this sense, participation in the Master's course guarantees SMEs a safe and reliable recruitment channel.

With regard to the ABB Training Centre Berlin, it has been noted that the number of companies that have concluded a collaboration agreement with the Centre has steadily increased since its modernisation and there are already plans to expand its campus. In October 2018, more than 90% of the apprentices trained at the Centre were from 140 regional companies (Eurofound, 2019c).

Another impact of good practices on companies has been highlighted in the context of the French case of the 'Job and Qualification Campus' (Eurofound, 2019g). Only a few years ago, companies had little interest in apprenticeship programmes because of their complexity and the fact that apprentice training and profiles did not match the skills needs of the industry. The Campus has improved visibility on the existing apprenticeship training offer and provided companies with the opportunity to participate and adapt training to their actual needs. In addition, the decentralised governance and the way it is anchored in the Valenciennes employment area reinforces the Campus' credibility with local businesses. According to the Campus manager, attitudes and behaviour of regional companies have changed: companies are increasingly aware that it is through the training of young people that they can solve their difficulties in recruiting, developing and retaining skilled workers and employees. It has also been highlighted that sponsorship has had a positive effect on the attitude of companies towards apprenticeship training. Local companies are able to sponsor students by regularly hosting a class of students, supporting them in their career project, developing educational projects with them and their teachers and/or sponsoring individual apprenticeship training centres (CFAs). As highlighted in the case study, the Campus has also created a business support and information service that interfaces with educational institutions. It operates on the principle of a one-stop shop that helps businesses in hiring and following up on apprentices. This service helps bring businesses and educational institutions closer together, thus creating trust and enabling the emergence of sustainable partnerships.

4.1.2 Impacts at regional level

According to key stakeholders involved, most practices analysed in this research are regarded as having a positive impact on the regional economic and labour market and on the attractiveness of the region. This has been highlighted in the case of Airbus and the Hamburg Aviation Cluster (Eurofound, 2019b), the Bosch case that, according to stakeholders, will contribute to the growth of advanced manufacturing know-how and competencies in Lombardy (Eurofound, 2019j) and the positive impact of practices such as the development of higher apprenticeship programmes in advanced manufacturing on skills improvement and industrial competitiveness in Piedmont (Eurofound, 2019k).

In all these cases, stakeholders interviewed have also highlighted the spillover effects on other companies in the region, and in particular SMEs that are the backbone of employment and innovation in all regions. For Piedmont, it has been reported that apart from some big companies, the regional industrial system mainly consists of SMEs (as in the Italian system as a whole) that are also the main target of the regional economic policy. According to Polytechnic University of Turin, the participation of SMEs in the high-level apprenticeship Master's course has grown over the years and by late 2018 accounted for about 40% of the University's partners, including micro-enterprises and start-ups.

Positive impacts on local companies are also reported in the context of the French case study of JVMA (Eurofound, 2019f). Stakeholders interviewed expect that the main impact of this initiative will be to improve the supply of skills at the local level in order to improve the competitiveness of the local industry. The observation shared by the actors is that there is a shortage of qualified labour in certain industrial trades and that there is a lack of responsiveness of the training offer to technological developments in the local industry.

The bundle of measures and practices carried out in the context of fostering digitalisation and advanced manufacturing within the Hamburg Aviation Cluster has a direct effect on more than 300 regional SMEs that are linked to the aviation sector's big players, Airbus and Lufthansa Technik. They benefit in particular from improvements in the quality and supply of initial and further training facilities, and innovation or competence centres. Amongst these are world-leading competence centres such as the carbon fibre reinforced plastic (CFK) Valley Stade near Hamburg that combines in one location around 100 companies and research and development institutes, focusing on the development of new processes, methods and products in lightweight engineering with controlled free radical polymerisation and other advanced materials, representing an internationally renowned centre for research, development and innovation. The successive expansion of the CFK Valley would not have been possible without an infrastructure of initial and further VET institutions and universities in the region that offer several pathways of secondary education and higher VET programmes (Eurofound, 2019b).

4.1.3 Other impacts

A separate, potential impact has been mentioned in the Danish case study report on the 'Knowledge centres for robot technology and automation'. Competence centres have a major impact with regard to the Danish VET system and policy: moving from a scenario of free-for-all competition towards one where specific vocational schools are given extra benefits to allow them to take the lead in relation to specific programmes. This specialisation

in VET is necessary by some actors and stakeholders to allow for apprenticeship to keep abreast of developments in technology, based on the fact that not all schools can be equally updated in terms of equipment and competencies of teaching staff. The official rhetoric surrounding the Knowledge centres does not underpin this interpretation but speaks of creating 'light towers' which will develop products and activities that will benefit all vocational schools offering the apprenticeship programmes covered by the Knowledge centres. However, a vocational school, which is part of a Knowledge centre, will have additional, earmarked funds to purchase equipment and to develop products, and this will add to their attractiveness for enterprises and learners over time, giving them an advantage over other schools offering the same programmes. This free choice of vocational schools for learners and enterprises may in time lead to a reduction in the number of schools offering these programmes. While this may be a desirable thing from the perspective of the development of programmes, it may negatively affect the recruitment of learners if they have to relocate or travel large distances to attend their programme of choice.

4.2 Attractiveness and capability of apprenticeship

The issue of attractiveness, capability and retention of apprenticeship has been highlighted by a number of good practices as a major objective in some countries that face certain challenges in this regard (Denmark, Ireland, France), while in other countries (Germany, Italy, the US and Australia) attractiveness and capability are not a priority.

As highlighted in the Jules Verne initiatives in France (Eurofound, 2019f), dual apprenticeship training appears to be the most relevant way to cope with the shortage of skills. However, one problem is the lack of interest shown by young people and companies for this type of training. Many young people prefer to go to university rather than embark on a dual training programme, particularly as industrial jobs are often associated with difficult working conditions. Hence, a series of initiatives to change young people's perception of these professions has been promoted by the employer organisation for the industrial companies of the metal sector (UIMM), in collaboration with the Academy of Nantes, the IRT and the CFAs that are described in depth in the case study report. Some of these promotional practices are similar:

- open days at companies and apprenticeship training centres addressing young people in primary school education and promoting a vocational career in manufacturing
- initiatives addressing young women in particular (for example, 'ABB Girls Camp'; see Eurofound, 2019c)
- initiatives that highlight the broad variety of career paths and progression into higher qualifications on offer in manufacturing following an initial apprenticeship (for example, 'Gateway to Higher Learning' in the Jules Verne case; see Eurofound, 2019f)
- improving the attractiveness of training by guaranteeing that all successful apprentices will get a regular employment contract upon completion of the course (*Übernahmegarantie)* as in the case of the two German companies where this guarantee has been initiated by the employee interest representation and the trade union (Eurofound, 2019b, 2019c)

According to stakeholders interviewed in the Jules Verne case, such activities have already improved the image of apprenticeship. Stakeholders noted that the downward trend in the amount of *alternance* has reversed in the last two years. After a steady decline, the number of industrial apprentices is starting to increase. In industrial trades, an increase by 2 or 3% in the number of apprentices is expected. If the professionalisation contracts are added, the increase would be 5%. There are also positive trends in higher apprenticeships. Figures from the Academy of Nantes show that the number of students in higher apprenticeships (Level III and above) increased by 39% between 2010 and 2016 compared to 29% nationwide. The number of engineer and Master's level students (Level I) has increased by 71% in the region against 53% nationwide. There is also a clear upward trend in recruitment for newly created or revised qualifications. The engineering curriculum created at Polytech Nantes in collaboration with the IRT has an enrolment rate close to 100% compared to enrolment rates of around 50–60% for other diplomas, according to interviewees (Eurofound, 2019f).

Such figures illustrating concrete impacts on attractiveness are not available for the other cases. Here, measuring success or failure of intended outcomes is more difficult and complex, as the Danish 'Talent Tracks' case shows (Eurofound, 2019d). One of the original aims of the 'Talent Tracks' project that started as a pilot in 2010 was to improve the image of vocational training and to help prevent non-completion. As for the first of these aims, we can see that the figures for enrolment of industrial technicians have risen markedly since then, but part of the explanation for this is also that the 2010 figures were heavily influenced by the financial crisis and thus at a record low level. In addition, there have been several other initiatives to increase the recruitment of apprentices in this particular field, notably the industry guarantee that all learners successfully completing the foundation year will receive an apprenticeship contract. Even so, the introduction of 'Talent Tracks', even when it was only a pilot project available in one school, has generated extensive press coverage and has certainly helped to boost the image of the programme.

As for non-completion, this mostly occurs now in the foundation year or immediately afterwards and before the apprenticeship contract has been signed. In fact, one of the causes of non-completion is that learners are not able to find an enterprise with which to conclude an apprenticeship contract, and therefore lose enthusiasm. Once an apprenticeship contract has been agreed, non-completion rates are reduced dramatically, and as 'Talent Tracks' is only an option for learners after the foundation year (and the conclusion of an apprenticeship contract),

it means that the problem is not as acute here as general figures for non-completion would indicate.

Generally, participation numbers in the 'Talent Tracks' programme for apprentice industrial technicians have been too low over the years to have had any marked impact on overall non-completion statistics, and it is not possible to produce any evidence to the effect that participants in 'Talent Tracks' would have been at risk of dropping out if they had not received and accepted the offer. According to the evaluation undertaken, participants in 'Talent Tracks' are generally very positive about the programme and the activities.

The complexity of various factors that influence enrolment and completion rates described in the Danish 'Talent Tracks' case is also representative for other cases analysed in this study. In sum, it is not possible to establish a clear link between a specific good practice and attractiveness.

4.3 Key success factors

When comparing the 14 cases of good practices we noticed that a number of key success factors were highlighted repeatedly across all cases, irrespective of their objectives and activities. The 10 most important success factors are briefly described in the following. It has to be noted that they are complementary, meaning that the more success factors are present in a specific practice, the better.

4.3.1 Firm commitment of key actors, including at top management level, to invest in VET training and apprenticeship

The company-level cases in particular, or those initiated by single companies or groups, highlighted that the firm commitment of high-level management has been a key success factor for good practices. For example, the practices of managing a comprehensive change process at ABB or Airbus would not have been possible without the firm commitment at the highest management level to modernise and adjust initial training and further qualification. At ABB, the modernisation of the training centre and the two programmes described here are related with quite a significant investment in VET, including also the creation of new posts within the company (for example a project manager at the training centre in Berlin).

Quite similar assessments have been made for the cases triggered by Bosch in Italy, Siemens in Australia or Festo in the US. Here, the stimulus, support and cooperation of the parent company for the practices implemented have been a key success factor. In Italy for example, the development of the higher apprenticeship programme was supported by German management, which also contributed to the implementation by hosting trainees for a training period of six months in various plants of the Bosch Group in Germany.

4.3.2 Collaboration, inclusiveness and sharing responsibilities in a multilevel network

All case study analyses concluded that the collaboration with regional education and training institutions, universities and public bodies has been a crucial factor for success in terms of outputs and impacts. As highlighted in the Danish 'Talent Tracks' case, the proximity to the stakeholders in the advanced manufacturing industry, that is the social partners, has been very important. It also should be noted that the project itself was initiated by the employers (the Confederation of Danish Industry), who also provided funding through the Danish Industry Foundation. Similar initiating and facilitating roles of social partners (mainly employer associations) has been reported in the French, Australian and Italian case studies.

For Ireland, the case study on the development of the 'New apprenticeships' programme (Eurofound, 2019h) stresses that the most significant success factor was the commitment of the Irish MedTech Association to coordinate from the beginning the development of two apprenticeships which address the training needs of the manufacturing sector. This is particularly impressive as the MedTech sector has little or no culture of apprenticeship training.

In terms of involving a broad range of stakeholders, inclusiveness has also been highlighted as a success factor in the second Irish case (Eurofound, 2019i). Here, SOLAS coordinated the development of the new MAMF curriculum, with support from individual employers (GSK, Dromone Engineering, Medite Europe and Liebherr); the TEEU, the trade union active in the sector; training providers, such as the Cork and Dublin institutes of technology, and representatives of education and training boards and finally, Quality Qualifications Ireland.

A well-functioning partnership and close collaboration of different actors has also been highlighted in the French and Italian cases as a major success factor. In the French Campus case (Eurofound, 2019g), the partnership of local actors already worked well before the initiative was launched. At the same time, the Campus has managed to expand by including secondary schools and CFAs.

In the case of the Piedmont region of Italy (Eurofound, 2019k), according to the key stakeholders interviewed, university–industry–government collaboration, articulated on several levels from research and technological development to worker training, has been crucial for the success of the practice. Clarity in the definition of roles, the construction of commonly accepted forms of coordination and the sharing of objectives has led to the accountability of the players involved.

However, as has been illustrated earlier, there are significant difficulties in ensuring that a high level of coordination is retained.

4.3.3 Backing of change and adjustment processes by social partners/ active involvement of employee representatives

The Danish and German case studies have highlighted that the support and commitment of trade unions has been essential for the development and implementation of good practices of modernising and adjusting apprenticeship. In Denmark, company-level union organisations and local trade committees have been mentioned as important co-actors. As noted in the

case study (Eurofound, 2019d), by participating in the local and national trade committees, trade unions have helped ensure quality and relevance of the activities on an ongoing basis. In addition, many enterprises have encouraged and supported their apprentices to sign up for 'Talent Tracks' and worked hard to offer appropriate learning opportunities and coordinate these with the activities of the vocational school.

For the two German cases, the involvement of works councils and the backing of trade unions (the German metalworkers' union is a key actor also in national industrial policy debates about advanced manufacturing, adapting the VET system and digitalisation of industry) has been even more essential. At ABB and Airbus, management representatives stated in the context of interviews that comprehensive change projects fostering Industry 4.0 or HR 4.0 would not be possible without the backing of the trade unions and works councils. It should also be mentioned that, according to the German labour code, company VET-related policies and practices are a matter not only of information and consultation but also co-determination. The framework agreement between the Airbus Operations works council and management on a joint approach to implementing the Airbus global Factory of the Future programme and the HR 4.0 projects exemplifies this strong and active involvement of employee representation bodies. It is also significant that the Airbus management head of HR 4.0 and the co-chairperson of the ABB German groups works council are members of a working group on initial and further VET that has been established in the context of the national 'Platform Industry 4.0' by the Federal Ministry of the Economy.

4.3.4 Supportive national and regional framework/reliable financing

Several case studies have highlighted that good practices in the adjustments of apprenticeship programmes and practices in advanced manufacturing are investments that require sound and reliable financing. There is a notable difference between the European cases and the two non-European ones. In the latter case, in the US in particular, it was highlighted that financing has been implemented entirely by the companies involved.

This contrasts with the situation in the European countries, where European, national and regional funds and programmes as well as funds allocated by involved companies have been highlighted as a crucial factor, or rather pre-condition, of good practices.

For example, in the French Campus initiative, the regional council provided strong support. In 2016, regional authorities established a learning development plan and tripled the premium granted to companies that recruit apprentices (from €1,000 to €3,000). In addition, the region provides financial assistance to apprentices (housing, transport, purchase of professional equipment, etc.). Each apprentice can receive up to €1,200. Regional support makes it easier for the Campus to promote apprenticeships and helps convince young people to choose the path of industrial apprenticeship. Moreover, the Campus initiative does this without a stable budget. In the Jules Verne case, both funding and the scale of the initiative have been reduced.

In Italy, the development of the Bosch programme (Eurofound, 2019j) was supported by funding for apprentice training provided by the region in Lombardy. In addition, the new higher apprenticeship programme benefitted from funding by the 'FixO S&U' programme that was established in order to bring more young people into higher apprenticeship contracts.

Another example that illustrates the essential need of sufficient financing is the modernisation of the ABB Training Centre Berlin (that also benefits by collaborating with regional manufacturing businesses): 90% of the infrastructure investments were provided by public funds from the Federal State of Berlin.

It should be noted that public investments in apprenticeship modernisation programmes in all EU countries have also made use of the EU Structural Funds, namely the European Regional Development Fund (ERDF) and the European Social Fund (ESF).

In addition to these crucial success factors, a number of further major factors have been highlighted as important conditions and aspects contributing to successful change projects and initiatives.

- **VET school teaching and infrastructure quality:** In Denmark for example, continuous investment by schools in upgrading teachers' knowledge, skills and competencies to keep abreast of industry developments was highlighted as a major success factor.
- **Quality and relevance of higher-level apprenticeship/VET programmes:** In the French case studies it was highlighted that the attractiveness of higher-level learning is linked to the quality of the available training programmes and the presence of a *technopôle*, a cluster of industrial actors, research centres and technological equipment such as the test and innovation centre.
- **Creating stepping stones for professional upward mobility:** The cases that also aimed to improve the attractiveness of apprenticeship highlighted this factor. In Ireland for example (Eurofound, 2019i), the MAMF apprenticeship demonstrated that it is an important stepping stone from formal schooling to the world of work. Moreover, although there is no academic research on the matter, according to one interviewee, it is considered that a MAMF leads on to a successful career in industry.
- **Customisation and flexibility in programme design:** In the case study of the higher apprenticeship in Piedmont in collaboration with Prima Industrie (Eurofound, 2019k), stakeholders interviewed underlined this aspect as a major success factor. The flexibility of the Master's course in planning off-the-job training content and activities made it possible to address the skills needs at company level and the training expectations of the apprentices.

- **Stable and prosperous regional/local economic conditions:** This aspect was highlighted in the French case study on the campus located in Loire-Atlantique (Eurofound, 2019g). The region is the second most industrialised in France, has strong production growth and hosts Airbus (with two large production sites and 5,500 employees), STX shipyards, Areva, Dassault, PSA, Safran, DAHER, Beneteau and many SMEs, amongst others. This stable and prosperous regional industrial cluster setting has been highlighted as an important factor contributing to the success of the campus initiative.

5 Conclusions

These case studies have demonstrated that it is possible to adjust apprenticeship training to meet the needs of advanced manufacturing. Advanced manufacturing requires workers with high-level skills in production, maintenance and programming, and apprenticeship training continues to provide the conceptual and practical means to develop these high-level skills. However, these case studies are not necessarily the norm, and specific conditions are needed to ensure that apprenticeship training and advanced manufacturing are brought together in the most appropriate way to ensure that this symbiosis functions optimally.

The sample of 14 case studies in this study is characterised by significant heterogeneity in terms of scope, type and pathway of apprenticeship, target groups, manufacturing sectors and occupations addressed as well as, of course, framework and context conditions in five EU Member States and two non-European regions. This heterogeneity should be regarded both as a weakness and as a strength. For example, social partner-driven initiatives such as the Danish 'Talent Tracks' case can hardly be compared with the creation of new occupational apprenticeship programmes such as the MT and the ME in Ireland. In turn, these are different from comprehensive practices, comprising various new practices as described in the example of Airbus Germany and the aviation cluster policies in the Metropolitan Area of Hamburg. While this might be seen as a weakness of the analytical approach, there are also clear strengths: all cases were selected on strict selection criteria and all are related to adjustment of apprenticeship training in advanced manufacturing. Thus, they also reflect the broad spectrum of solutions to the challenges of adapting to new, advanced and digital technologies, production modes and processes that are applied across Europe and two regions outside Europe. Against this background, this study highlights that there are no single solutions or pathways to respond to the skills challenges of digitalisation of industry and advanced manufacturing. Moreover, despite all heterogeneity, the study has identified a number of common success factors that apply across all case specificities.

Some general conclusions arising from the case study research can be drawn with regard to adjusting apprenticeship training in advanced manufacturing.

Adjustment of apprenticeship training happens continuously

All case studies show that adjustment of apprenticeship training is made on a continuous basis, irrespective of legal and institutional framework conditions. In particular, the fragmented apprenticeship system in the US shows that in the absence of centralised regulation, adjustments to programme content, skills provision and apprenticeship training outcomes are made at the company level.

There is a need for an integrated vision for change

Many case studies have stressed the importance of developing an integrated vision for change that combines advanced manufacturing policy with apprenticeship training policy. Developing advanced manufacturing, whether at national, sectoral, regional and/or local company level, without a strategy which includes skills must surely fail; likewise, developing a strategy for skilled workers without a thriving advanced manufacturing sector. Moreover, this integrated vision for change must include large companies as well as SMEs, collaborating in some sort of nexus, an 'ecosystem for development and innovation', as in Italy for example, linking skills and infrastructure.

Collaboration with social partners

Many case studies have underlined the importance of collaboration between social partners (companies, employers, employer associations, trade unions, public authorities and training providers) at different stages of the process of designing and implementing apprenticeship training policy. This may be at the sectoral level, regional level or at the local company level, depending on the appropriate national circumstances. Moreover, this collaboration needs to have some form of dynamic institutional coordinating presence, either in the form of works councils (Germany), trade committees at the sectoral and local levels (Denmark), sectoral employer associations such as MedTech Association (Ireland) or via industrial companies at group or local level (Siemens and Varley in Australia, ABB and Airbus in Germany, Bosch in Italy, Festo and Oberg Industries in the US). To be effective, this synchronisation of effort needs to take place at the level considered most favourable in each country; lack of coordination leads to confusion, inconsistency and inability to make decisions.

Nimble and targeted decision-making

Many case studies have drawn attention to the urgency, or rather lack of urgency, with which decisions on apprenticeship training strategy and programmes are taken; two to three years to define occupational profiles and training programmes, develop curricula and assessment methods and validate a qualification is simply inappropriate for a fast-moving industrial environment. By the time the qualifications have been approved, apprentices have been recruited, programmes have started and there is a real chance that apprentices are being asked to learn some skills that are already becoming obsolete. Moreover, as has been highlighted in some case studies, there is a need to be able to shape skill sets and to acknowledge prior learning. This then favours qualifications designed with some in-built flexibility so

that they can be implemented in tune with the evolving needs of companies in the advanced manufacturing sector.

Mismatch of supply and demand

Many case studies have drawn attention to a mismatch between supply and demand for apprenticeship places: there are too many young people applying for some apprenticeships, or not enough – or not enough with the appropriate basic maths, communication and social skills – or there are not enough companies willing to take on apprentices. Either way, employers and/or young people are wasting their time. Moreover, a lack of places may create a situation where training providers do not have enough apprentices to provide off-the-job training. This only underlines the importance of anticipating industry skills needs, creating appropriate and attractive pathways for young people into apprenticeship programmes and proactively matching services.

Specific versus transversal skills and competencies

The strength of our study has been that it has dealt not only with initial apprenticeship training (at EQF levels 3–5) but also higher apprenticeship/VET programmes (EQF levels 6–8). Here, the research has shown that two trends are clearly visible across national and other contexts. First, advanced manufacturing triggers the need to integrate new and transversal skills and competencies into initial training and apprenticeship programmes across all occupational profiles. As highlighted in case studies, for example 'Modernisation of dual apprenticeship training at ABB' (Eurofound, 2019c) in a future manufacturing work 4.0 environment, workers and employees across all manufacturing occupations need to possess skills and competencies in fields such as learning and working in a digitalised world, ICT hardware and software, data handling and digital systems and processes. In addition to these transversal skills and competencies, the case studies on higher VET and apprenticeship pathways have shown that advanced manufacturing also requires a deepening of skills and competencies in specific technologies, or advanced materials and their application in the production process. This has certainly initiated the current trend for new dual industrial Bachelor or Master's degrees highlighted in many case studies. At the same time, specialisation has also been introduced in initial apprenticeships as shown in the case studies that examined initial apprenticeship programmes in Denmark, France, Germany or Ireland. In this context, modular programmes play an important role.

Resources and investments in hardware and software

The case studies in this report have shown that adapting apprenticeship training to new skills and competencies requires significant effort at both company level and for the off-the-job part in VET schools; investment is also necessary in new advanced manufacturing technologies such as robotics, 3D printers or new materials, as well as in training places and digital devices. Furthermore, significant investment must be made in human capital, new pedagogical concepts and development of VET teachers' and mentors' skills. While such investments are possible for large companies, SMEs (often suppliers of the large companies) are much less able to afford this. Hence, the concept of collaborative training facilities – the new ABB Training Centre Berlin, the 'Knowledge centres for robot technology and automation' in Denmark, the JVMA or the Job and Qualification Campus in France – is certainly innovative because it also targets SMEs in the respective regions. The majority share of such investments cannot be made by companies alone but must be provided by local, regional and national public authorities, often with EU-level financing from funds such as the European Structural and Investment Funds. This public financing of VET infrastructure modernisation and adjustment of personnel development represents a clear competitive advantage for the EU when compared to the two non-European countries covered by our research, where nearly all investment in the apprenticeship system comes from the private sector.

Postscript: The cases in light of the European Framework for Quality and Effective Apprenticeships

The methodology for this research was established before the criteria for the Recommendation on a European Framework for Quality and Effective Apprenticeships were agreed by the Council of the European Union in March 2018 (Council of the European Union, 2018) and so does not specifically refer to the criteria laid out in the Recommendation. This means that the research design and the analytical approach for the national analysis of the apprenticeship systems (see Eurofound, 2018a) and the good practice case study analyses (this report) in the five EU countries and the two non-EU countries had no direct links to the Recommendation on a European Framework for Quality and Effective Apprenticeships. Thus, while some aspects included in the Recommendation – for example the definition of apprenticeship[2] and some of the criteria for learning and working conditions and for framework conditions – have also been analysed in the country-specific reports and the case study reports, others were not. For example, our analyses have not addressed criteria related to learning and working conditions such as social protection or work, health and safety conditions nor analysed more thoroughly framework conditions such as flexible pathways and mobility or transparency.

Moreover, at the time of writing, the process of monitoring the implementation of the Recommendation has not yet started, and it is only in March 2021 that the European Council will formally consider a report on the implementation of the Recommendation.

However, due to the overlapping of our national analysis of seven countries and the more in-depth analysis of 14 specific cases and the elaboration of the Recommendation by the Commission and the Council Decision of March 2018, the researchers conducting the analysis agreed with Eurofound to include a reflection of the national systems and the case studies in light of the European Framework.

Considering the limitations mentioned above, this reflection takes the form of a postscript that has been added to the main body of our research after fieldwork and interviews with key national and case-specific stakeholders were conducted. The information presented in this postscript is based not only on the case study analysis but also the analysis of the national apprenticeship systems in the seven countries covered by our research (see the respective country reports as well as the comparative report of the national analyses).

There is, however, some circumstantial evidence summarised in the following paragraphs and the two comparative tables that the criteria defined for learning and working conditions and for framework conditions in the Recommendation are generally reflected in the examples of apprenticeship training to be found in the five countries of the European Union (Denmark, France, Germany, Ireland and Italy) and one of the non-EU countries (Australia). The evidence for the other non-EU country, the US, is less convincing, particularly for the framework conditions.

The cases in light of the criteria for learning and working conditions

With a view on learning and working conditions frameworks, the Recommendation refers to seven criteria for quality and effective apprenticeships: written agreement; learning outcomes; pedagogical support; workplace component; pay and/or compensation; social protection; work, health and safety conditions.

Written agreement: In all seven countries and the 14 company cases, apprentices sign a written agreement with an employer and, where appropriate, a VET institution, related to learning and working conditions. This agreement may take the form of an employment contract (Denmark, France, Ireland, Italy), a training contract (Germany) or a combination of the two (Australia, US).

Learning outcomes: Each of the EU countries and Australia have established a national qualifications framework (NQF) based on learning outcomes describing what a learner knows, understands and is able to do. In Italy however, the vast majority of apprenticeship qualifications are not recognised formally by the Italian Qualifications Framework. Note that the alignment of national qualification frameworks to the EQF has not been addressed specifically by the national and/or case study analysis of our research. However, our study confirmed results of comparative overviews that show that the influence of the EQF on the development of NQFs differs across European countries. With regard to the sample of countries analysed in this study, France and Ireland had developed NQFs prior to the EQF, while all others have developed NQFs in response to the EQF. According to a recent Cedefop report (Cedefop, 2018), alignment ranges from direct use of EQF descriptors to going beyond the EQF by emphasising the notion of professional and

2 In the Recommendation, four aspects were highlighted as crucial for the definition of apprenticeship:

a) combine learning in education or training institutions with substantial work-based learning in companies and other workplaces; b) lead to nationally recognised qualifications; c) are based on an agreement defining the rights and obligations of the apprentice, the employer and, where appropriate, the vocational education and training institution, and, d) with the apprentice being paid or otherwise compensated for the work-based component.

Council of the European Union (2018), p. 3.

personal competencies for learning outcomes (for example Germany).

Pedagogical support: According to the Recommendation, 'in-company trainers should be designated and tasked to cooperate closely with VET institutions and teachers to provide guidance to apprentices and to ensure mutual and regular feed-back'. Furthermore, this refers to updating the skills, knowledge and competencies of teachers, trainers and mentors in line with the latest teaching and training methods and labour market needs. The topic of skills and competency development of training and mentoring personnel has been addressed in our study with a focus on the national apprenticeship systems as well as the individual case studies. Whereas the national analyses have identified a number of challenges and deficits concerning cooperation between in-company and off-the-job training (see the comparative report), the 14 case studies have highlighted this aspect as one crucial qualifying criteria of good practice both as regards initial dual VET practices and on higher apprenticeship programmes.

Workplace component: In all seven countries, apprentices spend at least half of their time engaged in on-the-job activities and training. As shown in Table 7, the workplace component varies from around 50% in the analysed higher apprenticeship programmes in Italy and Australia to around 80% in the case of initial apprenticeship training in the US.

Pay and/or compensation: In all seven countries and all cases analysed in the study, apprentices are paid a wage in line with national or sectoral requirements, collective agreements (Denmark, Germany and Ireland for designated craft apprenticeships), an agreement between the employer and the apprentice (Ireland for new apprenticeships) or a minimum apprenticeship wage (France).

Note, however, that the topic of pay and compensation has not been analysed specifically in this study but in the context of the national regulatory frameworks and case-specific contractual relations between the company and the apprentice.

Also, the issues of **social protection** and **work, health and safety conditions** have not been addressed specifically in the research. However, in all seven countries, apprentices should be entitled to social protection, including necessary insurance, in line with national legislation. Furthermore, in all countries and the analysed company-specific cases, the host workplace is required to comply with relevant rules and regulations on working conditions, in particular health and safety, as well as working time regulation, including specific/additional regulations for the protection of youth where applicable.

Table 7: European Framework for Quality and Effective Apprenticeships: Criteria for learning and working conditions

Criteria	Innovative practices at Airbus – Germany	Modernisation at ABB – Germany	Talent Tracks – Denmark	Knowledge centres – Denmark	Jules Verne Manufacturing Academy – France	Job and Qualification Campus – France	'New' apprenticeships – Ireland	Modernisation of designated craft – Ireland	Bosch Industry 4.0 Talent Program – Italy	Higher Apprenticeship – Italy	Siemens pilot programme – Australia	Varley Group – Australia	Oberg Industries – United States	Mechatronics Festo Didactic – Unitd States
Written agreement	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Learning outcomes	•	•	•	•	•	•	•	•	•	•	•	•	Weak	Weak
Pedagogical support	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Workplace component	70%	70%	75%	75%	75%	75%	60%	60%	50%	66%	58%	70%	80%	75%
Pay and/or compensation	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Social protection	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Work, health and safety conditions	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Source: *Authors' own elaboration*

The cases in light of the criteria for framework conditions

With a view on framework conditions, the Recommendation refers to seven criteria for quality and effective apprenticeships: regulatory framework; involvement of social partners; support for companies; flexible pathways and mobility; career guidance and awareness raising; transparency; quality assurance and tracking of apprentices.

In our study, some of these framework conditions have been analysed in the national analysis of the apprenticeship systems in the seven countries, namely regulatory framework, role of social partners, support for companies and quality assurance system and practice. These and other framework conditions (related to the local and regional settings) have been elaborated in the context of the case study research (see Table 8).

Regulatory framework: All the EU countries and Australia have detailed national, sectoral or regional regulatory frameworks, including: setting out institutional mechanisms for governing and managing apprenticeships; clarifying the rights, roles and responsibilities of stakeholders; establishing occupational profiles, training standards, curricula, assessment criteria and certification of learning; establishing eligibility requirements for training institutions and enterprises and deciding on the funding of apprenticeships. As described in more depth in the national analysis of the apprenticeship system and practice in the US, the regulatory framework for registered apprenticeships is characterised by a wide variety of registration practices at federal and state level.

Involvement of social partners: In all the EU countries and Australia, social partners (employer associations and trade unions) are involved in the design, governance and implementation of apprenticeship schemes. In some countries this represents a balanced partnership between the two (Denmark and Germany at national, sectoral and even local level), while in others (France, Ireland and Italy) apprenticeships are employer-led, but with trade union participation in some regulatory bodies. The more in-depth analysis into the case study examples in the countries showed quite a strong variety of involvement of employers and worker organisations at regional and company level. As far as the US is concerned, the national and the case study analyses both found that apprenticeship practice is driven largely by industry and companies, with some involvement of VET institutions but no engagement of trade unions.

Support for companies: The analysis of national apprenticeship systems and the case study analysis of company cases and their regional embeddedness shows that in all the analysed EU countries and Australia, various forms of financial and non-financial support and incentivisation to companies is provided by national governments and public authorities at regional and local level. Financial support may take the form of subsidies or tax credits for hiring an apprentice, financing of the off-the-job training part of apprenticeship training, subsidies or financing of apprenticeship wages during off-the-job training, specific support for certain occupations or incentives for female participation in craft-designated apprenticeships (Ireland) or for 'vulnerable' groups (Denmark, Germany) or apprenticeships coming from rural areas (Australia). Also, the case studies show that companies receive various forms of non-financial or indirect support in the form of regional and local economic and labour market policies.

Amongst the sample of countries covered by the study, the US is the only one where government funding for apprenticeship training remains marginal. Apart from limited funds made available for pilot actions or specific time-limited projects, companies undertaking apprenticeships generally must finance not only the costs of the on-the-job training but also the costs of related academic instruction themselves.

Flexible pathways and mobility: In most countries, qualifications acquired through apprenticeships are included in nationally recognised qualification frameworks which may improve access to learning at other education and training levels. However, national experience also shows that progression to higher pathways is complex in practice. In Italy for example, only a small percentage of apprenticeships recognised by the social partners have access to learning at higher education and training levels, not the majority of apprenticeships. In other countries, for example Germany, the easing of progression of apprentices to higher education pathways has been and still is an important topic addressed by education and VET reforms.

With regard to the 'flexible pathways and mobility' highlighted in the Recommendation – such as considering informal and non-formal learning, preparatory programmes or transnational mobility – these have not been addressed in this study.

Similarly, the 'career guidance and awareness raising' framework criterion has not been addressed in this study, neither in the context of the national analysis nor in the context of the case study research. However, the case studies show that the good practices analysed are characterised by relatively strong elements of mentoring and support for apprentices and learners provided by companies, VET schools and other actors (local and regional bodies). Some cases, for example the two German cases, are also characterised by active awareness raising and promotional activities for apprenticeship occupations in manufacturing conducted by local/regional actors.

Also, with regard to the 'transparency' criterion, our study has provided little additional information apart from basic requirements according to the national regulatory frameworks concerning institutions involved in the respective VET systems providing information on contents and access to apprenticeship offers. Union tools such as European Employment Services (EURES) have not been a specific topic of this research and also have not emerged as an issue in the national or case study analyses.

Quality assurance and tracking of apprentices: According to the Recommendation:

> *Quality assurance approaches should be in place taking into account the European Quality Assurance*

> *Reference Framework for Vocational Education and Training (EQAVET) including a process allowing a valid and reliable assessment of the learning outcomes. The tracking of employment and career progression of the apprentices should be pursued, in accordance with national and European legislation on data protection.*
>
> (Council of the European Union, 2018)

Though the issue of quality assurance has been tackled by the case study research and the analysis of the national apprenticeship systems, the research focused on national and case-specific practices. Differences and challenges of linking national practices to the European quality assurance concept were highlighted for Germany only.

With regard to the assessment of learning outcomes and the tracking of employment and career progression of apprentices, our study showed that significant variety exists between countries. Although this issue was not analysed systematically, evidence shows that existing data are inconsistent and do not allow quantitative cross-country comparison of data, for example on completion rates of progression to higher educational pathways.

Table 8: European Framework for Quality and Effective Apprenticeships: Criteria for framework conditions

Criteria	Innovative practices at Airbus – Germany	Modernisation at ABB – Germany	Talent Tracks – Denmark	Knowledge centres – Denmark	Jules Verne Manufacturing Academy – France	Job and Qualification Campus – France	'New' apprenticeships – Ireland	Modernisation of designated craft – Ireland	Bosch Industry 4.0 Talent Program – Italy	Higher Apprenticeship – Italy	Siemens pilot programme – Australia	Varley Group – Australia	Oberg Industries – United States	Mechatronics Festo Didactic – United States
Regulatory framework	•	•	•	•	•	•	•	•	•	•	•	•	Weak	Weak
Involvement of social partners	•	•	•	•	•	•	•	•	•	•	•	•	No	No
Support for companies	•	•	•	•	•	•	•	•	•	•	•	•	No	No
Flexible pathways and mobility	Only addressed partially by the study; significant differences between countries and cases												Depends on company	
Career guidance and awareness raising	•	•	•	•	•	•	•	•	•	•	•	•	Weak	Weak
Transparency	Only addressed partially by the study; transnational aspect/EURES not covered												Weak	Weak
Quality assurance and graduate tracking	•	•	•	•	•	•	•	•	•	•	•	•	Weak	Weak

Source: *Authors' own elaboration*

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

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Annex 2: List of organisation names and acronyms

Abbreviation	Definition in original language	Definition in English
AZB	ABB Ausbildungszentrum Berlin	ABB Training Centre Berlin
CEDEFOP	Centre Européen pour le Développement de la Formation Professionnelle	European Centre for the Development of Vocational Training
CFA	Centre de Formation d'Apprentis	apprenticeship training centre
CFK	Carbonfaserverstärkter Kunststoff	carbon fibre reinforced plastic
CMQ-FIAEM	Campus des métiers et des qualifications du Ferroviaire, de l'Industrie Automobile et de l'Ecomobilité	Job and Qualification Campus for Railways, the Automobile Industry and Eco-Mobility
Confindustria	Confederazione Generale dell'Industria Italiana	General confederation of Italian industry
DFKI	Deutsches Forschungszentrum für Künstliche Intelligenz	German Research Center for Artificial Intelligence
EUC Syd	ErhvervsUddannelsesCenter Syd	Vocational Educational Centre South
IG Metall	Industriegewerkschaft Metall	Industrial union of metalworkers
SDE	Syddansk Erhvervsskole	Vocational Education College South Denmark
SOLAS	An tSeirbhís Oideachais Leanúnaigh agus Scileanna	Further Education and Skills Service
SpA	società per azioni	public limited company
UIMM	Union des industries et métiers de la métallurgie	employer organisation for the industrial companies of the metal sector
ZAL	Zentrum für Angewandte Luftfahrtforschung	Hamburg Centre of Applied Aeronautical Research

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Building on the analysis of national apprenticeship systems in the 2018 Eurofound report *Adaptation of national apprenticeship systems to advanced manufacturing*, this report summarises the results of 14 case studies of good practice in the manufacturing sector in five EU Member States (Denmark, France, Germany, Ireland and Italy) and two countries outside Europe (Australia and the United States). Situated in different national and sector-specific environments, all case studies are characterised by the aim to adjust apprenticeship programmes and/or practices in response to challenges emerging from advanced manufacturing technologies and processes. The case studies examine a series of different issues, notably context, drivers for implementing change, impact and crucial factors for success.

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