WORKING PAPER

Future of manufacturing

Mechatronics Apprenticeship Program of Festo Didactic – United States

Company initiatives to align apprenticeships to advanced manufacturing

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Introduction

Scope of the research

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

One of the objectives of this study is to provide an analytical overview of apprenticeship systems in the selected countries and to review changes to the current systems following labour market shifts, changes in employment, career and mobility patterns and technological and structural change. Particular emphasis is placed on the impact of new technologies and the need for a high skilled and adaptable workforce in manufacturing and advanced manufacturing. This research is carried out in response to the increasing interest in apprenticeships among policy makers to tackle skills mismatches but also to integrate young people into the labour market. The appeal of apprenticeships is also growing particularly in a context where new technologies are transforming work organisation and production processes across all sectors, particularly manufacturing. The findings from this research will feed the policy discussions around the role of apprenticeships for the future of manufacturing and inform policy making in the context of current or planned reform of apprenticeship systems and the necessary links to be established between education/training and industrial policies.

For general information on advanced manufacturing and the apprenticeship system in the United States, the case study report builds on the information contained in the national report on apprenticeships in the advanced manufacturing industry in the US that was elaborated during the first phase of the study (Eurofound, 2018).

The case at a glance

Festo Didactic has implemented an advanced manufacturing apprenticeship program focusing on the need for advanced technical skills in mechatronics for companies in the region. The start for an apprenticeship program in 2016 arose after Festo located a Regional Service and Logistics Centre in Mason, Ohio. As Festo began interviewing and hiring workers from the local region, it became clear that the local workforce lacked the required skillsets, and that they would need to grow their own technicians locally with advanced skills in mechatronics, logistics and industry 4.0 technologies. In effort to find local support, Festo shared this information with the European American Chamber of Commerce of Greater Cincinnati, who later approached Festo and other local stakeholders to build a training centre that would help supply the region with an adequate supply of highly skilled workers.

This case study describes Festo's investment of 'physical capital assets' in the logistics centre and 'human capital assets' in a collaborative apprenticeship program called MAP 2 (Mechatronics Apprenticeship Program Partners) with Sinclair College. It discusses how these investments in physical capital and apprenticeship have stimulated growth in the community's economy and workforce development.

Assessment of the case study against selection criteria

The case examines four forms of adaptation of apprenticeship, including: (a) modernisation of a specific occupation; (b) creation of new occupations/emerging occupations; (c) creation of a

company apprenticeship and training programme; and (d) organisation of apprenticeships/training in (regional) clusters.

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1. modernisation of a specific occupation;
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Structure of the report

The report is made up of four parts. The first part provides background information on the company in the context of its region and industry sector. The second describes the set-up and implementation of the advanced manufacturing apprenticeship. The third part evaluates the early outcomes and impacts of the program. A final section views the initiative from the perspective of the ongoing development of apprenticeships in the advanced manufacturing sector and draws conclusions about the implications of the case for policy.

1 Context factors

1.1 Regional/sectoral and/or company-specific set-up

US durable goods manufacturing sectors have accounted for a declining number and percentage of jobs over the last decades. Though US manufacturing has experienced substantial growth over recent years, much of the growth is limited to the computer industry and not to automating other industries. As Houseman (2018) points out, manufacturing output growth and productivity growth outside the computer industry have been modest. In Ohio alone, where Festo is located, manufacturing jobs declined sharply from over 1 million to about 750,000 between 2000 and 2007. The recession of 2008-2009 led to further reductions and a low of 614,000 manufacturing jobs in the first quarter of 2010. Since then, employment in manufacturing has gradually increased, reaching 690,000 in late 2017.

In researching and interviewing US companies like Festo, the authors have observed international competition is such that the US must become better at adapting to sophisticated and advanced manufacturing technologies (see Eurofound, 2018). This includes beginning to produce talented workers with advanced manufacturing skills who can perform at high levels in using the new technologies. The specific skill areas of importance include: CNC production, Mechatronics, Logistics, Industry 4.0 capabilities, and Additive manufacturing.

Festo is a leading worldwide supplier of intelligent automation solutions, pneumatics and electromechanical systems, as well as components and controls for industrial processes and automated technologies. Festo's products and services are available in 176 counties. With approximately 20,100 employees in more than 250 branch offices in 61 countries worldwide today, serving 300,000 customers is over 35 industries, Festo's sales exceeded $3.5 billion (€ 3 billion) in 2017. Festo is one of the worldwide leading founding companies and contributors to the development of Industry 4.0 and the IoT (Internet of Things) technologies.

Festo was founded in 1925 and has a long history of hiring apprentices as its primary skills talent pipeline in Germany and other worldwide locations, and, more recently, now in the US. In Esslingen, Festo's worldwide headquarters, Festo employs 350 apprentices, 20 in Switzerland, 70 in China and 9 currently at Mason, Ohio with a total of 458 apprentices worldwide. Festo staff attributes Festo's worldwide leadership today in research, innovation and productivity to its long-term commitments into developing its future employees and workforce through apprenticeships.

In addition to Festo's worldwide presence as a global leader in intelligent automation solutions, Festo Didactic, a wholly-owned subsidiary, is the world-leading provider of equipment and solutions for technical education for CNC, Mechatronics, Industry 4.0, logistics and telecommunications. The product and service portfolio offer customers holistic education solutions for all areas of technology in factory and process automation, such as pneumatics, hydraulics, electrical engineering, production technology, mechanical engineering, and mechatronics.

Festo Didactic products incorporate the company's theoretical knowledge along with its practical experience in automation and technology. Intuitive and fast learning is achieved through practical learning systems and learning factories, which make the technologies and processes used in industrial production immediately tangible and understandable. As people learn these systems, they can use them to gather the real, practical experience that they need to work independently in industry and quickly contribute to the company's productivity.

The training equipment provided by Festo Didactic enables student apprentices to learn a combination of academic theory and lab training that adequately prepares them for on-the-job-

training with an employer in three of the five skillsets highlighted above, specifically mechatronics, logistics and Industry 4.0 skills capabilities.

Festo Corporation USA's Regional Service Center is in Mason, Ohio. Its primary focus is to serve as a distribution hub and service centre to Festo customers in North, Central and South America. It employs people with highly technically advanced skills in CNC production, Mechatronics, Logistics and Industry 4.0 technologies.

Festo initially invested $70 M (€ 60 million) into its RSC operations in Mason, Ohio and began operations in their new 200,200 square foot logistics and assembly plant in October 2016. With this new facility, Festo is able to reach over 70% of its North American customer base within one day. The facility has the following capabilities to provide services to customers:

- Warehousing and distribution of Festo component parts (utilizing employees with competencies in logistics and Industry 4.0)
- Customized product manufacturing – ability to customize an order in-house (utilizing CNC machine operators)
- Customer-specific assemblies using Festo components (utilizing Mechatronics Technicians and CNC machine operators)

In addition to these capabilities and competencies, Festo has dedicated 5,500 square feet of space to the FESTO MAP2 (Mechatronics 2.0) apprenticeship training centre within their logistics centre. It also invested $1.3 M (€ 1.1 million) to outfit the training centre with the proper equipment. Of the training centre's 5,500 square feet, Festo allocated spaces to a separate training lab for Festo apprentices and apprentices of other companies, and to a machine shop that houses Sinclair College equipment (lathes, grinders, CNC equipment), and to a Festo Didactic equipment area where all MAP2 student apprentices learn mechatronics skills (combining electronics, mechanics, pneumatics, hydraulics and PLC, etc.) and how to apply them on the job as an apprentice at Festo and other participating company sponsor locations.

1.2 Relevance of dual apprenticeship

The national analysis documented that the US is well behind other countries in creating apprenticeships at scale and in developing a well-structured apprenticeship system. 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 programs in the other half. Funding for the administration of the system is miniscule, with only 1-2 people in some large industrial states responsible for auditing, marketing to employers and registering programs. 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 program. As a result, each firm or small group of firms must establish their own framework and sometimes spend months or years getting their program registered.

Apprenticeships represent a very small share of the manufacturing workforce, only about 20,000-30,000 of nearly 13 million (Office of Apprenticeship). Yet, six out of 10 openings in manufacturing remain unfilled due to a talent shortage (Deloitte 2015). Although technical change is not the only reason for skill mismatches, the introduction of new advanced manufacturing technologies and automation is having a serious impact, as is the loss of embedded knowledge of experienced workers retiring or about to retire. Given these factors, manufacturing apprenticeships should appeal to employers dealing with new technologies.

Only recently has the US registered apprenticeship system begun to help establish broad-based skill requirements for apprentice occupations in manufacturing. Past practice has required employers and union-employer collaborations to create their own lists of skills, or "work processes," that their apprentices will learn and the hours devoted to each skill. Individual states often added regulations that go beyond federal requirements, such as setting a relatively high ratio of journeyman to apprentices. The ratio requirements may drive some employers to develop apprenticeships outside the registered system.

One of President Donald Trump's proposed reforms involves creating "industry-recognized apprenticeship programs" (IRAPs). These would require some sort of industry-recognized credentials but these would not necessarily register under existing registered apprenticeship regulations. The specifics of IRAPs have yet to be spelled out. President Trump has also proposed increasing federal spending on apprenticeship program development and increasing the number of apprentices over ten fold.

1.3 Needs and challenges related to manufacturing and advanced manufacturing

Intermediary groups are trying to promote apprenticeships within specific industries. These include Jobs for the Future (JFF), a non-profit focusing on apprenticeships in manufacturing and telecommunication. Meanwhile, the National Institute for Metalworking Standards (NIMS is developed detailed skill frameworks for several occupations, such as Computer-Aided Manufacturing (CAM), Industrial Technology Maintenance (ITM), Machine Maintenance, and Machining. Manufacturing employers in the metal industries are drawing on NIMS credentials in developing apprenticeships or other training. Some training for advanced manufacturing takes place outside the registered apprenticeship framework. A good example is the Kentucky Federation for Advanced Manufacturing Education (KY FAME), which uses apprentice-style programs that combine work-based learning with educational institutions.

The US registered apprenticeship system requires approvals almost on a one-by-one individual firm basis. Approval processes can be exceedingly slow. The structure of the existing system makes it difficult to respond to the changing nature of occupations.

Finally, a plethora of skill credentials has emerged in the context of the US labour market. Most of these credentials are far less broad than credentials from high quality apprenticeship programs and are generally not widely recognized by employers. They often emphasize skill development with short-term modules outside the formal apprenticeship system. Fortunately, Festo Didactic is on the forefront in helping to improve the credentials in mechatronics, logistics and industry 4.0 skills in the US. Festo Didactic has recently been working collaboratively with NIMS and the Urban Institute to improve credentialing standards in these skills where there is a lack of existing mechatronics standards, programs and curriculum in the US. In collaborating with NIMS and its national footprint of advanced manufacturing standards, Festo Didactic is preparing to roll out the Festo MAP 2 program across the US.

2 General information on the case

2.1 Background and reasons of initiating the practice

When Festo Corporation USA made its decision to locate its logistics and assembly regional service centre to Mason, Ohio in July 2013, the primary drivers for this decision were:

- Mason, Ohio provided a central location to its North American customer base (70% of customers can be reached within one day) and a central location for supplying customers in Canada and Mexico;
- As Festo decided to expand its local operations, Festo gained support from local stakeholders through well-established existing relationships with city, regional and state officials in Ohio;
- Foreign Trade Zone status (international component shipments that come in to the facility and are modified and shipped onward to customers without incurring import duties);
- The area consisted of a well-established regional economic and workforce development ecosystem that seemed capable of producing a workforce talent pipeline in advanced technologies innovation such as mechatronics, robotics and Industry 4.0/Internet of Things (IoT)

The initial investment into "physical capital assets" included a capital investment in new construction and equipment for an additional 150,000-square foot building on a 47-acre site (bringing total square footage to 200,200) to employ an additional 170 people. Festo announced the opening of its new RSC facility in October 2016.

Simultaneously, with the investment into the new facility, Festo also launched the Festo MAP2 apprenticeship program in collaboration with Sinclair College in August 2016. Festo Didactic, a well-established manufacturer of education equipment for more than 40 years, became involved to help launch the program.

Recently, on April 10, 2018, Festo announced another investment of $90 million (€ 77 million) to triple its current capacity by adding another 350,000 square foot of space and employing an additional 350 employees. This new announcement increases the priority for Festo to continue its investment into human capital through the MAP2 apprenticeship program.

Festo collaborated with four other local companies in (Art Metal Group, Clippard Instruments, MQ Automation and Nestlé) in August 2016 to start a two-year mechatronics apprenticeship program in collaboration with Sinclair College. 11 students were among the first group of apprentices recruited into the program in 2016, of which 5 of them were recruited by Festo. These apprentices began their training for careers as maintenance, service and manufacturing technicians, and automation specialist.

2.2 General and detailed objectives and expected results

Festo views the development of the Festo MAP2 apprenticeship program as a critical element to the company's success in keeping pace with changes in technology and continual upgrading of its Regional Service Centre. Though the apprentices will start their careers at Festo in occupations such as maintenance, service and manufacturing technicians, and automation specialists, Festo views these occupational areas as only the beginning for the new employees as they extend their careers with Festo.

The company recruits a new group of five student apprentices each year in order to keep their technically skilled recruitment pipeline adequately filled from year to year. This strategy will enable Festo to grow a strong base of highly skilled technicians that will stay with their company, potentially for their entire careers. Festo invests heavily into advanced training for all employees

to enable them to improve their skills on an ongoing basis, thereby helping them reach their maximum career potential. Typically, student apprentices at Festo have the opportunity to go on to middle and upper management positions and/or engineering careers. It is not uncommon that many of the upper management executive staff including Presidents and CEOs at Festo's worldwide facilities to have started their careers in apprenticeship programs.

With the recent announcement of tripling capacity with the expansion of their existing facility adding another 350,000 sf and 350 new employees, it is even more critical for Festo to maintain a leadership role to continue to develop a successful Festo's MAP2 apprenticeship program.

Though the German mechatronics apprenticeship program is a 3.5-year program that typically starts with high school students at the age of 16, Festo decided to begin their US program with students apprentices that are 18 years or older, typically at the community college level, and to develop a 2.5-year program. Festo chose this approach for several reasons. First, unlike several European countries, the US lacks governmental body to oversee manufacturing apprenticeship standards and assure that student apprentices attain required competencies by age 18. Second, customizing the German apprenticeship model is easier at the two-year college level than at the high school level. Third, apprenticeships in the US carry a blue-collar stigma that makes high school students and their parents reluctant to participate during their high school years. Starting students at the community college level will allow learners and their parents to see themselves as going to college and likely graduate with at least a two-year college degree. Fourth, by the time students reach the community college level, they are usually looking for work to pay for college. As a result, they become good candidates for employment as an apprentice and can earn income while going to school. Finally, implementing successful programs at the two-year college will help over time to win broad public support for apprenticeships nationally.

2.3 Linkages to national programmes and initiatives

In order to assure that mechatronics apprenticeship program meets the highest quality of world-class benchmark standards Festo is used to in Germany, Festo collaborated with the Midwest German American Chamber of Commerce (GACC Midwest). The GACC Midwest is the German governmental agency with offices in Chicago and Detroit that audits, monitors and ensures the quality of German apprenticeship programs in the Mid-West US states. The GACC Midwest also provides the mid-term testing and proctors the final exams to issue authentic German apprenticeship AHK certificates to the student apprentices who successfully pass the final written and practical hands-on exam.

In addition, the MAP2 program is a US DOL approved registered program. Festo registered with the local US DOL apprenticeship agency to assure that both the program is recognized as a registered apprenticeship program in the US and that the related occupation, Mechatronics Technician is recognized on the US DOL approved occupations list.

Festo has also worked very closely with NIMS to make sure its Festo Map2 Mechatronics standards are recognized by NIMS. This assures that the Festo MAP2 program can be either implemented as a time-based apprenticeship program or can be implemented as a modular competency-based apprenticeship program that will earn the student apprentice a NIMS certificate at varying competency levels.

Festo is also working in collaboration with the Urban Institute, which is under contract with the US DOL to review and establish competency-based occupational frameworks for apprenticeship programs in the US. Festo is making a formidable contribution of its time and know-how to help establish and verify mechatronics occupational standards in the US with the intended outcome to help create US mechatronics standards that are globally competitive with other world-class mechatronics apprenticeship standards, such as those established in Germany.

2.4 Scope of the programme/initiative

As mentioned earlier Festo aligned with four other local companies in August 2016 (Art Metal Group, Clippard Instruments, MQ Automation and Nestlé) to start a two-year mechatronics apprenticeship program in collaboration with Sinclair College. Eleven students were the first group of apprentices recruited into the program in 2016, of which five were recruited by Festo. These apprentices began their training for careers as maintenance, service and manufacturing technicians, and automation specialists.

Every week, the apprentices spend one day at Sinclair Community College for classes, one day using state-of-the-art equipment at the new Festo Learning Centre in Mason, then three days working at their respective employers. The apprentices are able to take what they learn in class, practice it at the Festo Learning Centre (with workstations that simulate a work environment), and use that new knowledge and skills in a real-life work environment**.**

To date, the Festo MAP2 apprenticeship program in Mason, Ohio has 50 apprentices enrolled. Festo currently employs 20 of these apprentices (recruiting 5 each year; MAP2 is currently in its fourth recruiting year), while 30 of the apprentices are employed at the other 11 participating companies. There are a total of 12 including the original five members (Festo, Art Metal Group, Clippard Instruments, MQ Automation and Nestlé). The seven new members that have joined the MAP2 program since its inception in 2014 are: ARKU, E-Beam, Logomat, Storopack, Thyssen Krupp Belstein, Vega and Peter Creamer.

The Festo MAP2 apprenticeship program is a two-year, time-based mechatronics apprenticeship program. The student apprentice takes all required coursework including courses that are specific to mechatronics about mechanics, electronics, hydraulics, PLC, as well as coursework in English composition, mathematics, engineering, and public speaking at Sinclair College. These courses and their apprenticeship qualify them to earn a two-year A.S degree in Mechatronics.

The Sinclair Community College component consists of 62 credit hours[1] of academic theory instruction over 5 semesters over a two and ½ year period. Simultaneously, the student apprentice spends one day at the Festo training centre each week and works 3 days at the respective sponsoring employer.

[1] A 'credit hour' is the unit of measuring educational CREDIT, usually based on the number of classroom or lab hours per week throughout a term. Credit hours are not equal to actual training hours. In the context of the Sinclair Community Component, students are in the training lab 8 hours per week.

3 Project design, planning and implementation

3.1 Needs assessment and type of change implemented

Due to Festo's high demands for skills in mechatronics, logistics and industry 4.0, Festo was the main driver who initially met with Sinclair College to express its workforce skills needs in mechatronics, logistics and industry 4.0. As a result of these discussions, Sinclair Community College agreed to provide the academic coursework and instructors required for the apprenticeship program.

Because an apprenticeship program in mechatronics was not already available, there were several steps that Festo needed to take with local educational, governmental and industry stakeholders. This included identifying world-class benchmark standards in mechatronics apprenticeship training for both the educational institution as well as the on-the-job practical training, developing curriculum for academic theory and lab training, developing local government support to help develop public knowledge and support of the program, as well as identifying and defining the roles required of Sinclair College and Festo, in developing a simultaneous academic and practical hands-on schedule. Festo had to also begin simultaneously to recruit local like-minded companies in the region to support the apprenticeship program, which required several meetings with each individual company. This was a very time-consuming process, and many times required several meetings to convince the companies to join.

3.2 Involvement of different actors

Festo has worked closely with Sinclair community College and the member companies in the apprenticeship program to develop the curriculum for courses relevant to the MAP2 apprenticeship program. Development of the curriculum included a process of identifying world-class benchmark standards in mechatronics, use of existing curriculum and development of new curriculum. The German IHK Mechtronics Fitter occupational frameworks were used as a guideline to be used in curriculum development. Festo Didactic curriculum was used for the lab training instruction and new curriculum was developed for the text book academic theory taught by Sinclair College to adapt to the most current technologies available in Mechatronics. Apprentices gain academic credits from these courses that are transferable to certificate or degree programs at higher education institutions.
Festo also worked very closely with the local economic and workforce development entities at the local, regional and state levels to market this program within the region and begin implementation of this program.

3.3 Financing

As with most US apprenticeships, where usually one company will lead and drive the program, Festo had to take the leading role in absorbing the initial financial burden to kick-start the program and has funded nearly all the program costs associated with the Festo Training Center. Festo, and most member companies, pay for the tuition and books for courses that MAP2 apprentices take at Sinclair College.

Each participating company, including Festo, pays the wages and covering the tuition, books, and training material costs for the apprentices. In addition, Festo funded the equipment costs for the training center at a cost of $1.3M (€ 1.1 million) and has donated in-kind usage of 5,500 square feet of space within its facility and provides 1 full-time Apprenticeship Supervisor, 1 full-time Master Instructor, an Administrator and 3 part-time instructors that work full-time at other positions within the company. These instructors are experienced technicians that take on the role

as mentors to the apprentices for both the Festo Training Center lab work, as well as the work-based learning within Festo.

Festo has made these investments and cover additional overhead costs that are not shared by other companies. Festo chose to do so because Festo firmly believes the investment is worthwhile in assuring that the quality of training for its new apprentice employees is world-class. Also, as a good corporate citizen in its local community, it is the firm belief of Festo' management and staff interviewed for this case study that the success of this apprenticeship will have a positive long-term impact to the future economic and workforce development potential for the area.

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

Sinclair Community Colleges provide a wide array of courses to meet the program's needs for technical instruction related to the apprenticeships and that helps to qualify apprenticeships for the A.S Degree in Mechatronics. The courses include: Tooling & Machining, DC & AC Circuits, Industrial Automation Measurements, Engineering Drafting, Math for Technologists, Digital Technology, Industrial Machine Wiring, Electrical Machinery, English Composition, Programmable Logic Controllers, Fluid Power & Control, Public Speaking, American Federal Government, Robotics in Integrated Manufacturing Systems, Lean Operations, Advanced Programmable Logic Control, Troubleshooting of Automated Systems, Sensors & Vision Systems, Art Appreciation – Introduction to Art and Art Media.

Festo employs an administrator who keeps track of each apprentices' progress and files information with the US Department of Labor's Office of Apprenticeship, as required for registered apprenticeship programs and as ways of documenting the certifications provided by the Office of Apprenticeship.

The Festo program goes beyond the formal requirements of a US apprenticeship requirement. The GACC Midwest audits and monitors the Festo MAP2 program to assure the quality of the training meets the German apprenticeship standards, in accordance with strict German IHK/AHK testing guidelines. The GACC is the sole organisation authorized in the US to administer the third-party testing to assure the quality of the examinations meets German standards, to give their stamp of approval and to authorize the program to be recognized and supported by the German IHK.

3.5 Implementing the programme/initiative

Apprentices participating in the program predominantly are male in the age of 18-22 years, with 1 female that was the only drop out of the total number of apprentices that have gone through the program since inception.

The occupational standard used in this programme is the apprenticeship occupation called Mechatronics Fitter that is typically a 3.5-year apprenticeship program in Germany. Festo and the GACC Midwest have condensed and modified these standards to satisfy the minimum needs of Festo and to custom fit MAP2 training into the 2.5-year program with Sinclair Community College. The occupational standard has two parts, one for the academics and training lab required to be taught at the school and training center, and the other at the company during the practical real-world on the job training. An outline of each of these academic and practical skills and content standards are listed below in the following tables.

Festo Didactics and Sinclair College Mechatronics Apprenticeship Programme:

Academic and lab training related instruction outline

		Classroom Hours
1)	Analyze functional correlations in mechatronics systems	40
2)	Produce mechanical sub-systems	80
3)	Install electrical equipment according due consideration to technical safety aspects	100
4)	Investigate the energy and information flows in electrical, pneumatic and hydraulic sub-assemblies	60
5)	Communicate with the assistance of data processing systems	40
6)	Plan and organize work processes	40
7)	Realize simple mechatronics components	100
8)	Design and develop mechatronics systems	140
9)	Investigate the information flow in complex mechatronics systems	80
10)	Plan assembly and disassembly	40
11)	Commissioning, trouble shooting and repair	160
12)	Preventative maintenance	80
13)	Hand over mechatronics systems to customers	60
14)	**Total hours**	**1,020**

C**ompany on-the-job training**

A.	VET, employment and collective wage agreement law	40
B.	Structure and organization of the company providing training	40
C.	Health and safety at work	40
D.	Environmental protection	40
E.	Company and technical communication	312
F.	Planning and control work processes, check and evaluate work results	192
G.	Quality management	120
H.	Check, mark off and label work pieces	72
I.	Cut, separate and reform manually or by machine	264
J.	Joining	144
K.	Install electrical sub-assemblies and components	312

L.	Measure and test electrical values	192
M.	Install and test hardware and software components	264
N.	Build and test control systems	312
O.	Programed mechatronic systems	192
P.	Assemble sub-assemblies and components into machines and systems	480
Q.	Assemble, dismantle, secure and transport machinery, systems and plants	432
R.	Test and adjust the functioning of mechatronic systems	384
S.	Commission and operate mechatronic systems	384
T.	Maintain mechatronic systems	312
U.	**1.1.1.1.1 Total hours**	**4.528**

Festo follows these German frameworks with regard to individual competencies but covers the work-based and academic components in a somewhat shorter period. In Germany, actual hours in the on-the-job training practical experience may differ slightly from one company to the next, as the practical training required on the company side is referenced in the German standards in weeks of experience (not hours).

Festo Didactic customized the MAP2 program using the German apprenticeship benchmark standards above and Festo Didactic's own mechatronics training equipment and curriculum to accommodate the 2.5- year timeframe. Festo Didactic has printed an online curriculum that is available for the training lab instructors' use, and that is available to Festo Didactic customers which is proprietary and not available to the public. These materials were used in developing the MAP2 program.

3.6 Quality assurance mechanisms

Festo 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, the GACC Midwest audits and monitors the Festo MAP2 program to verify that the quality of the training standards is met according to German occupational standards. The GACC Midwest also provides mid-term testing to ascertain the students' progress is sufficient through the program, and then proctors the final exams as a third-party testing agency to confirm that the student apprentices meet the competencies required by German IHK standards. The student apprentice must pass both a written and practical exam (a product or component part that needs to designed and/or manufactured). Apprentices will also receive a certification from the US Department of Labor, though the third-party examinations are not required.

3.7 Skills of involved training and mentoring personnel

At Festo, there are two dedicated full-time personnel that oversee the training lab instruction, an Apprenticeship Training Supervisor, and the Master Instructor, both who received German apprenticeship certifications in Germany in Industrial Mechanics. Both instructors have also received GACC Train-the-Trainer Certifications in Mechatronics. In addition, there are three Festo employees that are utilized on a part-time basis as instructors. These five Festo employees provide the training and mentoring necessary for the hands-on training centre exercises. Also, the

Festo student apprentices receive the same personal attention from mentors they are assigned while working on-the-job in the regional service and logistics centre.

All twelve partners in the MAP2 program establish key skilled technicians within their companies where student apprentices work side-by-side with these technicians who take on a personalized mentoring role to assure the student apprentices accelerate their skills through hands-on practical experience.

3.8 Difficulties and challenges during implementation

The case of the Festo MAP2 apprenticeship program has to be considered against the specific situation and framework conditions of apprenticeship in the US that have been described in detail in the national report on the US in the context of the FOME study. However, it is important to recall major difficulties and challenges that are obstacles in establishing advanced manufacturing apprenticeship programs in mechatronics, Industry 4.0 or advanced logistics in any state or region in the US. Many of these same obstacles are challenges that had to be overcome in implementing the Festo MAP2 apprenticeship program.

For these reasons, we have developed that following table that addresses each of the difficulties and challenges and states the outcomes and observations made by stakeholders interviewed and the conclusions drawn by the authors in this case study:

Difficulties and Challenges	Observations and Outcomes
Apprenticeship programs in general have a blue collar, dirty job stigma in the US and the perception is that factory workers enter a dead-end job with no upward mobility. This general misperception about the industry is too often shared by educators, career counsellors, government officials, parents and students.	This image is far from reality. Advanced manufacturing features highly automated robotic equipment and processes, a clean safe working environment full of exciting opportunities to advance forward in careers due to the rapidly changing technologies of today. Tours of modern advanced manufacturing facilities help to dispel this negative perception. Now three years into the program, Festo has observed a change in the acceptance of its apprenticeship program by educators and community stakeholders, as well as parents and students seeking opportunities to enrol in the apprenticeship program.
The American general public believes that the only way to become successful in life is a four-year college education.	Though a four-year college education is the right path to a better paying job for some people in some industries, it is not always the best pathway for manufacturing or manufacturing engineering. Students spend four years as a student and usually work part-time in restaurants or retail to earn a college degree at age 22 with generally no career applicable practical experience. They expect to have a high paying job when they enter a career, but manufacturers are reluctant to hire them because they have no practical experience.
Students who choose other career pathways than a four-year university degree, such as apprenticeship	Among the general observations by the stakeholders is the fact that some people learn better and faster

Difficulties and Challenges	Observations and Outcomes
programs are generally considered unintelligent and unable to fit into society.	through practical hands-on application of the academic theory than if they are taught only in a classroom setting. When applied simultaneously, these students rapidly discover a passion and drive to excel. They also discover that academic text book learning such as science and math become essential tools required to excel at their job and they begin to understand the concepts of math and science better when they see it applied in a real working environment. Festo knows through first-hand experience with that student apprentices gain confidence in their skills and excel more quickly if they can learn through hands-on applications. Festo has made these observations through its own commitment to apprenticeship programs for more than five decades in Germany. Festo has observed that these same principles apply in the US, when a student is given the chance to discover his/her capabilities and passions through practical hands-on experience
Apprenticeships in advanced manufacturing are not common in the US and seldom understood by most US community stakeholders (education institutions; manufacturers; government agencies, officials and policy-makers; and the general public).	Due to misconceptions stated in the last three difficulties and challenges above, there is a fundamental mindset that needs to change across all community stakeholders, before apprenticeship programs in advanced manufacturing will be fully understood and accepted in the US. Festo believes that over time the success of the MAP2 apprenticeship program is slowly being accepted and understood, particularly by those who are engaged, but it is a constant challenge to change the mindset and image of apprenticeship programs due to the vast number of community stakeholders that need to be convinced of the value and commitments required and to become fully engaged for the program to take root and to become sustainable. Festo recommends and helps administer within its local region having local schools start advanced manufacturing feeder programs from elementary school into middle and having high school programs with learning hands-on skills in robotics and advanced manufacturing. Such programs are beginning to stimulate increases in the number of students who develop a passion for a career in advanced manufacturing.
Establishing an advanced manufacturing apprenticeship program in the US requires continual effort to educate and re-educate all	As stated in the Observation and Outcome points discussed above, the marketing of the program becomes a little easier as more stakeholders come on board and speak highly about the success of the

Difficulties and Challenges	Observations and Outcomes
community. stakeholders.	program. As more companies become involved, there are additional testimonials to add, and these additional companies begin to take a stake in the promotions for the program. Still, even with the successes of the proof of concept, there is still a lot of continual effort to be placed on educating and re-educating community stakeholders about the benefits of the program to the community.
American companies do not understand the value and ROI of a long-term financial investment into human capital resources through apprenticeship programs.	Because apprenticeship programs in advanced manufacturing don't have the track record of success in the US as in Europe, American companies view the apprenticeship program as an added expense, instead of an investment that will benefit a favourable return on their investment. This is a mindset that needs to change among US manufacturers before apprenticeship programs will truly take hold in the US. One way to build the respect for apprenticeship programs among American manufacturers is a successful proof of concept. Apprenticeships are generally better understood by European, Japanese and other companies who already use apprenticeships. Therefore, it is generally much easier to recruit companies from these countries than from the US to participate in a core team in a company consortium to lead new apprenticeship programs. These companies fully understand the ROI benefits of apprenticeship programs. Within the MAP2 program are three European companies in the 12-partner consortium, namely Festo, Nestlé, and Thyssen Krupp Belstein. These three companies help to lead by example, explain the process and convey the ROI benefits to other existing partners and other local companies interested in becoming involved.
The process for registering an apprenticeship program in the US is very difficult and cumbersome.	The registration process is outdated, very bureaucratic, and the registrations usually take a long time to be approved. Also, the list of US DOL approved occupations for apprenticeships are outdated and do not recognize the most advanced occupations and skills required in advanced manufacturing technologies (i.e. Advanced CNC Operations, Mechatronics, Industry 4.0, Additive Manufacturing, etc.). The need to introduce globally competitive world-class advanced manufacturing occupational benchmark standards is not fully understood by State and US DOL representatives who process the registration submittals.

Difficulties and Challenges	Observations and Outcomes
	Festo has collaborated with the GACC Midwest so that student apprentices are tested and receive an authentic German Certificate that is recognized worldwide as a quality apprenticeship program. These credentials will translate into higher earnings and a more well-defined career pathway for the student apprentice Festo's work with the GACC Midwest has helped set the stage for Festo to expand the MAP2 model to other US communities interested in developing a world-class mechatronics apprenticeship program.
Most American manufacturers generally have a limited understanding about Industry 4.0 and are not prepared for automated and robotic manufacturing and Internet of Things processing.	Although the US is known for its advanced technologies in many areas with worldwide respected companies such as Microsoft, Apple, and Intel, many manufacturers moved offshore seeking lower labour costs, rather than investing in automated and robotic technologies. This has generally set advanced manufacturing back by 20 years in the US. With the re-shoring of manufacturing coming back to the US over the past couple of years, manufacturers are experiencing a vast shortage of skilled personnel in these advanced technologies. This is coupled by the fact that those who have the proper skills are baby-boomers nearing retirement. Festo has become a showcase in the Ohio region of advanced manufacturing technologies in mechatronics, industry 4.0 and advanced logistics. Festo and the MAP2 program are now beginning to change both the perception of advanced manufacturing and are beginning to erase the negative image of apprenticeship programs in the local community.

Working with Educational Institutions

According to the interviewed stakeholders, although the collaboration with Sinclair College has been positive from the start, the following general observations about most post-secondary technical and community colleges were obstacles to some degree that had to be overcome in implementing the MAP2 apprenticeship program:

Most educators in advanced technologies generally have academic knowledge but no industry experience even at high level postsecondary educational institutions. Instructors are generally highly accomplished professionals in academic theory, but are limited in industrial experience. They have generally concentrated more on achieving academic degrees (Bachelor's, Masters and Doctorate) that are required in the US for teaching degrees and prominence within the US academic infrastructure rather than application of the theory in the business world. This creates a very difficult obstacle to overcome, because it is very hard to find an instructor with the academic

credentials required to teach in the US system matched with practical experience in manufacturing.

Festo has collaborated with Sinclair College, who provides the instruction of the coursework, and has set up the Festo Training Center where students review the academics they just learned and apply that knowledge to simulate a real-world application on Festo training equipment (simulating the use of pneumatics, hydraulics, electro-mechanical and programmable logic control systems, etc). This approach gives the student apprentice some practical experience and knowledge that can be applied during their on-the-job experience at their company sponsors' facility.

Most American educational institutions do not have the equipment necessary to teach advanced CNC, Mechatronics, Industry 4.0 or Logistics. Festo has established the Festo Training Center and contributed space, equipment and instructors at their logistics to make sure student apprentices receive the proper training and mentoring in the training lab environment.

Most educators have limited knowledge about advanced mechatronics or industry 4.0 or are not adequately skilled to provide training and instruction in Mechatronics and Industry 4.0.

Festo readily implements and provides Train-the-Trainer instruction and highly recommends that more Train-the Trainer programs need to incorporate college instructors to enable them to acquire the sufficient experience to use the equipment in order to train the student apprentices at a training centre located at the educational institution.

4 Outcomes, impact and lessons learned

4.1 Major outcomes and impacts on company and region

Though the MAP2 program is only starting its 3rd year, the impacts on the companies engaged and the region are significant. The MAP2 program has now grown to 50 apprentices and 12 companies, and more companies now want to take part in the program. The first graduating class of 11 students are now finishing up their fifth semester and will be taking the German certification exam. Upon completion of the semester and passing the final German certification exam, all 11 student apprentices have full-time positions waiting for them at their sponsoring employers.

The MAP2 program is also gaining recognition from the community stakeholders. On April 10, 2018, Festo announced it would be investing another $90 million (€ 77 million) into the Mason, Ohio facility to triple its logistics centre capacity and will hire an additional 350 employees.

The impact that Festo has made on the community in both 'physical capital assets' and 'human capital assets' is best stated by the Mayor of Mason, Ohio: 'While this may seem like a traditional economic development announcement, this investment represents far more. Our four-year friendship with Festo runs deep. Through its incredible generosity to our community and schools, Festo has redefined what it means to be a partner, helping to inspire curiosity in STEM education in our youngest residents.'

Festo's successful implementation of Map2 is beginning to have a direct impact and influence on Mechatronics apprenticeship initiatives outside the State of Ohio. At the time of this writing, Festo Didactic has received several inquiries regarding the potential roll out of MAP2 elsewhere in the US and is currently in final negotiations with a regional apprenticeship initiative in Florida that plans to implement MAP2 within their region.

4.2 Attractiveness and capability of apprenticeship

The Festo MAP2 program is gaining recognition and momentum within the community as more students and parents seek to learn about the program and more students try to enrol. Each year, as Festo begins its recruitment process, there are more and more applicants enrolling and Festo has been fine-tuning its recruitment process. This process first includes announcements at Sinclair College and through the local media about apprenticeship position openings at Festo and MAP2 member companies with a request for applications and resumes. Then applicants are invited to a well-coordinated open house for students and parents to learn more about the apprenticeship program and tour Festo or one of the other participating companies. Next, an invitation is sent to candidates to register to attend an informal workshop, where student competencies are assessed and evaluated by production staff from Festo and other companies, and finally an apprenticeship position offer is made to the most qualified students.

With Festo taking the leading role in development of the program, Festo has taken great measures to assure the MAP2 apprenticeship program offers world-class training and on-the-job experience using the most advanced technologies available today.

The fact that *all* 11 apprentices will become in 2018 full-time employees at their respective company sponsors is an early proof of concept for the MAP2 program. Each of the student apprentices have excelled in their knowledge, experience and capabilities to be hired by each of the companies full-time. So far, the program has graduated an amazing 100% of its first-year apprentices into full-time positions with their sponsoring companies.

Each of the original five companies is still on board and have added a new class of apprentices for four consecutive years. This is evidence that the program is becoming more sustainable within the community and that these companies plan to maintain their commitment to the program. Additionally, the fact that seven new companies have joined the MAP2 program is indicative that the program has been deemed successful by industry within the region.

4.3 Key success factors and lessons learned

Several factors played a role in the success of the MAP2 program. Collaboration with other partners made a big difference. Festo successfully registered and launched the Festo MAP2 program in collaboration with Sinclair College and 4 other industry partners in August 2016 with 11 student apprentice recruits. Other key collaborations including work with the GACC Midwest, the US DOL, NIMS, NC3 and Urban Institute to establish a national opportunity to roll out MAP2 across the US.

The ability to work well with the apprentices has also proved critical. All 11 student apprentices that started the MAP2 program in the first year are graduating in 2018 with an A.S Degree in Mechatronics from Sinclair College and will be completing their 2.5-year apprenticeship program and will obtain their German certificate as a Mechatronics Technician and a full-time position at the companies of each of their sponsoring employers.

The quality elements mandated by Festo have helped to generate growth. The MAP2 program is now entering its 4th recruitment year and has expanded now to 12 companies and 50 apprentices. While American companies were reluctant to start the program and had to be recruited in the initial start-up, additional companies are now asking about an opportunity to become a partner. Similarly, students and parents are coming to see the MAP2 program as a high-quality option and seeking opportunities for enrolment.

Turning to the lessons learned from implementing MAP2, we find that it works well to start with a smaller tightly knit regional cluster of companies who all understand the value and ROI of apprenticeships and who are aligned and committed to build a successful pilot and then expanding than to try to start with a broad range of companies with little experience with high-quality apprenticeships. European companies, and other international companies from countries such as the UK, Canada and Japan who have experience in successful apprenticeships in their country are the best companies to recruit into a regional cluster (or consortium) to start as a core group to help American companies in the local region to understand the value and ROI of investments in apprenticeships.

Another lesson relates to time. A successful apprenticeship program over time will gain momentum and support from key community stakeholders and the public, but it may take several years to occur.

One concern is that the financial burden of developing a successful advanced manufacturing apprenticeship program in mechatronics, industry 4.0 and advanced logistics must be taken on by a company (or companies) willing to the lead role to champion the program through a financial commitment to the community, as these programs require a substantial investment into equipment, instructors and curriculum development.

With the growth now to 12 companies, Festo is beginning to see limits on how many companies their infrastructure can support. Festo believes the maximum threshold that the MAP2 program could support at their facility without additional investments in space, equipment, and instructors is about 20 companies, because the current investment in equipment and infrastructure will only handle a certain number of apprentices.

5 Commentary and conclusions

5.1 Adjusting dual apprenticeship in the light of advanced manufacturing

We as authors draw the following conclusions. This case study shows that a company with the financial strength, technical know-how, perseverance and determination to lead, nurture, and implement an advanced manufacturing apprenticeship will be able to create a program that is worthwhile for the company and apprentices and can take root in a community and region. Another necessary ingredient is choosing the in-demand occupations, in this case mechatronics, Industry 4.0 and advanced logistics. Unfortunately, it takes a major and continuing effort to affect the mindsets of all community stakeholders in education, industry, government and the public to see apprenticeships as immensely valuable.

But for programs like MAP2 to become sustainable across the US, more success stories such as the Festo MAP2 program with Sinclair College must become prominent in many more communities. Only in this way will dual apprenticeship programs (simultaneous academic theory and lab work at the educational institution and on-the-job apprenticeship training at the company) truly become widely understood and promoted by community stakeholders.

Unfortunately, widespread emulation of the Festo case will require far more educational institutions across the US to provide instructors with the proper industrial experience to teach not only the theoretical principles but also the required practical skills and competencies. It will also take financial investments by industrial companies. Winning over community stakeholders will take time as well as the same painstaking meticulous and relentless commitment of a champion like Festo. Ideally, government policies can speed the process by publicizing successes so that more companies see operating apprenticeship programs are necessary to remain competitive.

5.2 Policy implications and transferability

Although implementing a world-class advanced manufacturing skills initiative is difficult, US companies will not be equipped with the necessary workforce to compete globally, unless apprenticeship programs in advanced manufacturing can become as mainstream and widely adopted in the US as they are in several European countries. One needs only to look at companies like Festo, who are innovative leaders of Industry 4.0 technologies to realize that our mindsets and misperceptions of apprenticeship programs need to drastically change.

Recent policy changes over the past 10 years regarding apprenticeships are essential to expand the understanding, respect, acceptance and the mindset change that urgently needs to occur in the US. However, for the ambitious goals of the current administration to grow and expand apprentices from 500,000 to 5 million in five years, much more than the current funding of $200 M (€ 171 million) will be needed. It will also require a complete mindset shift of policy-makers across the US at all local, regional, state and federal levels to support apprenticeship programs with not only funding, but fundamental state statutes that currently impede or hamper apprenticeship expansions within their states and federal congressional changes to policy and procedures to encourage apprenticeship expansion. Changes will be required in to order to fully attain the level of quality required to develop the workforce talent pipeline in advanced manufacturing and to fill all the vacant jobs due to the lack of skilled workforce that exists today. It is common knowledge that a crisis is beginning to hit manufacturers today as more and more baby boomers with the proficiencies in these skills begin to retire.
This crisis exists today because students lack the necessary experience to fill the baby boomer jobs and training programs lack the mentoring process required over time to pass on and transfer practical knowledge to the next generation of skilled craftsman.

To maintain competitiveness in today's global economy, the US must expand initiatives that promote quality skill development, including apprenticeships. Among them are the development of consensus, high quality skill frameworks, funding for the off-job components of apprenticeship, and a vastly strengthened system of marketing apprenticeships to employers. Advanced manufacturing apprenticeships like Festo's MAP2 program at Sinclair College are a quantum leap forward in the right direction, but scaling apprenticeship throughout the US will require concerted actions at the federal, state, local, and private sector levels.

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Annexes

A.1 Glossary of terms/abbreviations

AHK	Chambers of Commerce Abroad
GACC Midwest	Midwest German American Chamber of Commerce
IHK	Chamber of Industry and Commerce
IRAP	ITM Industrial Technology
IRAP	Industry-recognized apprenticeship program
JFF	Jobs for the Future
KY FAME	Kentucky Federation for Advanced Manufacturing Education
MAP	Mechatronics Apprenticeship Programme
NIMS	National Institute for Metalworking Standards
ROI	Return on Investment
RSC	Regional Service Centre
STEM	Science, Technology, Engineering and Math
US DOL	US Department of Labor

A. 2 List of interviewees

Type of organisation	**Organisation**	**Interviewee**
Company	Festo	Marketing Communications Manager
Company	Festo	VP of Educational Programs
Company	Festo	Apprenticeship Supervisor
VET provider	Sinclair College	Director
Public Policy	City of Mason, Ohio	Mayor

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