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Study of the Current State of Engineering Education in South Tyrol in the Context of Industry 4.0

by

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ABSTRACT

Digitisation for education systems is discussed in many circumstances and situations. The fact is that thinking about the new industrial revolution by Industry 4.0 needs to consider also the education system. Young people grow up with new technologies and are confronted with concepts with a high degree of digitisation, which introduces completely new requirements and possibilities. In this thesis, the actual situation of education systems in Europe, and especially in South Tyrol, is analysed, focusing on actual offers available today and providing hypothesis of needed changes in the education system. Thinking about what could be the competences and possibilities for people working in companies and guiding the economy is a big challenge and requires a good and strategic farsightedness. Once having determined the competences for future skills, the education system and structures must be changed, in order to be able to support students in being competitive. In the meantime, there are growing courses, specialised trainings and studies on the topic of Industry 4.0 and digitisation. Looking at the reality of South Tyrol's small and middle-size companies, the implementation due to limited resources should not be underestimated. In the future, the education system has to reorganise the teaching structures and teaching methods. Developments in technology will help to go in this direction, but a change in the way of thinking and an essential financial support from the authorities are strongly required.

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NOMENCLATURE

3D	Three Dimensional
AR	Augmented Reality
BI	Business Intelligent
BIM	Building Information Modelling
BYOD	Bring Your Own Device
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CMM	Computer Measuring Machine
CNC	Computer Numerical Control
CPP	Cyber Physical System
CSE	Computer Science Education
ERP	Enterprise Resource Planning
ETL	Extract, Transform, Load
FEM	Finite Element Method
GE	General Electrics
GPS	Global Positioning System
HOME	Hierarchical Open Manufacturing Europe
IaaS	Infrastructure as a System
ICT	Information and Communication Technology
IDM	Innovation Development and Marketing
IoT	Internet of Things
IT	Information Technology
LIH	(in German) Lehranstalt für Industrie und Handwerk
MES	Manufacturing Execution System
MINT	Mathematics, Informatics, Natural Science and Technology
MIUR	(in Italian) Ministero dell'istruzione, dell'università e della ricerca
OEM	Original Equipment Manufacturer
OER	Open Education Resource
PaaS	Platform as a Service
PCK	Pedagogical Content Knowledge
PLC	Programmable Logic Control
PLM	Product Life Cycle Data Management
QR	Quick Response
R&D	Research and Development

RFID	Radio Frequency Identification
SaaS	Software as a Service
SLR	Systematic Literature Review
TFO	(in German) Technologische Fachoberschule
VDI	(in German) Verein Deutscher Ingenieure
VR	Virtual Reality

Chapter 1

INTRODUCTION

Digitisation has changed our life sustainably in recent years, just as the industrial revolution did years ago. This is especially true for the economy, but also for the society and all individual living areas. Above all, the use of new media and innovative information and communication technologies is revolutionising the education field and is going to become an integral part of teaching.

Digital learning systems, interactive Smartphones or learning apps are only three of countless keywords and are already required and used by students at school. This leads to new challenges for teachers and educators in schools, youth education or vocational training.

The use of digitised learning methods and elements requires new pedagogical competences and skills. In order to help teachers in the age of digitisation, digital education specific courses as well as individual seminars have to be developed. The individual education for teachers helps to professionalise their media competence and deepen corresponding didactic skills. In addition, they provide new ideas as well as practical applications for the lessons. Finally, the goal must be a comprehensive understanding of innovative media to recognise new digital applications as an opportunity for creative and innovative lessons.

Online learning units and the integration of new media in the classroom presuppose that teachers or lecturers must receive not only the needed hardware, but especially the right education for a correct introduction of new teaching innovations.

Teachers must be supported along their way as they learn or improve their media competences. Digitisation is the actual core topic that determines all processes of the education field. It is obvious that digital teaching is more than just showing You-Tube videos. Of course, using this medium is only a part of the concept of the digital transformation, which is used in the classroom. It has to be adapted to the target groups and learner types.

Experts believes that completely new knowledge and new skills are needed if you want to choose between the different learning methods, combine online and offline components and use different forms of media. This knowledge was not needed in the past because the technology was not available at that level. In addition, new applications in pedagogy are emerging ever faster because of technical developments. A good example is the learning apps, now a huge and constantly changing market.

Teachers in the future will not have other alternatives other than to start working by using new technology and methodologies in and outside the classrooms. The chances and opportunities, by which young people and adults can achieve by learning in this new way, are great and increasing day by day.

1.1 Industry 4.0 - the 4th Industrial Revolution

As in the past, new technologies are initiating a new industrial revolution. Today Industry 4.0 has become the name of the 4th industrial revolution. By mechanisation through water or steam-power in the 18th century, the first industrial revolution was introduced. It was followed 100 years later with terminologies like mass production, assembly lines and electricity, the second revolution. The third industrial revolution started in the second half of the 20th century by the introduction of logical controllers, to allow the use of electronic and IT systems for further automated productions. The last era, with cyber-physical systems, will increase further more the degree of complexity in industrial systems.

Figure 1 presents an overview from Industry 1.0 to Industry 4.0

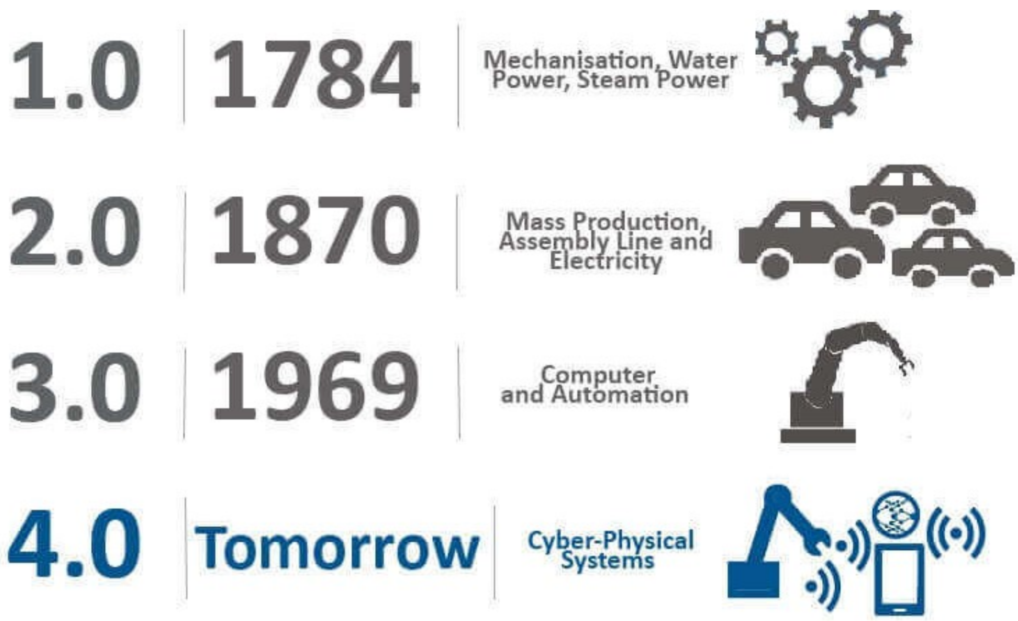


Figure 1: Industrial Revolutions [1]

Industry 4.0 introduces more intelligent or so called smarter machines, materials and consequently final products in the market, with the ability of networking and communication between them. This is supported by the concept about Internet of Things. A product must be able to be modified at a low cost in a short time to cover the always faster changing request on the market. This can be reached, by using more adaptive production systems to be able to change for example an assembling line in real time. The products of the generation Industry 4.0 can be tailored even more strongly to the needs of customers and are more versatile than before. An example about a standard equipment present in every household that support the user: a washing machine. Those machines know how to get the grass stains out of the football pants. To make this work, it is equipped with software that detects how dirty the trousers are. This goes hand in hand with the fact that technology in companies is becoming more intelligent.

1.2 Technologies used for Industry 4.0

What could be the technologies that are used in Industry 4.0? In figure 2, we can see an overview of Technologies for Industry 4.0 [2], which can be divided into three groups.

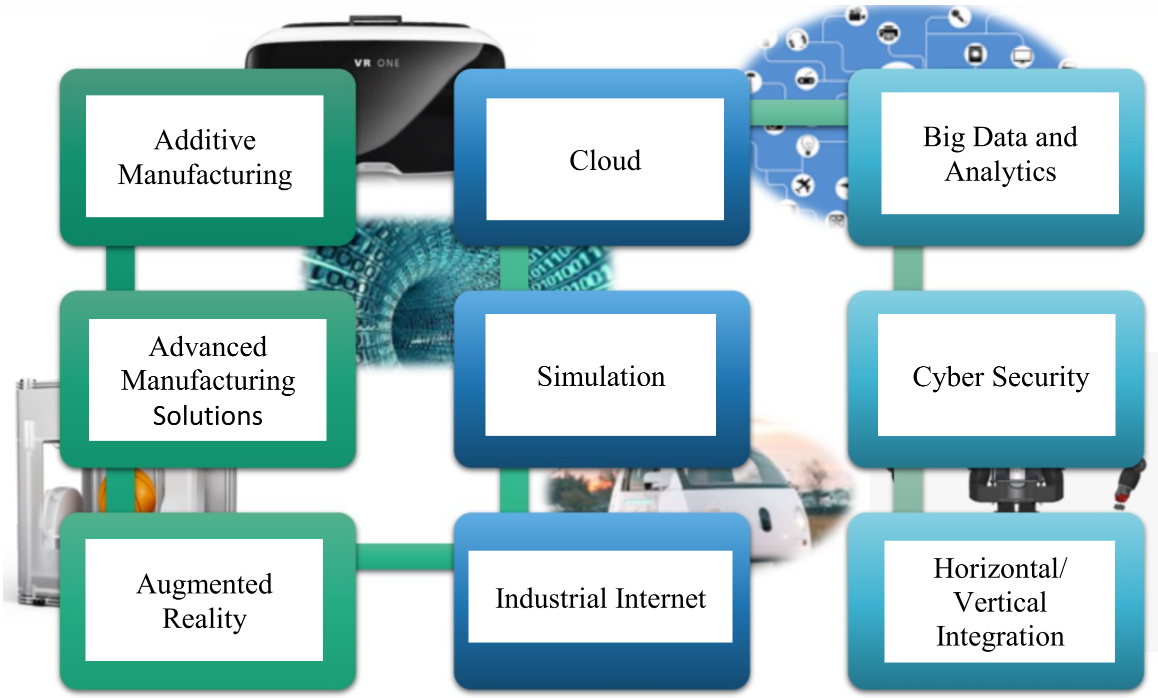


Figure 2: Technologies for Industry 4.0 [2]

The Technologies for Industry 4.0 divided into three groups:

Group 1:

- Additive Manufacturing
- Advanced Manufacturing

- Augmented Reality

Technologies in this group requires a certain hardware, like special machineries (3D Scanner or 3D Printer) or other physical equipment, which has to be installed in an industry plant.

Group 2:

- Cloud
- Simulation
- Industrial Internet

Working with those technologies implies the use of different technical prerequisites. Collecting data and being able to transmit them in a standardised system is one prerequisite. Simulating a process on a real build or fictive environment considers the possibility to virtualise a scenario. Of course, working offline with these kinds of technologies is nowadays no longer affordable.

Group 3:

- Big Data and Analytics
- Cyber-Security
- Horizontal- and Vertical Integration

Thinking about new technologies in this Cyber-Physical era leads to a certain demand for the used software. The software is required to analyse the collected data in a safe and efficient way and must be able to share them with other users.

Technologies around Industry 4.0 explained more detail:

Additive Manufacturing

Additive Manufacturing describes the technologies to build objects in a 3D shape. It is possible to do by adding layer-upon-layer using different materials. Most common materials are polymers, but also metal or concrete could be used. Depending on the materials and the typology of the printer, the raw material could be in a liquid, a powder or a solid state.
To work out an object, an advanced computer model must be drawn by using a CAD (Computer Aided Design) program like Inventor or Pro Engineering. Once the digital model is created, the 3D Model program slices the object to give the correct construction information to the printer [3].
The so-called Additive Manufacturing Technology with the 3D Printer Rapid Prototyping is limited in its application. As the name says, initially the focus is to create an object to build a prototype in order to have a better understanding of the dimensions or possibility to install or connect different pieces. Today, ideas for new application for this technology are

developed every day. Spare part management or individual products printing at home or clothes printing or even, why not, also food printing are fields for this technology.
The simplicity of the layer by layer technique continuously evolves new possibilities with a degree of sophistication to meet diverse needs, like a visual tool in design or industrial tooling or small items of production parts or even human organs.

Advanced Manufacturing

Advanced Manufacturing includes many technologies that are nowadays possible to find in different industry sectors to increase competitiveness and optimise productivity.

Some of the processes and advanced manufacturing technologies are [4]:

1. Additive Manufacturing (3D printing)
2. Advanced Materials (carbon fibre to increase strength and reduce weight)
3. Collaborative Robotics (interface between automation and robotics and analysis of Big Data)
4. Biotechnologies (genetically engineered crops)
5. Nanotechnologies (engineering and technology reduced to a nanoscale)

Augmented Reality

Augmented Reality is a technology where an interaction between THE real world and digitally created objects or information is created. Different sensors, which can elaborate visual, haptic or auditory modalities, are needed.

Augmented Reality can be divided into four classes [5]:

a) Marker Based AR
The Marker Based Augmented Reality can also be found under the name of Image Recognition. With the camera, a visual marker, generally a Quick Response (QR) Code can be read and out of a simple pattern different information can be extracted. Those technologies do not need a lot of calculation power and are quite easy to manage. The velocity of identification, as well as the possible definition of the orientation, opens the marker to many different application fields.

b) Markerless AR
Several more applications are available for the markerless-System. It works with

additional aids like GPS, velocity meter, accelerometer and digital compass. As all these technologies are nowadays available on a Smartphone, everyone could use a certain kind of data. A picture recognition software from a camera in relation to a location–based system can immediately provide information of objects, indications about directions or other location-centric applications.

c) Projection-Based AR

Projection-based AR is about projecting the shape of an object on a surface by an artificial light; users' movements can be recognised by a camera to work out an activity. For example, a contour of keyboard is projected and, by tapping on the virtual buttons, the system recognises the written word and transfers it out on to a screen or elaborates some output. The development of this technology is going to be able to use stronger projection sources to achieve 3D interactive holograms in mid-air.

d) Superimposition-Based AR

The last class of the different types of AR is the so-called Superimposition–Based Technology. It is possible to overlay on a screen the real environment by a full virtual object. Not only the orientation, how the object is immersed inside the environment, but also the scale of the object must be worked out by a software. A classic example is IKEA furniture. The Swedish company offers a range of articles, for example, a table, in a digital version, whereby the customer can be helped into the decision-making to buy an item of furniture by viewing it as a virtual object inside the real environment.

Figure 3 shows different application about augmented reality:

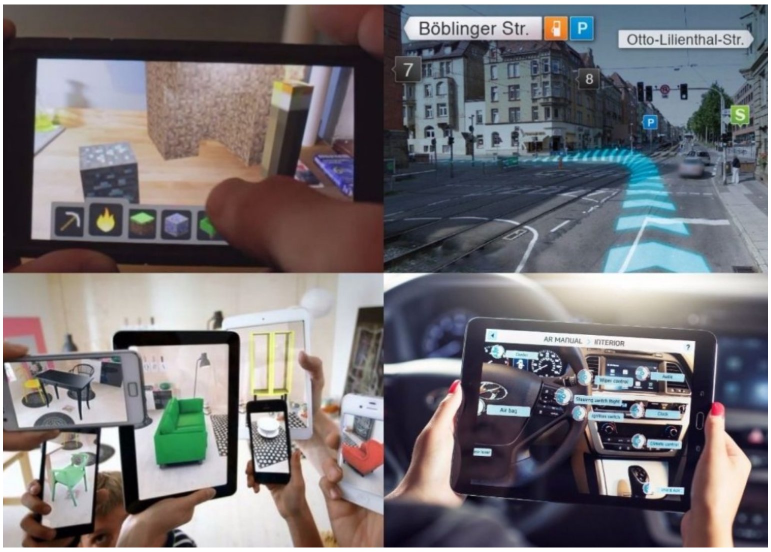


Figure 3: Augmented reality applications [5]

Cloud

The “Cloud” is a further development of the IT landscape. The function of a cloud is data or software storage space and outsourcing of computer power into a data centre. The advantage of cloud-computing is the interconnection between different computers, where hardware and software are not located on one specific device. All the resources are portioned into different systems, which makes them more dynamic. This means you only have to call-up the part of the resources which is required. As a result, it is possible to save many data, reducing the user’s IT infrastructure, as well, as eliminating the maintenance cost behind them. Clouds could be used by companies or private users. The flexibility to get data from wherever you are, of whatever you need, makes this technology essential for Industry 4.0.

Three different Cloud Computing Models exist [6]:

a) Software-as-a-Service (SaaS)
In this model, the software runs in the cloud. Installations on the user’s computer or server are no longer necessary. As a user, it is possible to use the provided software applications as a service via the Internet. In SaaS applications, they have nothing to do with maintenance and ensuring operational readiness. Costs are due for use, which vary on a monthly basis as required.

b) Platform-as-a-Service (PaaS)
This model stands for the demand-oriented provision of a development environment and is part of the cloud-computing concept. The provider offers to a user a programming model and development tools. This allows developing, testing, using and managing individual applications in the cloud. By using a PaaS solution, acquisition or servers or hardware management costs are eliminated. Billing is based on the cloud-computing principle, i.e. the amount of costs depends on actual usage.

c) Infrastructure-as-a-Service (IaaS)
IaaS is the demand-driven provision of a virtualised IT infrastructure. The provider offers, in this case, all infrastructure components, such as servers, computing power, communication devices, storage, archiving and backup systems and other necessary components of the data centre and network infrastructure. The scope of the infrastructure can be adapted in the IaaS model as required. Billing is also based on actual use.

Simulation

With the computer simulation technology, it is possible to create a virtual environment modelled by the real life or created by a hypothetical situation. In this environment, different scenarios could be run through, and, by changing input parameters, the results can be compared to each other. The aim is to create, or optimise processes in a relatively short time and with less expenditure. By using assumptions within the simulation and simplifying approximations, the simulation can include as a key issue the acquisition of valid source information about the relevant key behaviour and characteristics selection to verify and validate the outcome of the simulation. An ongoing field to other academic study are the protocols and procedures for the validation and verification of a model as well as the research and development for additional practical applications.

Industrial Internet [7]

General Electric (GE) invented the term Industrial Internet and, with companies like Cisco, IBM, Intel and AT&T, founded in the United States in 2014, the Industrial Internet Consortium.

The following innovation stages in industrial environments are characterised by the three industrial innovation waves [7]:

1. The first industrial innovation wave is covering the first and second industrial revolution considering Industry 4.0 (Figure 1). Machines and factors that empower the economics of scale and scope was in the centre of this wave.
2. The focus on computing power and rising of distributed information networks characterized the second industrial innovation wave. This was the reason, why this age became also the name of the age of the internet, supported by big developments on computer as well from the network for the information distribution side (from LANs, WANs and the client-server model to the “Big one”, the internet).
3. Now, the last wave could be comparable with the fourth industrial revolution considering the machine based analytics in a cyber-physical-system.

Figure 4 is a presentation about the industrial innovation waves:

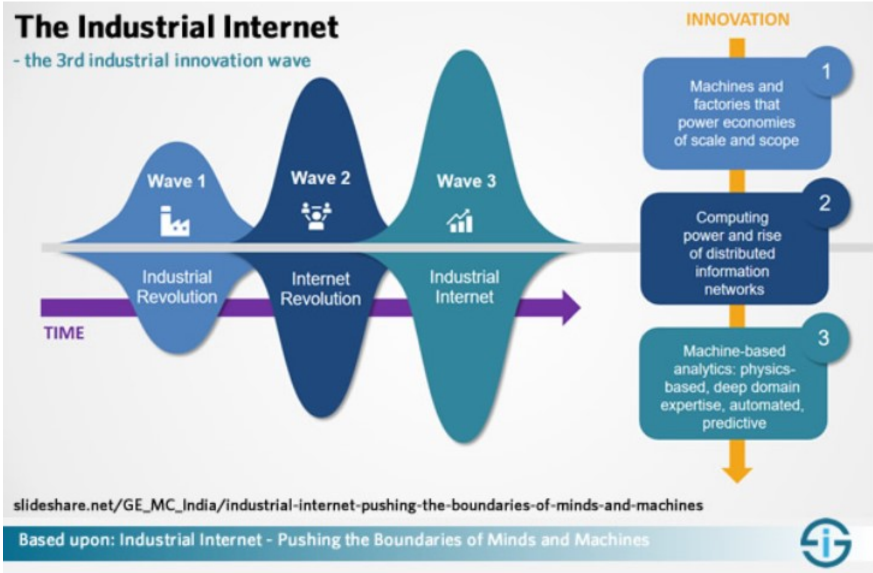


Figure 4: The industrial Internet – 3th industrial innovation wave [7]

Both terms, Industrial Internet and Industrial Internet of Things are often used with the same meaning, despite the differences between them. The consortium, of which European companies like Bosch, SAP and Schneider are also a part, sets as a goal promoting the concepts about the Industrial Internet of Things.

Internet of Things is the technology which bridges the gap between the physical world and the digital world, by the help of sensors or actuators. Developing such kind of equipment by making them smart is the big challenge. Connecting them via the Internet to clouds and data analytic systems can open up a new world.

Just a few examples of how smart sensors could be utilised in the different sectors are illustrated below in figure 5:

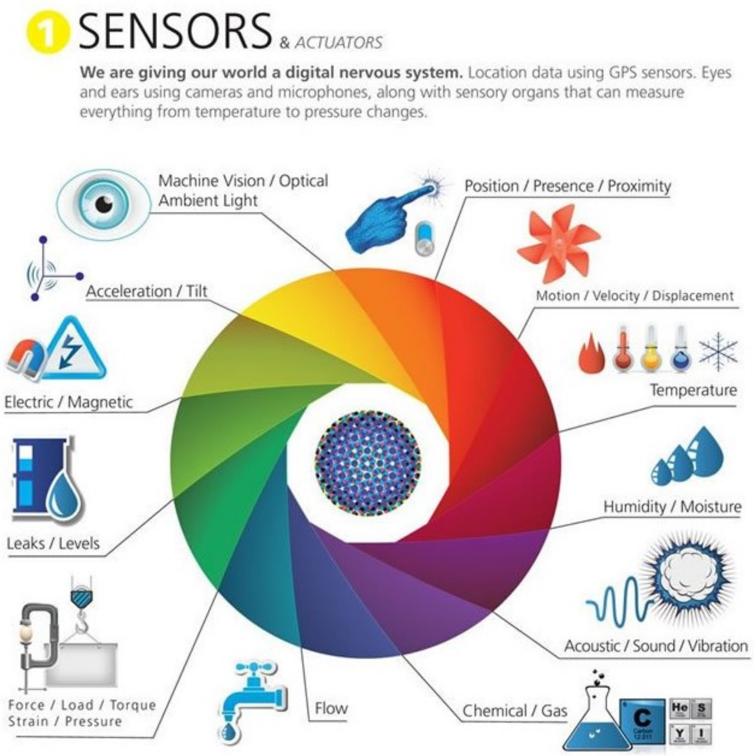


Figure 5: IoT - Smart Sensors [8]

Smart sensors should be connected with smart actuators to be able to interchange the needed data. That intelligent hardware must be supported by data management systems and adequate software.

<u>Big Data and Analytics </u>[9]

Increased digitisation leads to a veritable flood of large and complex data volumes, which can hardly be evaluated with classical methods of data processing. It needs a new form of data analysis and stable and secure transmission networks.
Initially, it is important to understand the meaning of Big Data, which can be defined as general dataset that overtakes the possibilities and limits of traditional Information Technology. Big Data includes everything which no longer works with conventional technology, due to the amount of data, for example: capturing, storing, searching, distributing, analysing and visualising large amounts of data. On standard databases and tools, the problems increase rapidly dealing with the new amount of data. Traditional databases fail because of the limited storage volume or the Extract-Transform-Load (ETL)

processes have difficulties and need too much time with the various data types. The conventional Business Intelligence (BI) is, therefore, too time-consuming and the masses of different data cannot be effectively processed.
The background to the discussions about Big Data is the sharp increase in the volume of data worldwide. A variety of different sources, like smart sensor data, logged data, machine data and RFID technology, are responsible for this. Already in 2011, the total amount of data volume exceeded the limit of the zettabyte and if this development continues in 2020 it could be that already 35 Zettabyte of data are in the system.
Not only the gigantic amount of data is the cause of the Big Data problem, but also the unstructured data storage or different data setups creates a problem for conventional enterprise software. Traditional BI software works on a data structure, where the data are stored in a clear and uniform way. This requires complex ETL processes in advance and is the only way of processing profitable data. In a situation about losing data structures and growing data volumes it is clear that the classical data storage must be replaced.
Big Data is particularly relevant for the area of Business Intelligence, which deals with the analysis of data (acquisition, evaluation, presentation). Big Data Analytics describes the systematic evaluation/analysis of large amounts of data using newly developed software. In contrast to conventional software solutions, Big Data software includes special functions and techniques that enable the parallel processing of many data like:

- Fast import of data
- Simultaneous processing of several queries
- Processing of many data records
- Analysis of different types of information
- Fast search and retrieval of data

Big Data Analysis represents one of the most important trends, wherein software industries are spending a lot on research and development.

Cyber-Security [2]

Industry 4.0 is asking companies to be open and connected not only internally, but also to other players in the sector. The supply chain is exchanging sensitive information on products, customers and suppliers. Using only traditional antivirus systems is no longer sufficient to monitor all access points to the company system, but it is necessary to plan strategies specifically for the management of digital security at 360 degrees. This is where the Cyber-Security plays an important role.

The Cyber Security includes the following aspects:

a) Resource Management

Managing in a safe but friendly way the integration of all stakeholders inside the supply chain.

b) Access Protection

Document management is changing significantly from the old IT systems, thanks to the digitisation and dematerialisation. New access policies must be introduced to be able to work with company data anywhere and everywhere

c) Machinery and Technology control

Opening up the industrial world to IP connectivity, operating systems and commercial applications introduces huge efficiency gains, but exposes companies to new risks of breaching the data and systems. New instruments and new approaches are needed.

d) Advanced Monitoring

It is essential to keep track of the events (who and where has had access to what information), so that any undesirable events can be traced and identified. In addition, the full visibility of what is happening on the network and on company systems makes it possible to discriminate between normal and abnormal behaviour.

Horizontal- and Vertical Integration [2]

Principally, it is important to understand the difference between vertical and horizontal integration.

The horizontal integration focuses on the relation between the functional areas inside a company to make taken decisions congruent along all areas. The problems are often divergent objects and poor communication between different departments.

The Product Life Cycle Management (PLM) system allows business data integration and processing, creating a widespread knowledge of technical product information and ensuring uniformity in its development processes. It is an integrated system with other applications, which are necessary for the advanced management of all product information throughout the life cycle.

The vertical integration, on the other hand, handles the relations between different actors inside the value chain. The objective is an efficient coordination of the customer-supplier-interface, where contrary opportunistic behaviours are acting.

Each actor operates in a coordinated manner with other actors in the supply chain, thanks to shared systems and solutions of analysis of sales, sales forecasts and generation of production plans. Advanced Production Scheduling systems, web portals for customer-suppliers, inter-company communication systems are only a few of the methods for vertical integration in a company.

1.3 The Limitation in this Thesis

In this thesis, the consideration is to analyse only the technical and engineering education. As the main topic is digitisation, it should take into account a formation related to an environment where a fundamental technical and technological knowledge is required.

1.4 Aims

The aim of this thesis will be to analyse the actual situation of the education system actually used in almost every industrialised country. At this moment, whether they want it or not, every company is affected with topics covered by the 4th industrial revolution. This leads to special education plans from different education entities. Which offers are actually provided, and on which topics they are focused, is only one aspect to be analysed. To understand where education must go and how the development should be, is a consideration about future competences and abilities that students must present out of the school. Changing a structure like that of education, which was developed over many decades and centuries, is a big challenge. Different nations have been working strongly on implementation plans for a few years, but until now the steps are only small ones. In this thesis, the question is how it is possible today to get an education about Industry 4.0, which could be the driver and competences to revolutionising the actual system and what could be the recommendations to achieve it for the future.

1.5 Outline

The thesis is structured into four chapters. The first chapter gives a short introduction and then Chapter 2 analyses the background of education systems. It is structured with a firstly a literature review on scientific papers and published texts and with the second part is giving an overview about how different countries are handling digitisation in the education system, what are the implementation measures, times and related properties. In Chapter 3, the actual situation of the education system is presented, by giving an overview on different possibilities for technical education in South Tyrol. It concludes with individual offers related to Industry

4.0. Chapter4 shows the trends and possible developments, analyses future qualifications and what could be the technology of tomorrow to assist education. The thesis concludes with Chapter 5, giving a short summary and a few recommendations which should be considered for future engineering education systems in South Tyrol.

Chapter 2

LITERATURE REVIEW – THEORETICAL BACKGROUND

To elaborate this literature review, two directions have been followed. The first direction was to collect a series of scientific literature by using SCOPUS. This literature gives an overview about the actual situation around the world, how Industry 4.0 is used for education and how education is changing, having as a result students later working with those technologies.

As the research in this thesis is not only related to education at university level, but also at the high school level, the second direction of research is to find the state of the art as well as applications about new technologies for technical high school education.

2.1 Digitisation in the Education System - Scientific Literature

The scientific literature review is structured in a first Section describing the research methodology and a second Section with content analysis.

2.1.1 Research Methodology for the Scientific Literature Review

By utilising the Systematic Literature Review (SLR) method, it is possible to identify scientific papers in a systematic way in order to not lose too much time in exhaustive literature research. Working through, the three-step method [10] is recommended. For the first step, it is important to identify the correct questions of what is the aim or which are the objectives to find out in this research during the preparation stage. In this phase also the development and the validation of the review should be done. The second step consists in the physical conduction of the review. Once identified, all the related articles through the help of the previous planning phase, have to be analysed. Through the defined questions, the interesting data should be extrapolated. Finally, the last step is to write down the report on the extrapolated data and to make the evaluations. An important part to consider during writing the report is the limitation of the analysed papers to underline the relevance of this study. By conducting such kind of an SLR, the review will be very powerful, doing it in a systematic way considering the huge amount of published and unpublished works possible to find on the Internet.

2.1.1.1 Establishing Research Objectives

In this thesis, the aim is to understand how the concepts of Industry 4.0 are actually introduced in the education system and how new technologies can support teachers, changing the world of education.

2.1.1.2 Conceptual Boundaries

By searching for the terms Engineering Education and Industry 4.0 in publications relating to engineering in the SCOPUS library, the conceptual boundaries were specified.
Detailed search string:
(TITLE-ABS-KEY ("Engineering Education") AND TITLE-ABS-KEY ("Industry 4.0"))

2.1.1.3 Inclusion and Exclusion Criteria

To find the related works for the analysis, the following inclusion criteria were defined:

1) No limitation on publication date
2) No limitation on used language

The result of the search string in SCOPUS database was a total of 63 documents (22.03.2018).

2.1.1.4 Screening of Search Results

Afterwards, the following criteria were defined to understand which studies should be analysed:

1) Strictly related to education context
2) Strictly related to teaching methodologies

By reading the abstract of all identified papers, only four papers were identified to be relevant for further analysis.

2.1.2 Content Analysis of Resulting Papers

The content analysis of the identified papers analyses the actual situation about Industry 4.0

in the education system.

Actual Situation about Industry 4.0 in the Education System

The emergence of Industry 4.0 has had a massive impact on the education system. According to Baygin et al. [11], qualified employees have to be trained and educated according to the new technology trends to be able to overcome the requested competences by the companies. Transparency of information, real-time data acquisition and processing, interoperability, modularity and distributed decisions as well as technical support are the new principles of the 4th industrial generation. Developments about sensor technologies and the Internet must be introduced in education by interconnected devices to allow students working in an interactive system. In addition, the paper presents also the disadvantages of the new era. A survey by the Boston Consulting Group found that the biggest challenge will be the lack of qualified employees and the need of excessive investments. The survey compared Germany with the United States of America (USA), where Germany is thought to handle bigger challenges than does the USA. In another survey done by the author, it was found that Germany relies on continuous education and less occupational retraining and has fewer new jobs arising with Industry 4.0. The USA, at the other hand, believes exactly the opposite. In conclusion, accordingly education must change using new technologies supported by visual elements and IT. More collaboration between education entities and companies must be introduced. Students should work more on practical applications, working out reports, including ideas and opinions, to recognise better specific topics. In this way, students will receive the appropriate qualifications for the industry. Consequently, without a significant reform of the actual education system, it will be difficult to hit the given requirements. This paper is limited in giving a broad overview about the change in the education system supporting Industry 4.0. Analysing more in detail the concept of Engineering Education considering the Cyber-Physical Production System Antkowiak et al. [12] elaborated a study. The content of this study is that, in the smart factories, the level of complexity is increasing and this will have an impact on the learning method, especially for the didactic method of problem solving. It must be considered that through the emerging digital transformation for production management, not only a change for decision-makers must come about, but also a previous step, in the academic teaching method. Individual skills of the students must be strengthened, to cover the requirement for future factories, which will becomes “smart”. Customer requirements, which will strongly increase, need new kinds of communications between manufacturing lines to turn into a flexible production system. Every part of this system, as well as the product itself, will exist not only in the real, but will be represented by a virtual copy utilising the Cyber Physical Production System (CPPS). To do this, new technical skills must be developed and it must be decided which kind of engineer has to be involved in this process. Antkowiak devised some concepts considering the 4^{th} industrial revolution and how teachers can cover future engineering requirements. From the last industrial revolution, topics like Manufacturing Execution System (MES) level or Enterprise Resource Planning (ERP) or Programmable Logic Controller (PLC) were introduced in the industry. Nowadays, artificial intelligence and machine learning will support these topics. The academic staff have, as a consequence, the assignment to give students the necessary know-how on cognitive constructivism to be able to learn in a problem-oriented way. New teaching approaches like Cognitive Apprenticeship, Cognitive Flexibility or Anchored Instruction will be introduced in future education. The approach of Cognitive Apprenticeship is focused on how new technologies can support students in particular situations during traineeship or internship by a strategic, implicit expert-knowledge. Cognitive Flexibility is the approach, which will help students to give them a multi-perspective point of view to be able to solve a complex problem in an everyday situation. Anchored instruction is the most important approach, because it considers the structure and design of a course to cover new topics on Industry 4.0. Those three approaches could be a possibility of future didacticism and must be evaluated in the next few years regarding their efficiency. The limitation on this paper is clearly detailed information about some guidelines on how to implement these kinds of interesting approaches. Considering today's situation, a big gap already exists between theoretical specific knowledge and the practical applications. According to Schulte et al. [13] for an effective and high quality teaching and learning method, much research and development in didactic methodologies is essential, specifically for Computer Science Education (CSE). This paper is analysing the content of CSE and what could be the development in engineering education, building on an already existing framework and knowledge. Today's informatics education is based on a low theoretical connection to the research. It is more taking a generic approach or examples from another discipline to describe and define topics. Considering this, teachers should develop their Pedagogical Content Knowledge (PCK) to counteract this situation. PCK is a methodology which takes into account not only the content knowledge of a subject, but brings it in combination with the didactical knowledge. Treated topics during a lesson must be represented and formulated in an understandable way for all students. To conclude, one aspect has to be underlined in more detail. Developments of competences for teaching staff must be supported by research coming out from different sectors in order to bring together objectives so as to have reliable outcome.

This paper gives some interesting approaches but is limited to the consideration in the field of computer science education. Leaving this special science tree, it is understandable that changing the education system is strictly related to give the teaching staff as much support as possible, not only in formation and in training courses, but with infrastructures and technologies. A new trend, which brings education closer to Industry 4.0 processes, is the so-called FabLabs. Angrisani et al. [14] discussed the academic FabLab at the University Federico II in Naples, stating that the development of "makers" with the dispersion of digital skills characterises the 4th-Industrial Revolution, inspired by Industry 4.0. In the FabLab, people who are interested in technologies can design and create prototypes by themselves, using a low cost hardware and also open source software. High-end product could be generated in this way. Those people with such interest are so-called "makers" and receive the opportunity to work in the laboratories named FabLab (Fabrication Laboratories). This laboratory, with specific training programmes, gives the young IT engineers the possibility to grow up and develop to a maker. Certain kind of laboratories can help to bring together companies with students as well as give teachers new possibilities to teach. Different kinds of master degrees can be offered on this topic too. The aim is in providing students with skills in sensor networks and tutorials, imitating the real working processes by a virtual company operating in IT research and development (R&D) as well as embedded measurement systems. The FabLab is an ideal environment for a team-based working space to develop prototypes. These kinds of courses have also a positive result in the didactic quality assessment. Projects inside the FabLab of Naples can work out aspects in different segments, like additive manufacturing, biomedicine or Internet of Things (IoT) monitoring. The advantages of having a FabLab for the students are many. Contact with the companies, new teaching possibilities supported by business or acquiring skills to work out in a series of integrative projects by team work are only a few of them. The limitation today is that the FabLab activities are not sufficiently recognised in universities or in the business world.

Summarising the literature review, it is possible to extract interesting information. Every paper explained clearly that the change in introducing Industry 4.0 in companies will be massive, and obligates education entities to adapt their study plans and structures. Of course, big changes are always related to fears about future developments of competences and skills, leading to reorganisation of personal occupation. On the other hand, the advantages of new possible applications, which are coming within new technologies, are actually difficult to define. Cyber-Physical systems has created a completely new generation of knowledge requirements. Anchored Instruction, Cognitive Flexibility and Cognitive Apprenticeship are the new keywords which have to be considered in Industry 4.0. The education system is facing a big challenge considering the actual teaching method. Giving the students a broad theoretical fundamental knowledge about specific topics and underlying this with a practical approach provides a high pedagogical content know-how from the teacher. Teachers receive support in this activity from different technologies and infrastructures, like the FabLab, which are laboratories equipped with new technologies where students can work out projects in collaboration with companies, acting in Industry 4.0, giving them the possibility to acquire the competences for their future employments.

2.2 Digitisation in the Education System – Practical Literature

In finding practical Literature about the state of the art for new technologies used for education, the Google search platform is used. Words like Industry 4.0 in relation to Digital Education were used in different languages, trying to find out the actual situation in different countries around Europe. In particular, along with Italy, Austria and Germany were also analysed in this thesis. The consideration was to compare education systems from countries with similar social and cultural realities to those in South Tyrol.

Using words such as those mentioned above in Google, the number f published results was extremely high. This led to an in-depth analysis to understand what could be an important paper or article related to the context of this master thesis.

The focus is to analyse the actual situation of methodologies related to Industry 4.0 used in higher education. The following are the questions the practical literature covers:

- How and in which context are the methods actually applied in the education system?
- Do implementation plans for digitisation already exist, and if yes, how are they structured?
- How do different countries handle this topic?
- How do politicians implement reforms to support activities to be able to achieve given goals?

The analysis starts with the guidelines, developed from the European Commission and then goes into detail from the different countries previously mentioned. First Italy, then Austria and finally Germany.

2.2.1 Digitisation in the Education System in Europe

European countries follow the guidelines created by the European Commission. Some important guidelines related to digitisation in education systems are developed from the Commission and are listheted below:

Timelines for Digitisation of education in Europe (according to Digital Education Action Plan 2015 [15]):

December 2014: the European Commission set the first guidelines of digital education for Europe by a high level conference. They are based on several publications of the OECD's Centre for Educational Research and Innovation, by the World Economic Forum's New Vision for Education Report and by studies such as the

Ambrosetti thinktank's Education for the 21st century.

March 2017: Underlining the EU Member States to implement education plans for young people.

May 2017: Development of an agenda named “Higher Education and School development and excellent teaching for a great start in life”.

October 2017: Training plans for education systems called “fit for the digital age” should be developed according to the European Council.

November 2017: Gothenburg Summit, the Parliament, the Council and the Commission proclaimed the European Pillar of Social Rights, which enshrines the right to quality and inclusive education, training and life-long learning. The Communication ‘Strengthening European Identity through Education and Culture, the Commission’s contribution to the EU Leader's Agenda discussion on education and culture at the Gothenburg Summit, set out a vision for a European Education Area and announced a dedicated Digital Education Action Plan.

January 2018: The first European Education Summit defined the foundations of the European Education Area for an innovative, inclusive and values-based education.

Considering the Digital Education Plan 2018 [15] all members and stakeholders should implement their action plan by the end of 2020. Guidelines on how to develop and implement those actions will be released by the Commission.

2.2.2 Digitisation in the Education System in Italy

In Italy, the Ministry of education, university and research (Ministero dell’educazione dell’universitá e della ricerca - MIUR) creates a law in 2015 (legge 107/2015) with the context of a national plan of school digitisation. The statement of this vision is the innovation of the school system and the opportunities of digital education.

Table 1 show an extract of the action plan between 2014 and 2020 developed from MIUR:

Nr:	Action	Implementation Date	Resources
1	Internal wiring of all Schools (LAN/W-Lan)	2015	88,5 million €
2	Charge for connectivity: the right to Internet access at school	2016	10 million €/Year
3	Fibre for ultra-wide Band to the entrance to every school	Until 2020	Plan Ultra-wide Band costs

4	Environments for integrated digital didactics	2015	140 million €
5	Challenge Price for the digital school (competitions)	2015-2016	2 million €
6	Active policies for BYOD (Bring Your Own Device)	2015	apply to the action
7	Laboratory Plan (new concepts for digital integration in the laboratories)	2016	45 million € (local laboratories) + 40 Mio € (creative workshops for the basic skills of the first cycle) + 140 million € (professionalising laboratories in digital key)
8	Single Authentication System (Single-Sign-On)	2015/2016	apply to the action
9	A digital profile for each student	2015/2016	apply to the action
10	A digital profile for each teacher	2015/2016	apply to the action
11	Enabling Solutions and Digitalising Administration of school	2016	Ordinary appropriations for the year 2016/17
12	Electronic Register	2016	About 48 million €, needed to equip over 141,000 classrooms in primary schools
13	Strategy School data	2016	1 million € + 100,000.- € per year
14	A common framework for digital-skills and media education for students	2015	No expenses needed
15	Innovative scenarios for the development of applied digital skills	2015	1,5 million €
16	A research unit for competences in the 21st century	2016	apply to the action
17	Updating the curriculum for technologies at lower secondary education school	2016	apply to training resources

Table 1: Extract of action plan MIUR – Digitisation in Education [16]

Totally, there are 35 activities on the national plan for digital education. Only the part which is more related to this thesis is listed above.

2.2.3 Digitisation in the Education System in Austria

The Austrian Federal Ministry of Education, Science and Research created the topic

Education 4.0, a concept which covers the entire school career. This involves a large number of competencies: from critical handling of information data to media competence, network security and problem solving.
The Ministry build the concept on four columns [17]:

1) Digital basic education from elementary school onwards:
In addition to media education, digital basic education is now gradually being integrated into curricula across all schools in Austria. Students receive proof of their basic digital education in the form of a collective passport. From the fifth to the eighth grade, a binding exercise, Digital Basic Education, with its own curriculum of two to four hours per week is introduced.

2) Digitally competent teachers:
From 2017 on, all new teachers will acquire standardised digital skills like:
- Digital competence check (digi.check) at the beginning of the career entry phase
- Completion of a modular course of six ECTS for digital didactics within three years of school entry
- Reflection on one's own teaching activities in a digital portfolio

In addition, the first Austrian Future Learning Lab was established at the Vienna University of Education in cooperation with the Federal Ministry for Family Affairs and Youth. Teachers will be able to experiment with digital tools and will be trained in their use.

3) Infrastructure and IT equipment:
State of the art infrastructure is also an important prerequisite for digital education. WLAN is available in all rooms at around 50% of the federal schools, 96% of all classrooms are connected to the Internet. At the compulsory schools, 31% currently have WLAN, 78% of the classrooms have Internet access.
The expansion of the classrooms with no Internet is one of the most important steps to reach, in order to have the possibility to work with digital tools or methods.

4) Digital Learning Tools:
Teachers need easy and free access to teaching and learning materials to teach digital content. The development of OER (Open Educational Resources) provides content and encourages the active use of digital media.

The start of the digital strategy is the academic year 2017/18 and the gradual implementation of digital primary and lower secondary education will then start with a pilot project. This is based on an eEducation network [18].

2.2.4 Digitisation in the Education System in Germany – Bavaria

The German region of Bavaria is very close to South Tyrol considering not only the geographical distance but also the similar culture and social development. Because of this, the region of Bavaria in South-Germany is often taken into consideration when a social or cultural development has to be analysed.

The following is the future strategy of the Bavarian free state [19]:
In Bavaria, media pedagogy is already part of the study courses. The aim is to strengthen and increase the sustainability of these contents. At universities, the area of "digital education" is to be further strengthened as part of media pedagogy for teacher training students. Digitisation is a continuous process which is significantly influenced by technical progress. Therefore, the training of teachers is imperative for maintaining and updating professional competence. The eLearning Competence Centre of the Academy for Teacher Training and Personnel Management in Dillingen (ALP) has, in the past, already launched and conducted several sustainable training initiatives, such as SchiLfTelum or Intel® Teaching, in order to address teachers who were still reluctant to use digital media in class. In order to take account of the constant changes in the digital world, the Ministry of Education in Bavaria intends to commission the eLearning Competence Centre to plan and roll out a further training initiative and to supplement and expand existing teacher training measures in line with needs, so that new technical and pedagogical developments are taken into account.

Below is only one of many measures the Bavarian ministry has developed for schools:

- a complete competence centre for media education was created. This centre, built on a digital platform, can be used by teachers as well as students with the following tools:
  - E-learning platforms for students
  - Strengthen T=teacher competences in various sectors
  - Open Education Resource (OER) to represent added value in the transfer and acquisition of knowledge and to promote pedagogical goals, such as the individualisation of teaching-learning processes
- The use of private equipment by teachers and students in the classroom is becoming increasingly relevant. The Ministry, with the project “Bring your own Device” (BYOD), will continue to accompany and support the existing initiatives in this regard.
- Organisation of projects, talks or studies about the MINT subjects. MINT is an abbreviation for the subjects: Mathematics, Informatics, Natural Science and Technical subjects.

- The Bavarian Media Driving Licence of the Media Education Foundation has already been used successfully on a voluntary basis in many schools in the past and makes it possible to recognise opportunities of digitisation and to counter dangers (e.g. in the areas of "cyber bullying" or "illegal downloads"). Further development of content and methods has the aim of making essential parts of the Bavarian Media Driving Licence available to all students.

The University of the Future will and must change in many ways in order not only to respond to the challenges of digitisation, but also to actively integrate all aspects of this development into its strategic activities.
The universities should become a "digital campus" on which all actors in science take advantage of the opportunities and possibilities of digitisation and benefit from them. The aim is to improve both the performance and equal opportunities of the higher education system as a whole.

Some of the implementation measures for universities in Bavaria:
- Platform of the Virtual Universities of Applied Sciences of Bavaria
- The Digital Campus Bavaria is to create the infrastructural conditions for a Digital Learning and Research Area in Bavaria
- Expanding cyber security at universities
- Creating a flexible, secure access for students' mobile devices to their individual learning environments
- More powerful Computer simulation Centre: The Leibniz Computer Centre is to be equipped with a new simulation computer of the highest performance class after the end of the SuperMUC computer's operating life in 2018.
- Building a Big Data Centre in the Leibniz Computer Centre
- Providing a digital professor almanac

2.2.5 Summary of the Different Action Plans of the Countries

With the analysis of the different countries, it is possible to see that digitisation in education is a topic followed by everyone. Each country has many ideas, written down in action or implementation plans seeking to help their own education institutes with different guidelines and platforms. The politicians have allocated high budgets so as to afford certain infrastructure investments.

Chapter 3

STATE OF THE ART IN SOUTH TYROL

3.1 Current Education System in South Tyrol

In the Italian province of South Tyrol, the so-called New Statute of Autonomy of 1972 [20] is a local law which forms the basis for the protection of minorities in the province of Bozen. The Statute came into force on 20 January, 1972 and gave the province of South Tyrol primary, secondary and tertiary powers.

Until 2001, the constitutional reform, the primary, secondary and tertiary legislative powers of the country were subdivided into different areas, all handled from Rome. Since then, the situation has been reversed. The legislative power of the state has a number of clearly defined areas, such as foreign policy, defence, currency, taxation, public security and jurisdiction, which are reserved and handled only from the Italy. For all other sectors, South Tyrol can influence or create its own laws through the primary, secondary and tertiary legislative powers.

In areas where the Province of Bolzano has primary powers, it can regulate these with its own laws. Secondary competences are also called "shared" or "competing" competences. South Tyrol can make its own laws in areas of secondary competence with the same restrictions as for primary competence, not violating the principles of the state law. In principle, the state regulates the fundamental part of the law, the region or province the details. For the education sector, South Tyrol has the secondary legislative power.

As previously explained, the province of South Tyrol has a Statute of Autonomy, which protects the German-speaking minority people in Italy. Part of this statute gives the minority the opportunity to learn in their own mother language. As a result, the education system in South Tyrol is structured with a German and an Italian-speaking infrastructure. In this parallel working system, a child can choose, starting from the kindergarten until the secondary high school, whether she/he wants to attend a German or an Italian-speaking school. The main difference between the two is that, in the German school all subjects are in the German language apart the study of Italian, which is considered in this school as a second language. In the Italian schools, the situation is reversed and German is defined as the second language to learn.

At the beginning, it is important to define the word “education”. Education can be divided into two sectors. In the first sector, you receive a classical education, for example, at schools to get a special orientation. For example, attending a technical secondary school in mechanics gives you a large basis of technical foundations, applications or methods to be able to get work in this field. The second sector of education is the huge area of further education considering the lifelong learning to achieve new competences. Nowadays, working your entire life in the same company is becoming rare. People will no longer work for more than 25 years doing the same thing all the time. Terms like “job rotation”, “job enlargement” or “job enrichment” are becoming more and more important for employment to keep the motivation and interest in working for a company continuously high. This can be achieved by a special education personnel training from the human resource department. For each worker, an individual training plan has to be worked out. Part of this plan are further education courses to be trained or educated in a special sector, area or method. As a result, with the new competences, a worker can get more responsibilities in a company and will be able, not only to change a job or work activity, but could also have an opportunity for a promotion.

The Italian school system is divided into several levels. Primary and lower secondary education together consist of eight years. After these eight years, students can choose at the age of 14 between an attendance of different upper secondary school types. Universities or higher vocational training institutions form the tertiary education sector.
Children and adolescents between the ages of six and 16 must attend an obligatory educational establishment in Italy for ten years. If a pupil does not want to continue their school education afterwards, it is possible to complete vocational training up to the age of 18. School attendance is free of charge until the end of lower secondary school.

Table 2 shows the education structure in Italy:

Age	School Level	Duration	Definition
3-6	Pre-School attendance Level	3 years	Kindergarten
6-11	Primary Level	5 years	Elementary school
11-14	Lower Secondary Level	3 years	Middle school
14-19	Higher Secondary Level	3 – 5 years	High school
>19	Tertiary Level	1 – 8 years	University - University of Applied Sciences

Table 2: Overview of the education structure in Italy

Figure 6 illustrates the education system in South Tyrol:

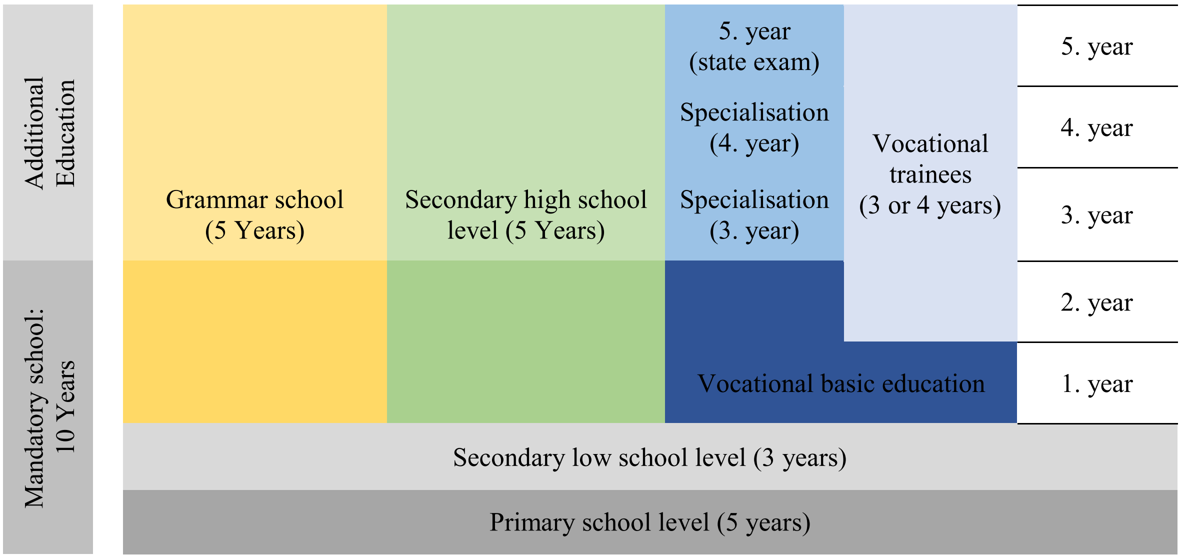


Figure 6: Graphical education overview in South Tyrol

The last big reform of secondary level schooling in Italy was made in 1923. In the past decades, new types of secondary schools and specialisations have been developed in South Tyrol. Also, new school locations have been added. In February 2010, the Council of Ministers approved the last reform, which is a smaller one compared to that in 1923, named "La buona scuola" with the goal to reorganise the school system. A landscape of 800 different disciplines and degrees was defined [21].

3.1.1 Current Education System in Schools and Universities

The analysis in this thesis regarding the education system in South Tyrol today considers two levels:

a) Structure of the education in South Tyrol after lower secondary level
b) Structure of the education in South Tyrol after higher secondary level

a) Structure of the education in South Tyrol after lower secondary level

The upper school level is based on three pillars of education [22]: the vocational education, the grammar school and technical higher secondary schools, which stand side by side in the same way. The professional education is ideal for those who are interested in learning practical applications especially doing a craft by hand, and who are primarily seeking a professional qualification. This qualification is a priority in vocational education. A certification for higher school can nowadays also be obtained at the vocational education schools after five years of attendance. The grammar schools provide a broad general education for the pupils and prepare them for a further study at a university or university of applied sciences. Finally, the technical secondary schools, which also give the students a broad general education, add, in addition, a preparation for studies in specific areas for a direct entry into the world of labour.

<u>The vocational education</u>

In the vocational education [23] there are three possibilities from which a young person can choose: apprenticeship, full-time education or education with preparation for the higher school certificate.

An apprenticeship offers the opportunity to learn a profession directly at the workplace in parallel to attendance in a vocational school. It is a dual education system. Learning through doing is the focus of this training. In South Tyrol, there are three different forms of apprenticeship. Classical apprenticeship is for 15-year-old teenagers with a duration of three years. Another, a more specialised apprenticeship, is for high school graduates who are trained in the workplace. The last apprenticeship is for higher labour education or research fields. This apprenticeship is used for students who will continue on to a university or a university of applied sciences.

Figure 7 explains graphically the possibilities for vocational education in South Tyrol:

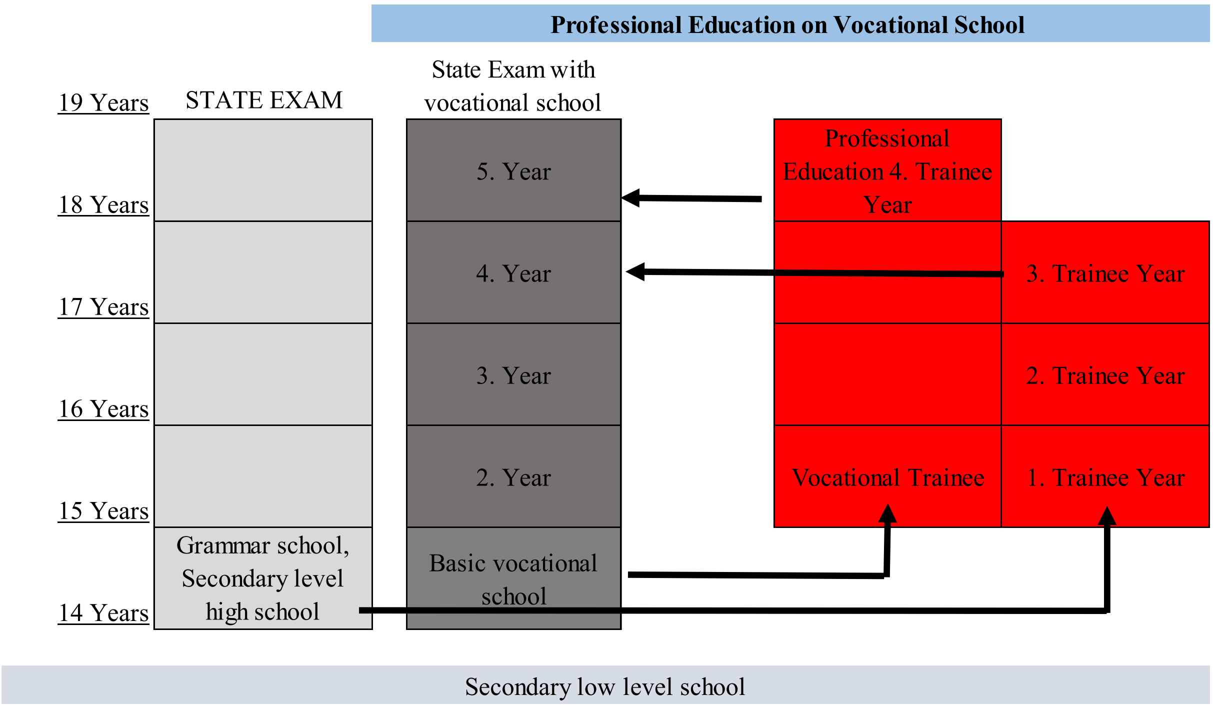


Figure 7: Structure of vocational education in South Tyrol [24]

The first year of the classical vocational education covers the basic professional level. After this, the vocational school begins with a duration depending on the type of qualification. After four years of education and apprenticeship, the students finish with a vocational training diploma. After three years of study, a third year qualification is achieved. In both ways, it is possible to switch to education for the preparation of the higher school certificate after five years.

<u>The technical higher secondary level school</u>

The specialised high schools teach general and specific methods through the learning of a topic, deepening it and working out specific applications on it. A close connection between theory and practice develops a strong cultural, economic, scientific and technological knowledge. In the technical secondary high schools, the students acquire the necessary expertise and skills to be able to solve appropriately economic and technological problems by applying standards and regulations. The specialised secondary schools enable students to enter into the world of work or continue with a further study. There are two types of specialised secondary schools:

I. Technical higher secondary level schools in the economic field
II. Technical higher secondary level schools in the technological field

I. Technical higher secondary level schools in the economic field

The technical secondary schools in the economic sector focus on the study of business processes, the information and communication technology supported administration and management of a company, marketing, finance and the business sector tourism. Students are able to develop economic tasks and transfer them into the system of a company, considering civil law as well as tax standards.
In practical simulations by a virtual company, the students of the fourth class acquire the necessary key qualifications for their future field of activity.

II. Technical higher secondary level schools in the technological field

The technical secondary schools in the technological field focus on technical-scientific and technological areas. The focus is on the ongoing development and innovation of technical products and work processes. The first two years have a more general educational character and prepare for the various disciplines of the following triennium. After completing the biennium, it is possible to change to many different fields of interest at the technical secondary schools.

b) Structure of education in South Tyrol after higher secondary level schools

After finishing the higher secondary level school pupils have the possibility to start to work, or continue with their education. There could be two paths. The first is the attendance of a university and the second, with a more practical approach, is registration in a university of applied sciences. The main differences between these education paths are many; two of them are analysed in more detail.

Difference 1: The universities are more specialised in research and development. Actual methods, technologies and processes based on existing standards regulations are work out to optimise, or find out new application or products. The goal is to understand and define new requirements coming from the market or customer, analysing them and developing the frame to be able to cover them. On the other hand, a university of applied sciences gives you an education which is more related to the practical application of a developed method or process. Consequently, the students are more involved in collaboration through projects with companies in order to implement new, or optimise existing processes.

Difference 2: The second point considers the acceptance of the university degree. The universities of applied sciences are more in use outside Italy. If students attend certain kinds of universities, for example, in Austria or Germany, and go to Italy afterwards to work inside a public organisation, the degree will not be accepted. A standardisation for the acceptance of all types of degrees from different universities between countries inside Europe does not actually exist.

University

University teaching is research-oriented. It does not present only fundamental knowledge, but at the same time considers the process of its acquisition and renewal. Research-oriented teaching serves not only to train scientists, but also offers those who are not going into research a qualification of their own. The basic principle is that university education for teaching and appropriation of knowledge does not run parallel or even is seen only as a personality development. This type of education must involve the transfer of technical knowledge in a constitutive way and includes both intellectual as well as personal considerations.

University of Applied Sciences

A university of applied sciences is a possible institution to choose for the tertiary education sector. A distinction is made between scientific, scientific-application-oriented, artistic-scientific, creative-scientific or artistically oriented universities. The universities serve to foster the sciences and arts, where a university of applied sciences is a type of university that conducts teaching and research with a more application-oriented focus on a scientific basis. This type of education infrastructures are mostly located in Germany, Austria and Switzerland. In South Tyrol, there is one university of applied science in the form of the regional technical college for health professions, named Claudiana. The course related to technical subjects is “Prevention techniques for the environment and the workplace” [25].

3.1.2 Current Location of Education Infrastructures

The location of the education infrastructure is generally established in the different city centres of South Tyrol. The advantage of this is the good connection by public transport in order to give the students the possibility to reach the schools by bus or train.

The vocational education [26], [27]

The vocational schools are allocated in different parts of the region. Especially this kind of education is dispensed with a strategic plan, considering the different needs caused by the requirements of the economy or tourism in certain areas. The following are the locations for technical vocational education:

The regional vocational schools are located in most of the cities of South Tyrol. These are: Schlanders, Meran, Bozen, Brixen and Bruneck.

Figure 8 shows the regional landscape with the technical vocational schools:

Figure 8: Landscape of technical vocational schools in South Tyrol

Further vocational education infrastructures are outside a centralised location. For technical education those places are: Sarnthein, Neumarkt and Sterzing. Only the first two years of basic vocational education is held in those subordinate infrastructures.

The technological higher secondary level school [28]

The technological higher education Schools are located like the vocational Schools in the cities of South Tyrol with the same reasons vocational schools have. Those cities are starting from the west going to east are Schlanders, Meran, Bozen, Brixen and Bruneck.

Figure 9 indicates the location of technological higher secondary level schools:

Figure 9: Landscape of technological higher secondary level schools in South Tyrol

University and University of Applied Sciences [29], [25]

The Free University of Bolzano-Bozen is located in the centre of Bozen can offer the students the best connection. The Claudiana University of Applied Science is located close to the province hospital on the boarder of Bozen for practical applications.

Figure 10 presents the landscape of the Universities:

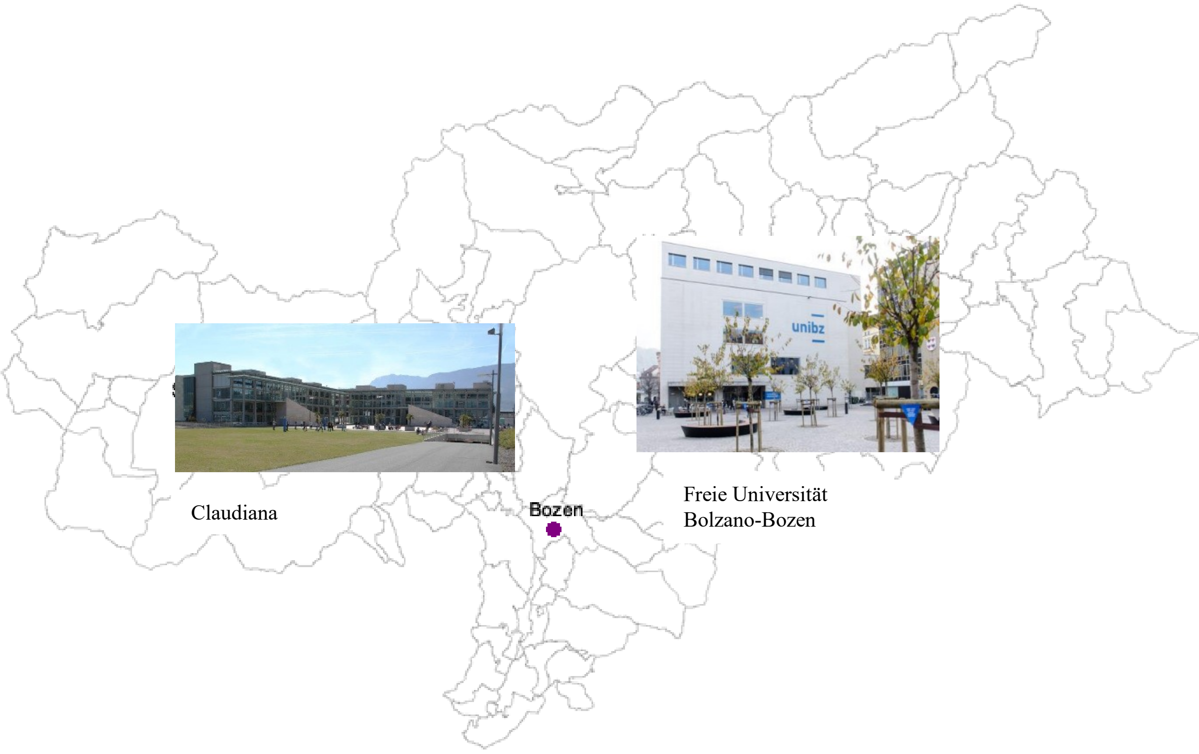


Figure 10: Landscape of the Free University of Bolzano-Bozen (Computer Science, Engineering) and Claudiana University of Applied Sciences in South Tyrol

3.1.3 Current Typology of Engineering Education Infrastructures

In this chapter, the different types of offers about engineering education will be listed, considering only the technological sector. The lists are structured by the different infrastructures possible to find in South Tyrol.

Table 3 shows the education programme of the vocational schools [26], [27]:

Location	Name of the School	Language	Basic vocational level	Vocational school	Specialisation course
Schlanders	Landesberuf schule	German	Craft and Technology	Metal Technology	Stone sculptors
				Stone working	
Meran	Luis Zuegg	German	Craft and Technology	Electro Technology	
	G Marconi	Italian	Craft and Technology	Electrical-electronic operator	

				Mechanical operator	
Bozen	Lehranstalt für Industrie und Handwerk (LIH)	German	Craft and Technology	Electrical engineering for buildings and infrastructure	IT systems electronics engineer/application developer
				Computer Science	Servicing and Maintenance
				Mechatronics	
	Galileo Galilei	Italian		Maintenance and Technical Assistance	
				Dental technician/Dentist ry	
	Luigi Enaudi	Italian	Craft and Technology	Electrical-electronic operator	Vehicle Diagnostic Technician
				Mechanical operator	Technical operation and maintenance of automated systems
				Automechanics	Technical designer modeller
Sarnthein	Landesberuf schule - Außenstelle	German	Craft and Technology	Craft and Technology	
Neumarkt	Landesberuf schule - Außenstelle	German	Craft and Technology	Craft and Technology	
Brixen	Christian Josef Tschuggmall	German	Craft and Technology	Computer Science	Computer Science and Network Technology
			Metal Technology	Wood Technology	Servicing and Maintenance
					Mechanical Engineering
	Enrico Mattei	Italian	Craft and Technology	Electrical-electronic operator	
				Mechanical operator	
Sterzing	Landesberuf schule -	German	Craft and Technology	Craft and Technology	

	Außenstelle				
Bruneck	Landesberuf schule	German	Craft and Technology	Building and Construction Industry	Industry and Building Automation/Automation
				Electro Technology	
				Mechanical Engineering	

Table 3: Educational programme of vocational schools in South Tyrol

Table 4 shows the technical higher secondary level school [28], [30]:

Location	Name of the School	Language	Direction/Field	Focus/Articulation
Schlanders	Oberschul-zentrum	German	Mechanical Engineering, Mechatronics and Energy	Mechanical Engineering, Mechatronics
Meran	Oskar von Miller	German	Construction, Environment and Spatial Planning	Construction, Environment and Spatial Planning
			Electronics, electrical engineering and automation	Electronics and Electrical Engineering
			Chemistry, Materials and Biotechnology	Biotechnologies in the medical sector (Regional focus on nutrition)
Bozen	Max Valier	German	Mechanical Engineering, Mechatronics and Energy	Mechanical Engineering, Mechatronics
			Electronics, electrical engineering and automation	Electronics and Electrical Engineering
			Electronics, electrical engineering and automation	Automation
			Transport and Logistics	Logistics
			Information Technology and Telecommunications	Information Science
			Information Technology and Telecommunications	Telecommunications
	Peter Anich	German	Construction, Environment and Spatial Planning	Construction, Spatial Planning, Environment
			Construction, Environment and Spatial Planning	Geotechnical engineering
			Construction, Environment and Spatial Planning	Wooden construction
	Galileo Galilei	Italian	Mechanical Engineering, Mechatronics and Energy	Mechanical Engineering, Mechatronics
			Electronics, electrical	Electronics and Electrical

			engineering and automation	Engineering
			Information Technology and Telecommunications	Information Science
			Information Technology and Telecommunications	Telecommunications
			Chemistry, Materials and Biotechnology	Biotechnologies in the medical sector (Regional focus on nutrition)
			Chemistry, Materials and Biotechnology	Chemistry and Environmental Biotechnology
	Rainerum	Italian	Mechanical Engineering, Mechatronics and Energy	Energy
	A. e P. Delai	Italian	Construction, Environment and Spatial Planning	Construction, Environment and Spatial Planning
Brixen	Jakob Philipp Fallmerayer	German	Information Technology and Telecommunications	Information Technology
			Graphics and communication	Graphics and communication
Bruneck	TFO-Bruneck	German	Mechanical Engineering, Mechatronics and Energy	Mechanical Engineering, Mechatronics
			Electronics, electrical engineering and automation	Automation
			Chemistry, Materials and Biotechnology	Chemistry, Materials and Biotechnology

Table 4: Educational programme of higher secondary level school

Table 5 shows the study plans of the Free University of Bolzano-Bozen [29]:

Faculty	Degree level	Title	Specialisation
Science and Technology	Bachelor	Industrial and Mechanical Engineering	Mechanics
			Energetics
			Logistics and Production
			Automation
	Bachelor	Wood Engineering	Industry
			Wood construction
			arts and crafts
	Bachelor	Agricultural Sciences and Environmental Management	
	Master	Industrial Mechanical Engineering	Mechanics and Automation

			Logistics and Production
	Master	Environmental Management of Mountain Areas	Rural Development
			Environmental Protection
	Master	Energy Engineering	
	Master	Food Sciences for Innovation and Authenticity	Applied Engineering and Genetics
			Food Quality and Management
			Nutrition Sciences
			Food Chemistry
			Food Packaging
	Master	Horticultural Science	
	Master	BEE: Building, Energy and Environment – CasaClima®	
	PhD	Mountain Environment and Agriculture	
	PhD	Sustainable Energy and Technologies	
	PhD	Food Engineering and Biotechnology	
Computer Science	Bachelor	Computer Science	
	Master	Computer Science	Data and Knowledge Engineering
			Software Engineering and IT Management
	Master	Computational Data Science	Data Analytics
			Data Management
	European Master	Computational Logic (EMCL)	
	European Master	Software Engineering (EMSE)	
	PhD	Computer Science	Knowledge Representation and Data Management area
			Software Engineering area
			Information and Database Systems area

Table 5: Study plan of the Free University of Bolzano-Bozen

Table 6 shows the study plan of the Claudiana University of Applied Sciences [25]:

Location	Degree level	Title
Claudiana University of	Bachelor	Prevention techniques for the environment and the workplace

Applied Sciences		
	Bachelor	Medical-technical radiology assistance

Table 6: Study plan of Claudiana University of Applied Sciences

3.2 Current Situation of Lifelong Learning in South Tyrol

South Tyrol is covered by a relative high degree of infrastructures, which offers many courses for qualifications to the different target groups. Target groups could be the industry sector as well as the trade and service sector or the huge tourist sector.

Public entity: Office for Further Education [31]

Public entities manage a large variety of courses. Some of them are for special professional groups like pedagogics or safety managers, others are generic courses covering individual requirements like cultural or language courses. In addition, the Office of Further Education collects on the homepage not only all those courses but also further education courses from private providers. This helps people to find the right course in a broad range of offers.

Vocational schools

Vocational schools offer many training and education programmes, mostly organised in their own fields, where students are instructed for their professions. This means, if a vocational school provides a technical instruction for the pupils, they have the available machinery or laboratories to propose further education with this kind of equipment. Already having those machineries, vocational schools can offer additional courses to cover individual or economical/industrial needs.

Chamber of Commerce [32]

The Chamber of Commerce in Bozen is well-organised and covers many activities as well as the handling of the Register of Companies, for example, market research by the Institute for Economic Research or organising customised courses by WIFI Training and Further Education Centre.

IDM (Innovation, Development and Marketing) [33]

IDM Südtirol was founded in 2016 and provides South Tyrol companies with business services. The goal is to develop South Tyrol to the best tourist destination as well as the most attractive location for entrepreneurs and start-ups in Europe. To do this, product development and Export and Innovation services are provided by IDM for local companies, to increase their competitiveness in the global market. IDM is clustered in technology fields for South Tyrol's areas of strength and each cluster is structured by ecosystems, institutes and research entities [34]:

- Alpine Technologies
  - Ecosystem Constructions (IDM)
  - Ecosystem Health and Wellness (IDM)
  - Ecosystem Wood & Agricultural Technology (IDM)
  - Ecosystem Sports & Alpine Safety (IDM)
  - Terraxcube (EURAC)
  - Institute of Mountain Emergency Medicine
- Green Technologies
  - Ecosystem Energy and Environment (IDM)
  - Institute for Renewable Energy (Eurac)
  - ClimaHaus Agency
- Food Technologies
  - One-Stop-Shop food.bz.it
  - Ecosystem Food (IDM)
  - Free University of Bolzano-Bozen
  - Research Center Laimburg
- ICT & Automation
  - Ecosystem Automotive (IDM)
  - Ecosystem ICT & Automation (IDM)
  - Fraunhofer Italia
  - Free University of Bolzano-Bozen

NOI Techpark [35]

Many different laboratories are developed to support the ecosystems of the IDM. Laboratories like the makerspace are located inside the NOI Techpark. This Park has developed since 2016 with a focus on the practical application and realisation of ideas developed by IDM or entrepreneurs. The NOI Techpark is a big site in the industrial area of Bozen, where many laboratories are located as well as various research entities, like

Frauenhofer Italia. In addition, empty offices for new start-ups are offered to cover the first years of entrepreneurship. The IDM headquarters is also inside the NOI Techpark. There are also laboratories outside the park, managed by other entities like the Smart Mini Factory Lab from the University of Bolzano-Bozen. In the field of their core competences, IDM organises many courses and individual trainings for companies or people with special technical interests.

Figure 11 is a concept study about the infrastructure of the NOI Techpark realized by IDM:

Figure 11: Infrastructure NOI Techpark [36]

Makerspace [37]

In recent years, a new type of laboratory has emerged with the name makerspace in which people are invited to develop new products or optimise existing products. To be able to do this the makerspaces are equipped not only with traditional machineries such as numeric controlled lathes or milling machines, but also with new technologies like 3D Printers or Scanners as well as laser or water cutting machines. Of course, in order for people to be able to work with a certain kind of equipment, a specialised training must be first attended. The owner of the park organises these courses on-site. The makerspace in Bozen is allocated in the NOI Techpark.

BITZ – unibz FabLab

There are currently 650 FabLabs spread around the world, 65 of them in Italy [37]. One is in the city centre of Bozen. The Philosophy of the BITZ is nearly the same as the makerspace. The difference is that the makerspace located in the industrial area of Bozen is dedicated to companies or entrepreneurs, whereas the BITZ in the city centre should serve more the private person interested in technical applications.

Smart Mini Factory [38]

The Smart Mini Factory laboratory was developed in 2017 for research on flexible and agile production systems in the following fields:

- Industrial Automation and Robotics
- Cyber-physical production systems for Industry 4.0

The lab is used to show and teach new technologies to students and other stakeholders, like companies or other entities, and organises specialised courses in the fields listed above.

CasaClima® - KlimaHaus Agency [39]

The KlimaHaus Agency is an institution of the Autonomous Province of Bolzano and it was founded in 2002 for the energy certification of buildings in South Tyrol. It offers a comprehensive range of training and further education for all actors involved in construction. The staff organises and promotes initiatives to public awareness in the areas of energy efficiency, sustainability, construction quality and climate protection. Today, specific further education courses and trainings have led to over 8,000 certificated buildings in South Tyrol and the rest of the country, where KlimaHaus standards are used as a template to work out a quality inspection protocol at a high level.

Adult Education Centre ("Volkshochschule") [40]

The Adult Education Centre South Tyrol is a traditional institution in the field of further education. It began its activity in the 1920s and organises all courses planned from the Office for Further Education. The Education Centre is structured with 24 local offices across the province of South Tyrol and offers a wide range of different individual courses from culture and society to language, special profession education and IT and multimedia trainings. The wide spread of local offices around the region, gives also people who live in the periphery the possibility to attend an attractive course. Locations are in: Bozen, Brixen, Sterzing, Auer, Eppan, Neumarkt, Kaltern, Tramin, Welschnofen, Deutschnofen, Terlan, Sarnthein, Kardaun, St. Martin/Passeier, Kurtinig, Lana, Ritten, St. Leonhard/Passeier, das Schlerngebiet, Sexten, Tiers, and das Pustertal. The Adult Education Centre South Tyrol has already been awarded the quality certificate EFQM, - "recognised for excellence: 5 stars", for its efforts. In addition, it holds an ISO 9001:2015 certificate.

EURAC Research Centre (EURopean ACademy) [41]

Since 1992, EURAC Research Centre has been an association created by a private law with the aim to research in the areas of Law and Language, Autonomous Regions and Minorities as well as the Alpine Environment. The centre's divisions t are currently the following [42]:

- Alpine Environment Institute
- Applied Linguistics Institute
- Biomedicine Institute
- Comparative Federalism Institute
- Earth Observation Institute
- Minority Rights Institute
- Mountain Emergency Medicine Institute
- Mummy Studies Institute
- Public Management Institute
- Regional Development Institute
- Renewable Energy Institute
- TerraXcube
- Centre for Advanced Studies

Despite these many areas of research, the centre is gradually expanding its activities into new sectors and has introduced new departments like the Education and Training Department. Under the motto "Continuing education for lifelong learners", EURAC offers compact courses, special seminars and degree courses related to their activity fields. In addition, the department organises workshops and in-house seminars structured around individual needs of companies.

Trade association for handcraft and services (LVH/APA-CNA/SHV)

The trade association for handcraft and services focuses its activities to support all companies in South Tyrol in their daily challenges. The small and middle-size companies often grow up in a fast way and need to be helped for different aspects wherein the entrepreneur and the few employees often don't have the competences or simply the time. With different courses or, for the company, individual tailored seminars, the association offers its members the possibility to optimise their processes or to be able to stay up-to-date with new regulations or laws.
CNA/SHV is the Italian association in handicrafts for small and medium-size companies.

Each member is part of a national unitary system, which unites 670,000 companies [43], with 1,160 offices throughout Italy, which operates to preserve the distinctive values of the enterprises.

Entrepreneurial Association (CTM) [44]

The Service Co-operative Centre for Technology and Management (CTM) was founded in 1983 with the aim of promoting corporate human capital. CTM is part of the South Tyrolean Business Association and is, for the members, the first point of contact for vocational training and further education.

The service of CTM is:

- Requirement analyses
- Operational training projects
- Courses
- Turnkey "Fondimpresa" project management

3.2.1 Current Lifelong Learning System

Further education trainings or courses are offered by the different entities listed above. Generally, the way these courses are held is quite similar. It is a fundamental selection of the theoretical part of the subject. These basic fundaments get strengthened by practical activities in the application fields or through exercises in the classroom.

Normally, courses are offered for a wide range of interested people, or different sectors where companies are acting. These kinds of courses are arranged in classrooms or infrastructures located in the organisation entity's buildings. If individual courses for companies are organised, normally the training is on-site of the company. In this way, the training can be held in the environment, where the people who are trained are working by having a closer practical approach and, in addition, it is much easier to organise having the participants in house. Of course, for such kind of education the provider can ask a higher fee.

For education today in South Tyrol, only some special trainings are held online. For example, the safety courses for technical teachers must be attended if she or he is working in a laboratory in front of a PC. Certain kinds of courses are held completely online. The reason is that different laboratories need a different level of safety training. By organising this online, each teacher can register themselves to the course which is related to the teaching subject. In order to understand if a teacher has to attend the needed safety course, the participant must log in with a special requested password and go through the various presentations. After a certain period, it is possible to attend an online Multiple Choice exam where the result is shown immediately. Another example is the internal language test at the University of Bolzano, which is held online. In this case the preparation for the exam is organised by the students via self learning at home, using also online preparation tests to understand how the test is structured. Finally, the test is held inside the university on a computer logged in by the language centre, which is the provider of the exam. In addition, in this case, the participant immediately sees the result of the exam, as it is again a Multiple Choice test.

3.2.2 Location of Current Lifelong Learning Infrastructures

Vocational schools

Further education courses are organised between the Office of Further Education and the different vocational schools around South Tyrol. As a result, the location of the courses are in classrooms of the German and Italian speaking vocational schools spread around the Autonomous Province. In Chapter 3.1.2 (Current Location of Education Infrastructure) all infrastructures are clearly seen.

Further Education Providers in Bozen

The Chamber of Commerce is located in the centre of the provincial capital, Bozen. This allows a good connection to all the different parties the Chamber is serving. In addition, other entities like Eurac, CasaClima®, FabLab, Smart Mini Factory and makerspace are strategically located in Bozen, as can be seen on the map below.

Figure 12 shows the location of further education infrastructures in Bozen

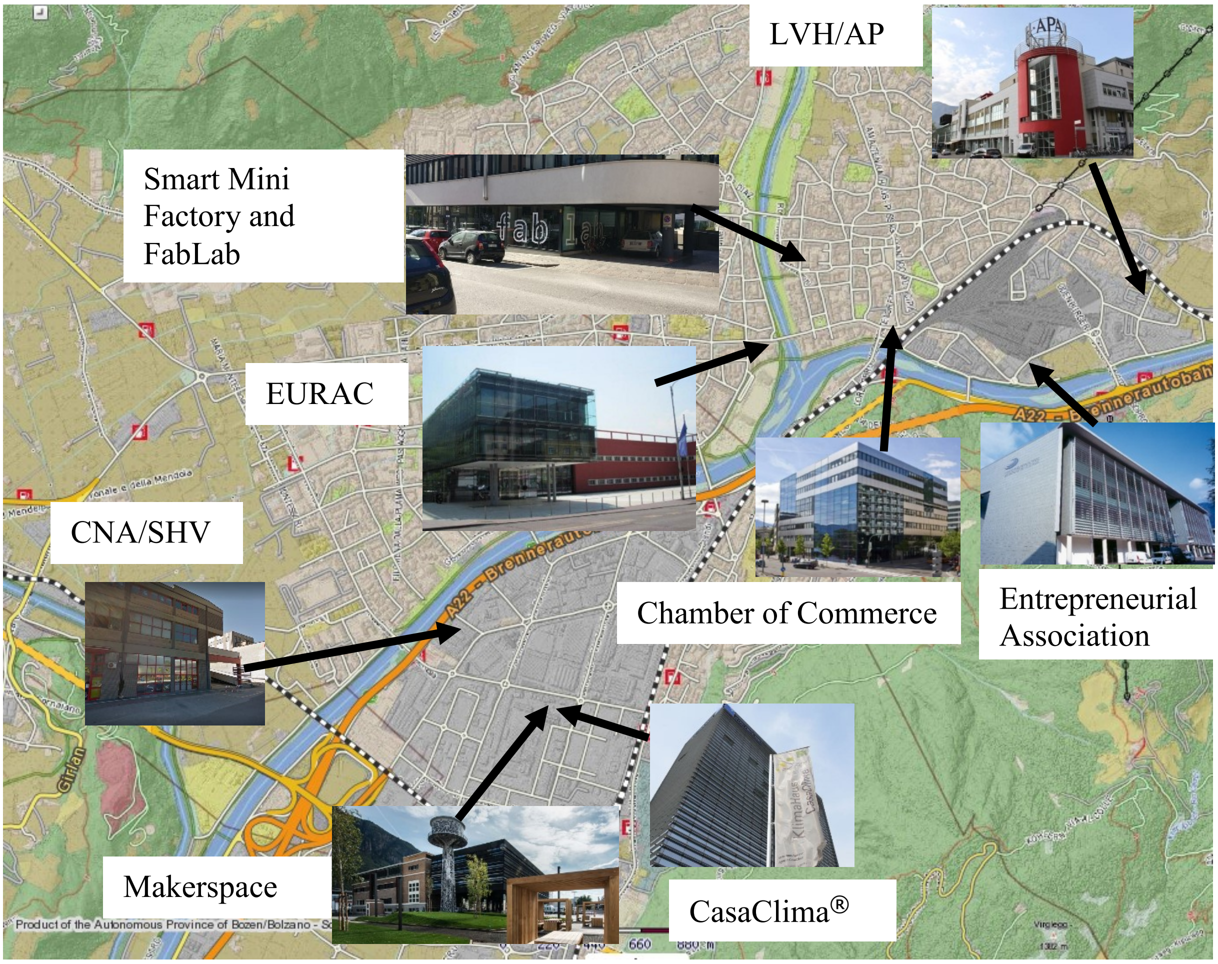


Figure 12: Location of further education infrastructures in Bozen

The IDM has its headquarters in Bozen but it is also located with small subsidiaries in Glurns, Meran, St. Christina, Brixen and Bruneck.

Adult Education Centre ("Volkshochschule")

The Adult Education Centre, as described before, is present in South Tyrol not only in the cities, but also in many smaller villages. All locations of infrastructures can be seen in the map below.

Figure 13 presents the Adult Education Centres in South Tyrol

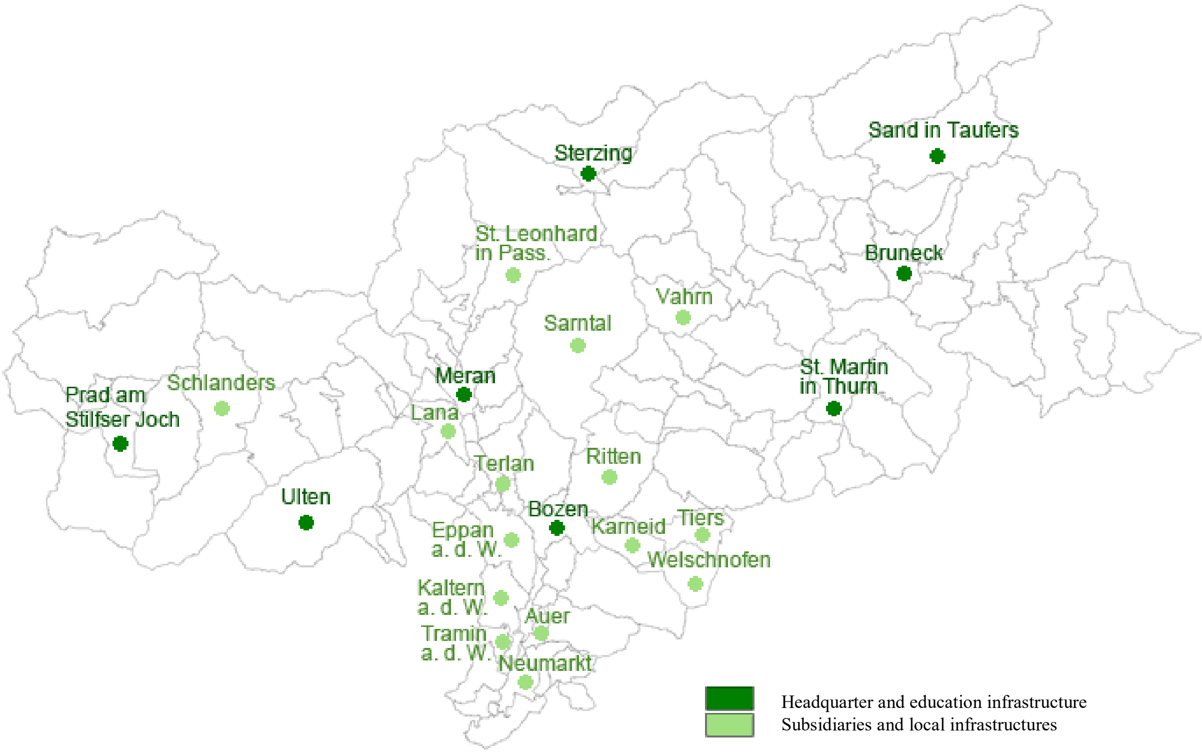


Figure 13: Adult Education Centres in South Tyrol [45]

3.2.3 Current Lifelong Learning in Engineering Education

Engineering Education as a keyword is important to define in order to understand which kind of further education courses could be considered. As our situation in South Tyrol regarding companies is of a small and middle size reality, the offer of trainings is matched on that. In this thesis, all technological-related educations are listed.

<u>Vocational schools</u>

The offer of courses is high, starting from the welding ability exam to safety trainings or PLC programming courses. Especially, the German speaking vocational school Lehranstalt für Industrie und Handwerk (LIH) provides a wide offer of technical courses. Only a few are listed in the table below [46], [47]:

Table 7 shows the further education courses in vocational schools:

Course name	Duration	Costs	Location
European Bus (KNX) installation with certificate	40 h	200.00 €	LIH Bozen

E-Commerce: Online shop	14 h	76.00 €	LIH Bozen
3D CAD Basic - Design, Rendering with Rhinoceros 5 (Working with 3D Mouse)	22 h	108.00 €	LIH Bozen
Courses Web Digital Manager: WEB DESIGNER	325 h	810.00 €	LIH Bozen
PLC - Programmable Logic Controllers (1st level)	20 h	60.00 €	Enaudi
Technical consultant in acoustics environmental	24 h	80.00 €	Enaudi
Forklift driving license	16 h	80.00 €	Marconi

Table 7: Further education courses in vocational schools

Chamber of Commerce

The Chamber of Commerce in Bozen focuses strongly on digitisation. Courses such as "Digital enterprise - opportunities of digitisation for companies" show the actuality of the topic. The Chamber also organises in the evenings a few information meetings free of charge, talking about digitisation.

Below in table 8 are just some of the offers [48] which the Chamber of Commerce organises

Course name	Duration	Costs	Location
Digital enterprise - opportunities of digitisation for companies	2 h	free	Bozen
Mobile Revolution	3 h	free	Bozen
Cloud & Enterprise 4.0	3 h	free	Bozen
OneNote - Introduction	3 h	59.00 € +VAT	Bozen
E-Commerce course: How to open up (new) markets	5 days	565.00 € +VAT	Bozen
More success with an effective social media strategy	1 day	79.00 € +VAT	Bozen
Compact Seminar: Project Leadership	2 days	480.00 € +VAT	Bozen
Individual Management Training for Companies	To	To define	On company-

	define		site

Table 8: Further education courses - Chamber of Commerce

Additionally, the Chamber provides:

- Support for company foundation
- Individual trainings for personal competences
- Courses for Marketing, Sales, Purchase and Logistics
- Courses and Support for Internationalisation
- Support to define further education programmes for companies
- Potential analysis for employees and companies

IDM (Innovation, Development and Marketing)

The IDM provides many services for companies. Seminars are organised and, in addition, the IDM provides information about exhibitions around the world to specific topics and organises trips as well as planning conferences or discussion tables [49] and listened below in table 9:

Activity	Duration	Costs	Location
Seminar: Food Sensory Systems	4 h	free	Bozen
Representation Travel: Wabel China Summit	4 days	free	China
Exhibition: Construction and Energy	3 days	free	Bozen
Exhibition: The Big 5	4 days	free	Dubai

Table 9: List of activities from IDM

NOI Techpark

Inside the NOI Techpark, many different laboratories are allocated. All laboratories support the different technological sectors listed above.

The following are the laboratories inside the NOI Techpark[50]:

- Makerspace:

  A high-tech workshop with a laser cutter, 3D printer and more
- Automation Lab:

Automation of industrial production processes

- Laboratory for Flavour and Metabolites:
  Studies on food quality and plant health
- Accelerated Life Testing Lab:
  Climatic chamber for accelerated life testing
- Energy Exchange Lab:
  Infrastructure for testing new district heating and cooling systems
- Facade System Interactions Lab:
  Investigating the interaction between facade systems and indoor climate
- Heat Pumps Lab:
  Lab for testing heat pump systems
- Multifunctional Facade Lab:
  Analysing the performance of multifunctional facades
- PV Integration Lab:
  Integrating photovoltaic systems into buildings and power grids
- Solare PV Lab:
  Solar simulator for photovoltaic modules
- Design Lab:
  Supporting innovation processes through design
- Bioenergy & Biofuels Lab:
  Research on energy generation from biomass
- Thermal Physics for Buildings Lab:
  Energy efficiency, indoor environmental health and building comfort
- Laboratory of Food Quality (e-Sense Lab):
  Studying the quality and shelf life of food and ingredients
- Laboratory of Food Technology (Food Pilot Lab):
  Research on food processing and technology
- Smart Data Factory:
  Capture and “smart” analysis of complex data

Makerspace

Figure 14 is a picture of the inside from the Makerspace in Bozen:

Figure 14: Makerspace inside the NOI Techpark - 2017 [37]

As previously noted, the makerspace is one out of a big list of laboratories inside the NOI Techpark.

This high-tech workshop is open to everyone, but more focused on entrepreneurs and companies. People working in the creative industry, companies and any other individuals may use the cutting-edge devices on-site, build or print prototypes or unique objects, or develop new products from new or recycled materials. As everyone operates the devices individually, regular training sessions and courses are held, explaining how to use the machines and required software.

The makerspace is equipped with [37]:

- Laser Cutting Machine
- 3D Printing
- Computer Numeric Control (CNC) mortising machines
- Open Source platform with Arduino
- Vinyl cutter
- Many different non-digital devices to build products

All of these machines need a special training to can work on them. The makerspace organises courses about general technical topics as well as individual training on special processing machines.

Smart Mini Factory

The Smart Mini factory is located in the city centre of Bozen, close to the university and is managed by the Faculty of Science and Technology. Seminars with different topics, related to digitisation, Industry 4.0 or new technologies are organised to teach the students, as well as discuss with South Tyrol`s companies in order to strengthen the collaboration.

The following Seminars are organised [51] and listed in table 10:

Seminar name	Duration	Costs	Date
Construction 4.0 – Digital tools for construction sites	4 h	120.00 €	29.03.2018
Human-centred work design in cyber-physical production systems	4 h	120.00 €	16.05.2018
Automation and Augmented Reality in Logistics	4 h	120.00 €	01.06.2018
Collaborative Robotics	4 h	120.00 €	21.09.2018
Gripping systems for robotic handling	4 h	120.00 €	10.10.2018
Computational Design for Digital Product Engineering and Development	4 h	120.00 €	25.10.2018
Smart electrical drives	4 h	120.00 €	16.11.2018
Embedded and cyber-physical systems	4 h	120.00 €	30.11.2018
Eye tracking in product development and production	4 h	120.00 €	20.12.2018

Table 10: Seminar programmes in Smart Mini Factory

BITZ

BITZ is the so-called FabLab, located in the same building as the Smart Mini Factory. As it is located in the centre, it offers a workshop dedicated more for private persons, where the Maker Space, built on the same concept is more reserved for companies and entrepreneurs. Each person how wants to work inside the FabLab must attend a safety course, organised each Wednesday at 06:00 pm or Saturday at 11:00 am. The content of this course it is not only the safety advices and regulations, but also some short introductions to the equipment in the BITZ.

The following is the equipment list of the FabLab [52]:

- Laser Cutter and Engraver
- 3D Printer for Polymers like ABS, Nylon, PC and many more
- 3D Scanner
- Plotter for vinyl adhesive films
- 3D milling machine for resins, wood, plastic, mouldable wax (not appropriate for metal)
- Hot press for vinyl printing on clothing and textiles
- Styrofoam cutter
- Sewing machine
- Drilling machine

For most of that equipment, it is required to attend an additional individual course for a correct application before it is possible to work on it.

<u>Adult Education Centre</u> [53]

With 1,530 courses and 20,687 hours of further training, the VHS not only recorded the highest number of courses last year 2017, but also passed the 18,000 participants mark for the first time.

Only a small view of technical courses available is listed below in table 11:

Course name	Duration	Costs	Location
Intensive bookkeeping fit for all accounting tasks	25 h	229.00 €	Bozen
Certificate Course: Human Resource Management Fundamentals, Topics and Tasks of Human Resources	30 h	495.00 €	Brixen
EDV-Update for the professional re-entry	15 h	139.00 €	Brixen

Table 11: Adult Education Centre – technical courses

<u>EURAC Research Centre</u>

The EURAC Research Institute focus its competences strongly on their core competences, which is researching. Nevertheless, the Department of Training and Education organises some special trainings, like [54]:

1) Malik - General Management Summer School 2018
   In this, a more economics and managerial training programme, the focus is on applying competences in personal and organisational management. This summer school has a duration of five days with a cost about 3,490.00 €.

2) FACE - Facades Architecture Construction Engineering (3rd edition)
   The second courses, organised by EURAC, are more technical based. Experts, coming also from outside South Tyrol, train architects and engineers. The following is the course description:
   "The FACE-camp project offers to a selected number of professionals a free of charge training program aimed at increasing the know-how of companies and freelance professionals operating in the field of complex technological building facades. The course aims to transfer to freelance professionals and technical staff of facade construction companies, concepts and innovative methods in the sector of complex technological facades.
   The educational program has a complete structure regarding the covered topics, to provide innovative concepts, tools and methods, while stimulating the growth of local skills in the construction sector, increasingly subject to environmental and energy regulations."
   The programme is held in English, and requires six units for a total 15 days (120 hours).

Trade Association for Handicraft and Services, LVH/APA and CNA/SHV

The associations divide their education programmes in the following groups:

- Occupational Safety for entrepreneurs
- Occupational Safety for employees
- Qualification for construction machinery
- Fire Prevention
- Scaffolding and Rope Safety Courses
- Profession-specific Courses
- First Aid courses
- Personality-developing courses

The following table 12 is a list of further education offers from the Trade Association for

Handicraft and Services from LVH/APA [55].

Course name	Duration	Costs	Location
Occupational safety for entrepreneurs (ATECO code medium and basic course ATECO code high) Module 2: Occupational safety management in companies	8 h	125.88 € +VAT	Bozen
Instruction in personal protective equipment against falls from a height (3rd category)	4 h	61.18 € +VAT	Bozen
Refresher course in scaffolding - PiMUS	4 h	125.88 € +VAT	Andrian
Preparation course for the technical escort for special transports	6 h	116.47 € +VAT	Bozen

Table 12: Further education courses offered by LVH/APA

The association also offers actually their members an analysis to find out the actual situation about the level of digitisation [56].

First step: The company can analyse its own situation about how much of Industry 4.0 is actually applied.
Second step: With the result of the self-check, the company gets some basic proposals by an implementation of a digitisation strategy. In collaboration with some external experts, it can work out an individual strategy for the company
Third step: The association put the company in touch with the right contacts for advice and support on all aspects of digitisation in the craft sector.

The Association for Handicraft and Small and Medium-size Companies CNA/SHV divides their further education programme into five groups or sectors:

- Environmental
- Automotive Transport
- Professional
- Safety
- Online courses

Table 13 shows an extract of some education offers [57]:

Course name	Duration	Costs	Location
Technical Responsible for Waste Management - BASIC COURSE	40 h	Not available	Bozen
ADR (transport of dangerous goods) with exam	21 h	309.00 € +VAT	Bozen
Digital Cronotachigrapher	2 h	Not available	Bozen
RSPP for entrepreneur – high risk	24 h	305.00 €	online

Table 13: CNA's further education course offer

<u>CasaClima® - KlimaHaus Agency</u> [58]

The KlimaHaus Agency offers many trainings and further education to aim for an energy-efficient construction policy in South Tyrol. With the courses, the agency wants to improve or expand the skills of planners and artisans, but also give the building owners the relevant information they need in their position during the planning and construction phase. In recent years, more than 30,000 people attended about 1,800 courses.

Some of the courses are listed below in table 14:

Course name	Duration	Costs	Location
ProCasaClima - Basic Course	8 h	160.00 € +VAT	Bozen
Construction Biology	8 h	160.00 € +VAT	Bozen
Planning and certification with KlimaHaus	4 h	90.00 € +VAT	Bozen
Systems technology for KlimaHaus	16 h	360.00 € +VAT	Bozen
Introduction to building automation	4 h	120.00 € +VAT	Bozen
Comfort ventilation for residential buildings	16 h	330.00 €	Bozen

		+VAT	
KlimaHaus for building owners	12 h	50.00 € +VAT	Bozen

Table 14: Further education programmes from KlimaHaus Agency

3.3 Summary of the State of the Art in Education Offers for Industry 4.0 and digital Teaching Aids in South Tyrol

In the chapter 3.4 is worked out a summary of the offers related to Industry 4.0 in South Tyrol and a description of the technical teaching aids in education.

3.3.1 Summary Industry 4.0 Offer in South Tyrol

Nowadays the term Industry 4.0 is observed by companies from a critical point of view. In South Tyrol, there is a huge number of small-size companies and handicraft businesses which actually do not consider the various aspects of Industry 4.0. On the other hand, in recent years many companies have had to grow up quickly and handle new technologies related to this topic if they wanted to stay competitive on the global market. For this reason, more companies are always investing or planning to invest for the next years in the development and implementation of new technologies.

The offer for courses related to Industry 4.0 today in South Tyrol is not so high. Of course, the university as a research entity is focusing on this topic and supports companies in implementing new technologies or processes, organising seminars and courses. Only a few other further education providers are acting today with Industry 4.0.

In an earlier step, the secondary level higher schools now are trying through different collaborations with research and education entities to insert some aspects of Industry 4.0 in their study programmes.

It also must be said that, if a company is buying a new machine which is able to cover some aspects, for example, the interconnectivity of machines or collection and analysing Big Data, the producer provides individual courses for the delivered equipment. Such kind of courses don't only have the correct utilisation of the machine or maintenance works to do on it, but also an explanation as to possible data collection, evaluation or interchangeability with other departments or equipment.

Today in South Tyrol, the following offers are available by covering various aspects of Industry 4.0 and described in table 15:

Institution	Course/Seminar	Covered Aspects of Industry 4.0
Vocational schools	E-Commerce: Online Shop	- Larger Application Field of Internet - Big Data and Analytics - Cyber Security
	Courses Web Digital Manager: Web Designer	- Big Data and Analytics - Horizontal/Vertical Integration - Cyber security
Chamber of Commerce	Cloud & Enterprise 4.0	- Cloud - Cyber Security - Industrial Internet - Horizontal/Vertical Integration
	Digital enterprise - opportunities of digitisation for companies	- Advanced Manufacturing Solutions - Industrial Internet - Simulation - Cloud - Cyber Security
	Mobile Revolution	- Cloud - Cyber Security
IDM	Seminar: Food Sensory Systems	- Advanced Manufacturing Solutions - Industrial Internet - Big Data and Analytics
Makerspace	Training: 3D Printing	- Advanced Manufacturing Solutions
Smart Mini Factory	Construction 4.0 – Digital tools for construction sites	- Industrial Internet - Simulation - Cloud - Cyber Security - Horizontal/Vertical Integration - Building Information Modelling (BIM)
	Human-centred work design in cyber-physical production systems	- Cyber Physical Systems - Human Machine Interaction - Simulation - Augmented Reality - Cloud - Cyber Security - Horizontal/Vertical Integration
	Automation and Augmented Reality in Logistics	- Industrial Internet - Simulation - Augmented Reality - Virtual Reality

		- Autonomous Guided Vehicles - Cloud
	Collaborative Robotics	- Industrial Internet - Advanced Manufacturing Solutions - Human Robot Interaction - Ergonomics and Safety - Simulation - Cloud
	Gripping systems for robotic handling	- Advanced Robotic Systems - Bin Picking - Vison Systems - Haptics
	Computational Design for Digital Product Engineering and Development	- Computational Engineering - Advanced Manufacturing Solutions - Computer Aided Engineering (CAE) - Finite Element Methods (FEM) - Parametric and Generative Design - Simulation
	Smart electrical drives	- Industrial Internet - Cyber Physical Systems - Simulation - Mechatronics
KlimaHaus	Introduction to building automation	- Industrial Internet - Building Automation and Control - Simulation - Cloud - Cyber Security - Big Data and Analytics

Table 15: Summary of education for Industry 4.0 in South Tyrol

3.3.2 Technical Teaching Aids in Education 4.0

There are very few technical aids which are actually used to support a new generation of education. As, generally, public education entities are limited in their financial resources, nowadays it can be observed that more changes in software packages, available for free are being introduced than in the acquisition of new hardware devices.

Following are the major teaching aids introduced in recent years in the South Tyrolean engineering education providers:

- Smartboard
- Open Learning Platform - Moodle
- Digital teaching work flows

- Interdisciplinary Teaching Programmes

Smartboard

To support new technologies in education, in 2017 the autonomous Province of South Tyrol distributed one smartboard to each secondary school. The smartboard represents the next generation of beamer technologies.
An interactive whiteboard is the next generation of the traditional whiteboard. The teacher has the possibility to write, sketch or sign something on the board and, through the connection with a computer, all the activities are immediately digitalised on a file defined by the user. This new technology has an intuitive application software and is very easy to use. An incorporated touch control, through a camera and a real time image elaboration, recognises all movements in front of the digital whiteboard, which allows in an extremely efficient way to reduce time for additional movements or activities. Cost reductions for eliminating chalk or cleaning material is only one of many advantages of a digital smartboard.

Some functions/properties of the smartboards [59]:

- Touch sensitive system
- Touch recognition
- Object recognition (pen, hand, finger or sponge)
- Expansion slots
- Installation on wall bracket or as stand-alone solution
- Digital ink (different pens for different pre-installed colours)
- Pen locking function (setting new pens for the board)
- Collaborative Learning Software
- Central control from the teacher’s desk
- Free of shadows and reflections on the screen
- Long life lamp (4,000 hours)

Figure 15 shows a classical smartboard

Figure 15 Smartboard - Smarttec Series 7000 [58]

<u>Open Learning Platform - Moodle</u>

Moodle is open learning platform which could be used for many different applications. Generally, it is possible to build a group, including specific people for dedicated areas with individual authorities to act inside. Initially, this platform is used for education systems, where teacher and students can work inside a digital classroom together, sharing documents, for example. A big advantage of Moodle is that it is an open and flexible software. It is possible to easily handle classrooms year by year considering changes in students, as well as on the teacher side. In addition, as this software is free of charge, Moodle becomes an interesting tool for schools or other entities with the same requirements.

Different features available with Moodle [60]:

1. General features:
    - Modern and easy to use interface
    - Personalised Dashboard
    - Collaborative tools and activities
    - All-In-One calendar
    - Convenient file management
    - Simple and intuitive text editor
    - Notification
    - Track progress

2. Administrative features:
    - Customisable site design and layout
    - Secure authentication and mass enrolment
    - Multilingual capability
    - Bulk course creation and easy backup
    - Manage user roles and permissions
    - Supports open standards
    - High interoperability
    - Simple plug-in management
    - Regular security updates
    - Detailed reporting and logs

3. Course development and management features:
    - Direct learning paths
    - Built-in collaborative publishing features to encourage collaboration
    - Multimedia Integration
    - Group management
    - In-line marking
    - Peer and self-assessment
    - Outcomes and rubrics

The higher secondary level school, Max Valier, in Bozen, has been using Moodle for several years. Every physical class in the school has its own digital classroom in Moodle. Entering the area of a class it is possible to allocate teachers in respect to the subject they teach. Office documents are able to be inserted to share with the class. In addition, homework can be presented in Moodle giving some special submission date indication.

Figure 16 presents a screenshot from Moodle utilized in the TFO Max Valier:

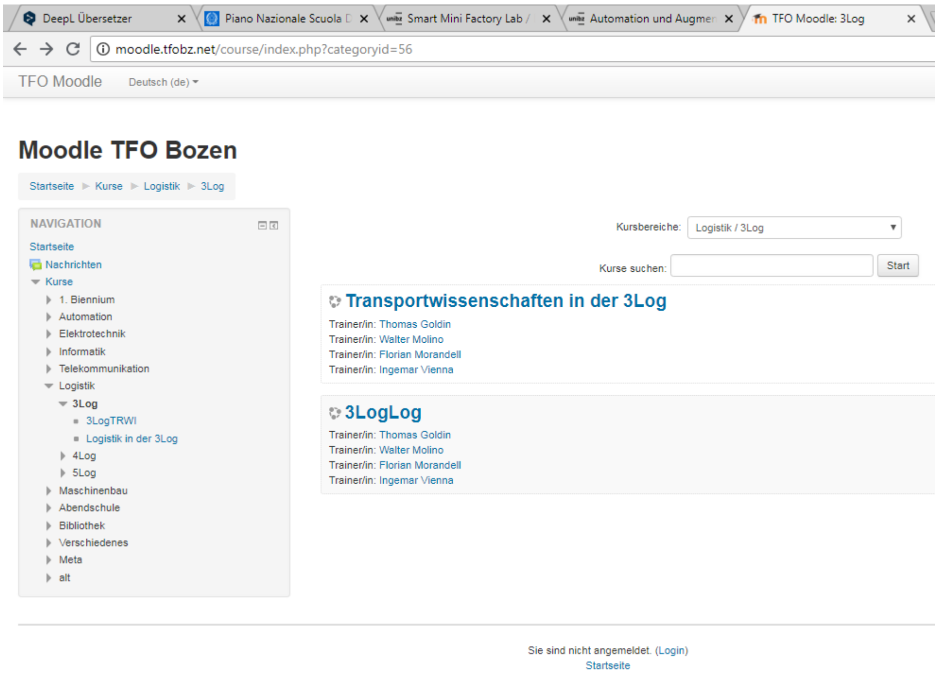


Figure 16 Moodle print screen from TFO Max Valier - Bozen

Digital teaching work flows

The traditional documentation in a school is done by two books. The register for teacher and the class register. The register for the teacher is a book held and filled out only by the teacher. The class book is a register, which is located inside the classroom and filled out by each teacher who is holding the lesson, to write in if a student is not present or arrives late, and describing the lecture topics. The teacher has to insert the same information in their own register with the addition of different evaluation and grades for each student. Generally, the teacher has to insert the same information twice, which takes time and could generate discrepancies.

The digital register saves time and reduces errors. Inside the program, all information relevant to the class or the single student can be inserted, given individual authorities access to students, teachers or other involved persons, like parents. The system offers transparency for the students and their parents and reduces bureaucracy for the teachers. Of course, each student can see only their own marks and analyse their school attendance. In addition, parents can see in real time if a pupil is in the school or not.

Some important aspects must be considered in using the digital register. It doesn't make sense introducing such a web based application if the infrastructure is not equipped with the right technologies and does not have the appropriate connectivity to a fast operation on the register.

This means, that the school has two possibilities. The first option is to provide all classrooms, laboratories or locations where students attend a lesson with computers connected via LAN to the Internet, or a second option is to generate a high-speed wireless that can work on the register with a Smartphone or similar devices. Additionally, the aspect of Internet security must be analysed in detail. Data inside the register have a high privacy level and must be protected in an extremely safe and sensible way. User IDs, but in particular the access password of a student and the teachers, must be handled very carefully in order to have correct data inside the system. On the other hand, the digital register increases drastically the transparency for all participants.

Summing up, the digital register gives the following advantages:

- Organises lessons
- Simple evaluation
- Greater transparency
- Access for parents and students to the evaluations
- Register is always up to date
- Less work: class and teacher registers are generated automatically. The advantage of the digital class register is that hours no longer have to be entered twice in the class and teacher registers. Thanks to the central database, these views are automatically generated from existing data.

Following figure 17 gives a short overview about the digital register software:

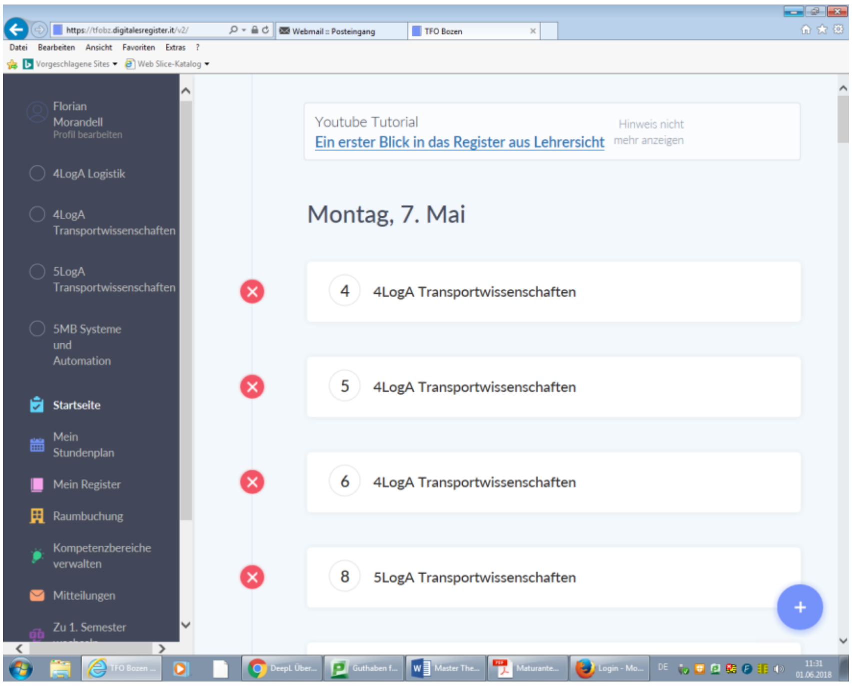


Figure 17 Online register TFO Max Valier - 2018

The University of Bolzano-Bozen changed some years ago to the paperless system. Cockpit, the name of the platform where students, professors and other academic staff can work, has different applications:

- General information about the university
- Timetable management
- Student card management
- Student study plan
- Exam management
- Teaching register
- Course evaluation
- Contract management
- Student graduation

Figure 18 shows the Cockpit Software at the Free University of Bolzano-Bozen:

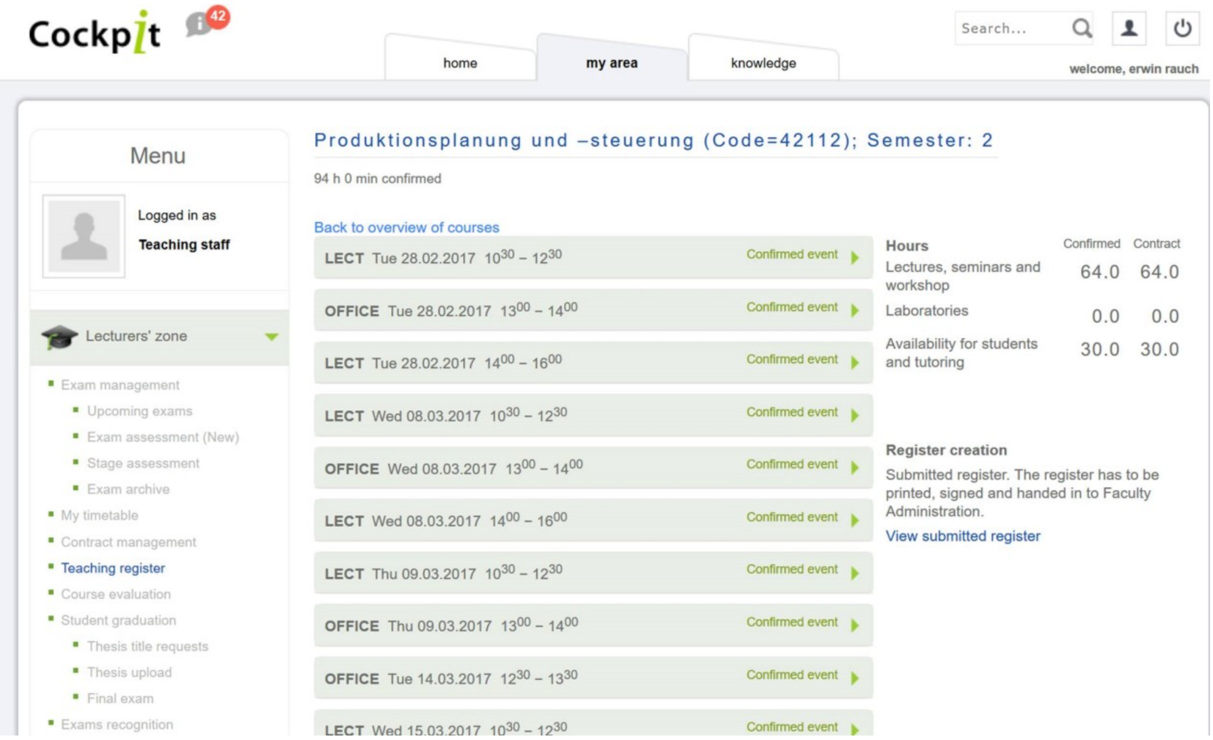


Figure 18 Extract of the Cockpit - platform of the Free University of Bolzano-Bozen

<u>Interdisciplinary Teaching Programs</u>

The last school reform, “La buona scuola” in 2015 [21] introduced many points according to the topic of interdisciplinarity. The subjects Moreno longer have a clearly defined programme, which says that, for example, in the technical upper level school, the third class subject, Material Technology, the topic of material characteristic has to be concerned. Instead of special defined topics, the Ministry of Education gives only indications about knowledge and properties a student should achieve after a school year. This gives the teacher a lot of free space for interpretation of how a topic could be presented to the student. In addition, “La buona scuola” focuses many descriptions of knowledge and properties on interdisciplinarity. Interdisciplinarity can be understood from two points of view. One is the collaboration between different subjects, like Material Technology in relation to Construction design. The other interdisciplinary possibility is the application of theoretical foundation on practical examples. Since 2015, based on the so-called “Alternanza scuola-lavoro” [61], each student in a technical upper high school must participate for 400 hours in practical applications during their school education. During a mandatory stage of about two weeks, 80 hours could be covered. The remaining 320 hours must be worked out through projects, collaborations or external seminars and excursions between the schools and companies or research entities. Different projects can be started depending on the school and study direction.

Interdisciplinarity activities from TFO Max Valier direction Transport and Logistics are listed in table 16

Type and topic	Subject	Partner	Dura-tion	Class
Expert seminar: driving license category	Sciences of transport	Autoscuola Europa	4 h	3 Log a
Excursion: Warehouse management and picking technologies	Logistics	Rothoblaas SRL	8 h	3 Log a
Excursion: Road freight transport vehicles	Sciences of transport	Fercam AG	4 h	3 Log a
Seminar: Optimisation of assembling station	Logistics	University of Bolzano-Bozen	8 h	4 log a
Excursion: Production Management	Logistics	BMW, Jungheinrich; MAN	8 h	4 Log a
Expert seminar: Rail freight transport	Sciences of transport	TX Logistics	12 h	4 Log a
Excursion: Train shed and rail guidance system	Sciences of transport	SAD and STA	4 h	3 Log a
Uni meets school	Logistics	University of Bolzano-Bozen	16 h	5 Log a
Project elaboration	Logistics, Sciences of	Depends on the project	50 h	5 Log a

	transport			

Table 16: List of interdisciplinarities of TFO Max Valier – Specialisation Logistics

3.4 Summary

Industry 4.0 in South Tyrol is actually under development. Business News and different studies are underlining the importance of the 4th industrial revolution. Nevertheless, the realities in South Tyrol are small and middle-size companies, for which ii is often difficult to be at the edge of new technologies. Many different approaches about courses are offered from different entities, especially research institutes like a university. In addition, different collaborations between schools and companies or institutions are already worked out to meet future requirements. Nevertheless, there are two big limitations to taking a big step in the next few years.

1) Many small industries grow up very fast, or started up after the economic crisis in 2010. A fast growth is a good driver, but does not give the company the time to organise different parts well, as it should be. This leads generally to disorganisation or working in a way just to fulfil customer orders. Problems or optimisation cannot be worked out because of the limited resources available. Many companies grow up by doubling the human resources, keeping management structures, and processes the same as before. In satisfying the increasing customer orders, companies often do not take time to dispute with new technologies.
2) Education infrastructures like upper level schools are actually not working with up to date hardware. For example, many schools do not have computers in every classroom. Introducing a digital register, where each hour should be registered in real time, and teachers do not have a computer in the classroom to do it, is a big challenge. In addition, the computers actually in use in different laboratories are maybe five years old, but, for actual new developed software, they can no longer be used because of their limited performance. The possibility to work with students on Enterprise Resource Planning (ERP) is quite impossible.

   The University of Bolzano-Bozen is trying to fill the gap by introducing a kind of first step to achieve a new trend named “Bring Your Own Device”. Since 2017, the university has closed every PC room and bought a number of laptops to hire out, which the students can use. All programmes are inside a cloud and are possible to be accessed through a campus login. Students, who have a good laptop work on their own and other students with no laptop could rent one for free in the library, using the student card. After one year of testing, it is possible to say that most students are working with their own laptop and only a few are renting the laptops from the university.

To gain future requirements, different actions could be introduced to fill existing gaps in order to be able to switch to new technologies about Industry 4.0. Education systems are actually in the children’s hands and they have to afford many challenges to develop a new generation of education.

Chapter 4

TRENDS AND DEVELOPMENTS IN ENGINEERING EDUCATION 4.0

With the 4th industrial revolution another terminology emerged at the same time. We're talking about Education 4.0. To find out the trends, it is necessary to understand what could be the drivers for certain developments. Those are [62]:

Extreme Longevity – The world population is increasing continuously and the number of people over 60 is rising too.

Smart Systems and Machine – Killing repetitive jobs, utilising augmented reality technologies by extending own capabilities.

Computational Work – The world will be a programmable system by the help of smart sensing systems and processing methodologies. By scaling objects, it will be possible to see details in a way no one could have imagined years ago.

New Media Ecology – A different approach to information instead of reading texts will be developed by using new communication media and visual technologies.

Super Structured Organisation – The new social tools change also the way to create value in the industry or change production forms considering working under a different scale.

Globally Connected World – Adaptability and diversity is at the centre of operations where not only Europe or the United States hold the monopoly on new jobs.

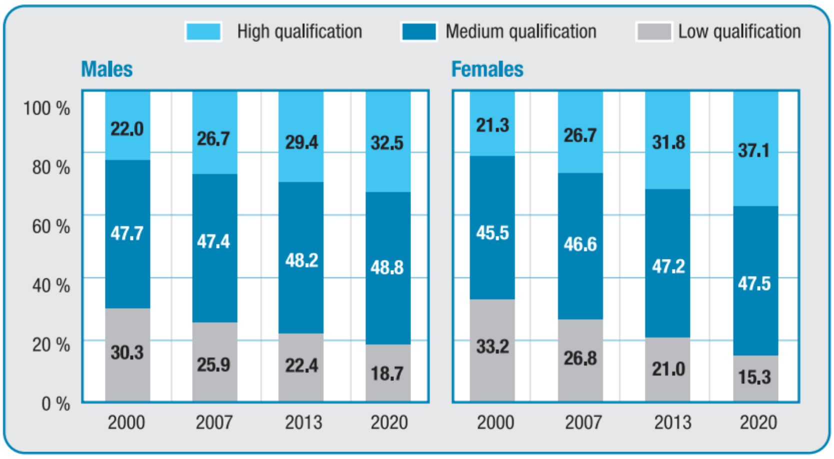
Connecting the drivers with future abilities [62] results in an interesting overview visible in table 17, helping to classifying new possible future work skills:

Future Competences		**Drivers**					
		Longevity	Smart Machine	Computational work	New Media Ecology	Super Structured Organization	Globally Connected
Sense Making	Ability to determine the deeper meaning or significance of what is being expressed						
Social Intelligence	Ability to connect to others in a deep and direct way, to sense and stimulate reaction and desired interaction						
Novel and Adaptive Thinking	Proficiency at thinking and coming up with solutions and responses beyond that, which is rote or rule-based						
Cross Cultural Competency	Ability to operate in different cultural settings						
Computational Thinking	Ability to translate big amount of data into abstract concepts and to understand data base reasoning						
New Media Literacy	Ability to critical assess and develop content that uses new media form, and to leverage these media for perusal communication.						
Transdisciplinary	Literacy in and ability to understand concepts across multiple disciplines						
Design Mindset	Ability to represent and develop task and work processes for desired outcomes						
Cognitive Load Management	Ability to discriminate and filter information for importance, and to understand how to maximise cognitive function						
Virtual Collaboration	Ability to work productively, drive engagement, and demonstrate presence as a member of a virtual team						

Table 17: Future skills abilities

4.1 Future Competences and Skills

Qualifications, by introducing the new industrial revolution, are changing with certainty. Analysing the change in the last 20 years is represented in the figure 19.



Source: IER estimates from StockMOD.

Figure 19 Changing qualifications structure of the labour force (25-64) [63]

It is impressive how fast skills with low qualifications are being reduced. It is more than a half of all skills looking at the female chart and not far away from half considering the male analysis. Increasing, on the other hand, the high qualification skills leads to an important requirement of the future. Lifelong learning by an efficient education programme is only one of many requirements needed to achieve the goal.

The use of new media, and thus innovative information and communication technologies, is revolutionising education and has become an integral part of teaching. Learning management systems, interactive smartboards or learning apps are only three of countless keywords and are already required and used by students. This poses new challenges for teachers and educators in schools.

Figure 20 is showing in which direction the skills will evolving looking forwards into the next years.

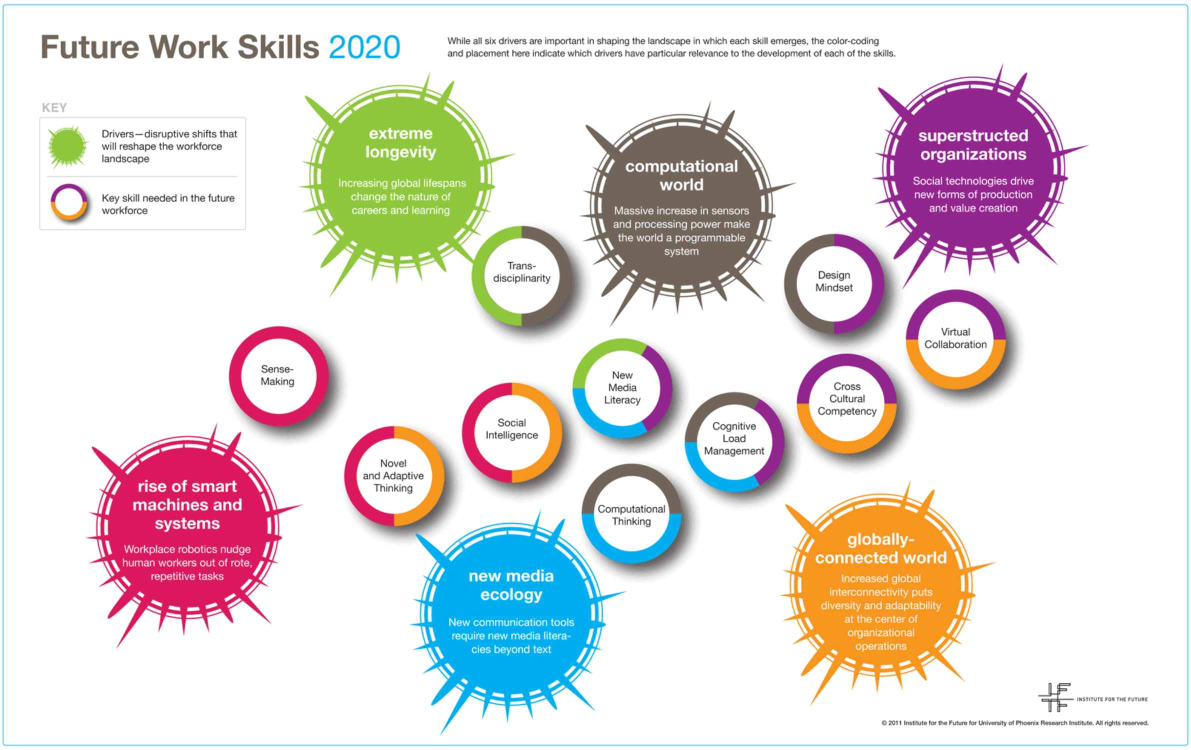


Figure 20 Future skills [64]

In Germany, according to VDI (Verein Deutscher Ingenieure), Industry 4.0 is the integrated networking of production. Everything communicates autonomously with each other: parts, machines and systems. Even customers can be integrated into production from the outside. If a customer sends out special requests, the assembly process can be changed flexibly in real time. The control of this digitised production method becomes more decentralised, because the individual components control each other in an open "cyber-physical system" [65].

<u>Know-How about software becomes indispensable</u>

In a "Smart Factory", the boundaries between the disciplines of information technology, mechanical and electrical engineering and engineers are melting together at the interface between hardware and IT. This means that IT knowledge will become indispensable in the future - know-how relating to software, programming and electronics. The impact of production IT will increase. Therefore, the demand of software engineers for Industry 4.0 will drastically increase.

Mastering complexity

The increasing networking of devices and systems as well as the availability of any information will make industrial plants even more complex. Further questions about data availability, security and validity will arise. These have to be solved in a very large context. This means additional challenges for engineers in developing, projecting and commissioning such systems. Complexity is increasing in Industry 4.0. Technicians must be able to master this complexity.

Flexibility is required

Industry 4.0 will lead to a change in design, development, sales, service and maintenance. This make engineers work more at interfaces, rather than in their traditional functional areas of research, development and production. As ICT, production technology, automation technology and software converge, more work tasks will have to be mastered in a very broad and flexible field of action in technological, organisational and social terms. The classical engineer, as an exclusively technically experienced expert, will have to broaden his profile and bring himself to a more interdisciplinary position. Cross-sectional qualifications are increasingly requested.

4.2 Qualification Offers

Different qualification offers are actually possible to find. In the following sections the offers are described in reference to:

- Education Study Programmes
- Lifelong Learning Programmes – Certificated Courses
- Lifelong Learning Courses (single courses)

4.2.1 Education Programmes

Different education programmes with the topic of Industry 4.0 are offered. Actually it is easier to find a study programme of a university of applied sciences than a Bachelor or Master-study of a university. This could be because the universities of applied sciences are more practical-oriented and, as such, it is easier to offer a study programme with some main topics of Industry 4.0, as a full covering study. In addition, having the focus on the practical approach is helping the students to go more into detail for new technologies, applying it into a company through a real situation.

Study courses at university

Bachelor programmes:

Location: Free University of Bolzano-Bozen (Italy)
Study Programme: **Bachelor in Industrial and Mechanical Engineering** [66]
Specialisation: Automation
Faculty: Science and Technology
Short Description: The Major Automation (only offered as a dual study course) focuses on topics of industrial automation. Through a strong partnership with hi-tech industry, this major trains professionals in the 4.0 industry.
Dual study Programme: These are nationwide unique dual study programmes where Automation is offered in collaboration with the Entrepreneurial Association of South Tyrol, the association of the local entrepreneurs. Students have the opportunity to combine studies and work. In this case, the duration of the course is extended to four years. In the first year, the study is full time, whereas, starting with the second year, it is alternating work and study. Students conclude an employment contract with a company when starting the studies. Choosing this programme, the student gains real work experience in a company that has agreed to invest in training and that allows to obtain a degree while working. Learning by doing and projects combined with self-paced study and specific tutorship programmes (company tutors and university tutors) are the success key of this awarded study programme. Next to the knowledge of the specific study programme, students acquire precious professional skills like team-working and problem solving.
Career Opportunities: The major in automation prepares for activities and a career in the following areas: system integrator or user of automation components, R&D, process engineering, process quality (quality assurance and management), production planning and control, maintenance, lean manufacturing, production management, plant management.
Study fee: 1,300.00 €/Semester

Location: Politecnico di Torino (Italy)
Study Programme: **Bachelor in Computer Engineering** [67]
Faculty: Information Science Engineering

Short Description: Computer engineering students get a solid basis on basic sciences (mathematics, physics and chemistry) as well as engineering sciences, providing the tools and scientific methods to ensure a rigorous approach to engineering problems. The themes that characterise the computer engineer's training range from the development of computer systems for businesses, to automation in industry and services, multimedia applications, robotics, intelligent systems and the development of telematics systems. The analysis, design and maintenance of IT systems requires wide-ranging scientific knowledge in key areas of information engineering (electronics, automation, telecommunications), accompanied by thorough technological and methodological expertise in the main areas specific to computing.

Career Opportunities: The education enables students to find a job in a broad field of engineering, in particular with other information professionals, but also specialists in the economic-management area and all those who increasingly use these technologies.

Study fee: 1,425.44 €/year

Location: University of Graz (Austria)

Study Programme: **Bachelor in Informatics and Computer Engineering** [68]

Faculty: Information Science

Short Description: They are used almost everywhere and every day: Smartphones, navigation systems, apps and, of course, the Internet. All this would be unthinkable without the technologies of information technology, microelectronics and telecommunications. In the Bachelor's programme, Information and Computer Engineering (formerly Telematics), it is possible to learn from internationally recognised scientists and work on the technologies of tomorrow.

Career Opportunities: Graduates have a wide range of career opportunities. They conduct research at universities, other research institutions or design, operate and evaluate complex hardware and software systems in the field of information technology and telecommunications.

Study fee: Not available

Master programmes:

Location: University of Munich (Germany)
Study Programme: **Master in Robotics, Cognition, Intelligence** [69]
Faculty: Information Science
Short Description: The Master's programme Robotics, Cognition, Intelligence is unique in Germany. It combines various engineering disciplines, such as mechanical and electrical engineering, with computer science. The students acquire a wide range of methodical and theoretical basics of robotics, cognition and intelligent autonomous systems. In addition to computer science, graduates are also familiar with the relevant aspects of electrical engineering and mechanical engineering. In addition to classical robot control, also the areas of perception, image processing and artificial intelligence are concerned. The students acquire methods for signal processing, sensor data evaluation or fusion and programming. They develop concepts of behavioural control, machine learning and human-robot interaction. Through cooperation with partners from industry, it is possible to gain initial experience with practical projects.
Career Opportunities: The successful completion of the studies enables a subsequent doctorate or even demanding activities in the field of technical development of control systems for motor vehicles, aircrafts and machineries. In addition to the large automotive industry market (both car manufacturers and automotive suppliers), the aerospace industry and developers of mechatronic controls of all kinds are also suitable fields of activity.
Study fee: 129.40 €/Semester

Location: University of Munich (Germany)
Study Programme: **Master in Data Engineering and Analytics** [70]
Faculty: Information Science
Short Description: The Master's programme in Data Engineering and Analytics deals with the evaluation and processing of extremely large amounts of data. This is an urgent problem in many areas and requires completely new techniques and procedures. This trend towards Big Data is driven by a number of developments. First, it is becoming easier and easier to generate and store large amounts of data, for example, due to low-cost

storage space, sensors, smart devices, social networks, etc. Second, these large amounts of data can also be processed on a large scale through technical advances such as fast multi-core systems and cloud computing. Thirdly, such data volumes are no longer generated only by "classic" application areas such as business data, but are now generated in many areas of life. For example, more and more vehicles are generating large amounts of data using sensors and intelligent networking, which can be used, for example, for further model development or for diagnostic purposes. Another important area of application at present is intelligent energy network control.

The Master's programme in Data Engineering and Analytics takes up these developments and provides training that enables graduates to design and plan practical solutions in this field on the one hand, and to provide a solid basis for research on the other.

Career Opportunities: Graduates of the Master's programme in Data Engineering and Analytics have countless career prospects, for example in research, consulting, IT security or as data analysts or data engineers in companies in almost all industries.

Study fee: 129.40 €/Semester

Location: University of Trento (Italy)

Study Programme: **Master in Data Science** [71]

Faculty: Information Science

Short Description: The amount of data has increased extremely in the last year through digitisation and cyber physical systems. Big data is the name of this development. Smart Manufacturing or Industry 4.0 is represented in Data-Driven Manufacturing. Thanks to the improved performances and the reduced cost of sensor and processing systems, information extracted from large amounts of data has become an essential factor in the development of industrial automation and advanced robotics. The availability of large amounts of data is also an inescapable factor in reducing energy costs and environmental impact, increasing productivity, optimising resources, and, ultimately, allowing companies to be more competitive in the global economy.

Career Opportunities: Graduates are able to work in companies, which needs an in-depth informatics knowledge, both theoretical and practical, of the tools of mathematics, statistics and computer science and an expertise in one or

	more domains of applications, such as social sciences, business, psychology, industry and communication.
Study fee:	346.00 €/Semester

Location:	Politecnico di Torino (Italy)
Study Programme:	**Master first level in Hierarchical Open Manufacturing for Industry 4.0** [72]
Faculty:	Information Science
Short Description:	The Master is mainly aimed at training professionals to support the project HOME - Hierarchical Open Manufacturing Europe, within the framework of the regional call for tenders: Intelligent Factory, However, these skills are required by all small, medium and large companies that compete in advanced manufacturing.
Call for tenders:	The Piedmont Region Apprenticeship of Higher Education and Research 2016-2018 provides: • hiring (before the start of the Master's), for selected graduates who have not yet reached the age of 30 at the time of hiring, at the partner companies (pursuant to Art. 45 - Legislative Decree 81/2015); • a training course at the Polytechnic of Turin and at the partner companies, at the end of which (expected to last about 24 months) they will be awarded the Diploma of First Level University Master.
Study fee:	Free of charge

Study courses at universities of applied sciences

Bachelor programmes:

Location:	Mittweida University of Applied Sciences (Germany)
Study Programme:	**Bachelor in Automation - Industry 4.0** [73]
Faculty:	Engineering Sciences
Short Description:	Extensive knowledge of production processes, robotic and digital networking, which are associated to the trend Industry 4.0, will be developed. Therefore, the visualisation of production sequences, the development of user interfaces and local networks are the main parts of

the study. Advanced laboratories, which are kept up to date by common research with our industry partners, ensure practical education. There are some university projects conducted with industry partners for those who would like to apply theoretically gained knowledge to practice. In addition to the development of practical experience, participating in the projects helps finance your studies.

Career Opportunities: Examples of career paths are inside the automotive industry, the mechanical engineering companies or for renowned suppliers.

Study fee: Not available

Location: Berlin University of Applied Sciences (Germany)

Study Programme: **Bachelor in Digital Industry 4.0** [74]

Faculty: Industrial Engineering

Short Description: The ever-faster networking of economic areas, companies and consumers is a central trend of the beginning of the 21st century. Effective cooperation between man and machine is playing an increasingly important role in this process. Decisive factors here are the progressive individualisation, increasing product diversity and an ever-increasing range of services. In the age of various smart products and the progressive expansion of the Internet of Things, it is important to attract employees with interdisciplinary skills in order to survive in this digital competition.

Career Opportunities: Industrial engineers plan and optimise operating processes as a team member in all functional areas of companies, such as the automotive industry, mechanical engineering, electrical engineering, the IT sector, environmental technology, medical technology or construction. Competitiveness and economic efficiency are the focus of the work. Thinking and acting across the board, taking into account aspects from logistics, production and marketing.

Study fee: 16,920.00 €

Master programmes:

Location: Baden-Württenberg University of Applied Sciences (Germany)

Study Programme: **Master Integrated Engineering** [75]

Short Description: The dual Master in Integrated Engineering enables engineers with technical bachelor degrees to put together their individual curriculum from the master's programmes in the field of technology. Students choose their courses from the following list:

- Mechanical Engineering
- Information Science
- Industrial Engineering
- Electrical Engineering

Career Opportunities: The dual Master's programme is carried out in a professionally integrated manner, so that there is a direct link between the content of the programme and professional activity. At the university, students take up the challenges of everyday working life, analyse complex problems and develop practicable solutions. Continued employment with the employer during your studies ensures your financial independence.

Study fee: 20,200.00 €

Distance Learning

Location: AKAD Stuttgart University of Applied Sciences (Germany)

Study Programme: **Bachelor in Digital Engineering and Applied Computer Science** [76]

Short Description: This study support students who want to use their intuition to analyse, secure and identify all kinds of digital indication about "digital forensics" or want to work with Industry 4.0 and create an interface between IT expertise and practical knowledge. In addition, the Internet of Things is a topic in this study. The Bachelor's programme, Digital Engineering, gives all the necessary ability about Big Data, Embedded Systems and Computers and as well as Cyber-Security and Virtual Reality. A Bachelor's degree in Digital Engineering and Applied Computer Science qualifies the student to be hired as an expert for a management position or another responsible engagement in industry.

Career Opportunities: The Bachelor in Digital Engineering and Applied Computer Science gives students not only technical, media and computer science knowledge, but also knowledge of the economy. The programme prepares optimally for the challenges of a professional career, whether as a project manager, system developer or system administrator,

	development engineer, marketing specialist or game and design developer.
Study fee:	13,986.00 €

4.2.2 Lifelong Learning Programmes – Certification Courses

Location:	VDI Düsseldorf (Germany)
Certification Course:	**Specialist Engineer Additive Manufacturing VDI** [77]
Short Description:	The Specialist Engineer for Additive Manufacturing VDI is a joint project of the VDI and experts from the industry have developed a practice-oriented qualification. It includes seven seminar modules and concludes with a VDI certificate examination as well as a recognised certificate. The objective of the qualification course is to cover the entire process of additive manufacturing: from the selection of the component, the decision of the type of production and the construction up to the implementation of additive manufacturing in the company.
Duration:	1 year
Course fee:	1,780.00 €

Location:	Liechtenstein University (Liechtenstein)
Certification Course:	**Industry 4.0 Management** [78]
Short Description:	The Industry 4.0 Management certificate prepares employees for the challenges of a digital working environment. The application-oriented transfer of knowledge in the area of interlocking industrial production with modern information and communication technology is in the foreground. The graduates of the programme have extensive knowledge of intelligent and digitally networked systems and their effects on new business models and value creation networks that go beyond company boundaries.
Duration:	1 year
Course Fee:	8,000 €.- CHF

Location:	AKAD Stuttgart University of Applied Sciences (Germany)
Certification Course:	**Industry Manager 4.0** [79]
Short Description:	This AKAD course focuses on the one hand on production management, production programme planning and production control.

On the other hand, change management with its different phases, tools and secrets of success, the process organisation and models of change. In addition, specialist knowledge is imparted on the use and coupling of prefabricated hardware function modules to completely embedded systems. This professional training course qualifies the participants for the various requirements in professional practice.

Duration: 10 months

Course Fee: 1,980.00 €

Location: AKAD Stuttgart University of Applied Sciences (Germany)

Certification Course: **Specialist Industry 4.0** [80]

Short Description: Production in Industry 4.0 is increasingly focusing on intelligent products as well as new processes and procedures. On the one hand, the professional course focuses on communication systems and networks. With Specialist Industry 4.0 (AKAD) you move safely through classic communication networks and those of the next generation.

Duration: 10 months

Course Fee: 1,980.00 €

4.2.3 Lifelong Learning Courses

Further education courses are nowadays the most practicable offer for those who will immerse into the topic of Industry 4.0. Many different adapted courses, in individual realities or scopes exist in almost all industrial countries. Short and specific courses give the companies gradually the possibility to include Industry 4.0 in their own processes and technology. For this reason, finding courses about Industry 4.0 is not so difficult.

Location: University of Aachen (Germany)

Course: **Industry 4.0 - Smart Production** [81]

Short Description [81]: Smart production systems are solutions that solve gaps between data-technology- and process-oriented production forms in order to meet the challenges of today‘s production conditions.

This certificate course opens with an introduction to the topic smart production and shows both background and application possibilities of the individual models. The course also shows how production planning and management for intelligent production systems are developed and

	linked with logistics and automation systems. Finally, participants deepen their knowledge about technologies used in smart production and develop roadmaps for different implementation approaches.
Duration:	5 days
Course fee:	3,600.00 €

Location:	VDI Baden-Baden (Germany)
Course:	**Predictive maintenance and appropriate digital business models** [82]
Short Description:	The special one-day Predictive Maintenance and Digital Business Models provides an up-to-date overview of the topic and its anchoring in the context of Industry 4.0. It shows what is currently actually being realised, what are the necessary technical prerequisites and what is still being "researched". Existing technologies and products are presented and how they can be used. Business models in predictive maintenance round off the topic.
Duration:	1 day
Course fee:	840.00 € + VAT

Location:	VDI Stuttgart (Germany)
Course:	**Augmented and Virtual Reality: From practice for practice** [83]
Short Description:	Augmented and virtual reality applications in the industry place special demands on the operation and presentation of content. While, in recent years complex prototypes with AR and VR-use cases have often been used, there are now a number of solutions with significant added value in daily use. The use of prototypes and scalable industrial solutions benefits from these developments and becomes more cost-effective.
Duration:	2 days
Course fee:	1,690.00 € + VAT

Location:	VDI Düsseldorf (Germany)
Course:	**Digital Transformation - Practical tools for use in everyday business life** [84]
Short Description:	Digital transformation is the central confrontation for companies in the future. While much has already been said about the subject, the hurdle between “listening” and “acting” remains large, especially in

	companies of small and medium-size. Fear of contact and the complexity of the undertaking ("Where to start?") are the main reasons for this.
Duration:	2 days
Course fee:	1,690.00 € + VAT

Location:	Sfida Italia 4.0 - Brescia (Italy)
Course:	**Assembly 4.0** [85]
Short Description:	The aim of the course is to provide participants with the skills to read and redesign the process, integrate 4.0 technologies and interpret company data by creating a new system of indicators adapted to a competitive production reality and always oriented to innovation.
Duration:	5 days
Course fee:	3,000.00 € + VAT

Location:	Sfida Italia 4.0 - Brescia (Italy
Course:	**Production 4.0** [86]
Short Description:	The course provides an understanding of the usefulness of 4.0 technologies and their possible integration into your production reality. It provides participants with the basic skills to read measure and redesign the process. It evaluates how to insert and integrate the main 4.0 technologies, collect, process and interpret the data obtained by creating a new system of indicators suited to a competitive production reality that is always oriented towards innovation.
Duration:	8 hours
Course fee:	700.00 € + VAT

Events and Exhibition on Industry 4.0

Topic:	**Siemens Industry day 2018** [87]
Company:	Siemens
Location:	Different locations (Germany)
Short Description:	Stay ahead of the competition and take advantage of the potential of digitisation. The digital transformation creates new competitive advantages and business models in the discrete and process industries.

Take advantage of this development and understand how this works at Industry Day 2018. Finding out the value of digitisation by using digital twins or by completely simulating your system and intelligently analysing the drive data is the main topic.

Topic:	**Achema 2018** [88]
Company:	Siemens
Location:	Frankfurt (Germany)
Short Description:	At Achema 2018, concrete applications showing how the potential of digitisation can be used to become more efficient and flexible, to increase quality at the same time - and to shorten time-to-market, are presented.

Topic:	**Automatica 2018** [89]
Company:	Siemens
Location:	München (Germany)
Short Description:	Under the motto "Digital Enterprise – implement now!", it is possible to see integrated solutions for systems in the digital age. It demonstrates the meaning of virtual commissioning.

Topic:	**Industry 4.0 Summit** [90]
Company:	Siemens
Location:	Manchester (United Kingdom)
Short Description [90]:	The Industry 4.0 Summit & Expo is the UK's premier gathering of senior level executives from the UK manufacturing industry interested in developing their digital strategies. Industry 4.0 Summit & Factories of the Future Expo 2018 gathered 1,900 attendees and 53 speakers from 39 countries at the Manchester Central Convention Complex to discuss the digitisation of manufacturing. The Summit provides a great opportunity for manufacturers to hear from senior speakers from government, associations and industry, plus to see Industry 4.0 case studies in action. The Expo showcases hundreds of innovations to help manufacturers digitise and upgrade operations.

Topic:	**Automation and Testing** [91]
Company:	A&T
Location:	Torino (Italy)

Short Description: The Fair is dedicated to Industry 4.0, Measurements and Tests, Robotics and Innovative Technologies. It is divided into two-macro areas:

- Robotic world: This represents the "automation" component of the event that includes robotics and innovative production technologies, wanted by industrial robot manufacturers and sponsored by SIRI.
- Testing and Measurement: This is the testing component of the event, which includes the great world of instrumentation and services for measurement, testing and industrial processes.

4.3 Trends for Digital Teaching Methods

The following are some of the major trends for technology adoption in education [92]:

1. Codification

   The digital economy in the future will be led by people with an understanding of how computers work and having programming skills. The interaction with technology becomes increasingly important for students, to be able to control programs, apps and devices connected to each other.

2. Collaborative Learning

   A new successful trend is the so-called collaborative learning models. Collaboration is showing how people are solving problems supported by the interconnectivity of the students. Parallel and virtual workspaces are created in tools such as Microsoft Classroom and Google Apps for Education, and eliminate space, demographic and time barriers for students.

3. Supporting Students as Creators

   Students no longer want just a passive consumption of content, instead they want to start to explore subjects by an active creation and collaboration. Makerspaces, fabrication laboratories, creative and intuitive suites of desktop programs, media centres and applications provide the practical related possibilities for students to use their creativity for a new development about solutions, expressions and inventions.

4. Rethinking how Schools Work

   Open educational courses, as well as adaptive learning tools, help individualising students and give transparency about how to improve the way to learn. In combination with new communication technology like Smartphones or tablets, the students receive an ideal learning environmental anywhere and anytime.

5. Redesigning Learning Spaces
   Leaving fixed classrooms and moving to flexible learning spaces enables students to build groups with the certain number of participants as needed for lessons. Being connected gives the students the possibility to collaborate in social modalities and familiar locations, which is easier to find outside the classical classroom.

6. Deeper Learning Approaches
   Giving the students an idea of how their abilities and experience have an influence is needed to stay motivated. Using different social media platforms, such as Snapchat, WhatsApp and Twitter, gives the students the possibility to stay connected to work out local and global issues. Including during education social platforms as well as tools like WeVideo or YouTube could be useful and contribute in working out solutions, or giving some insights in meaningful ways.

4.4 Technologies to Support Future Trends in Education 4.0

Why it is so important to include technology inside the future education system?

Several points are listed below giving an answer to the question:

Students demand it
Students outside the classroom are constantly immersed in technology. Young people want to be up-to-dated and always connected to be interactive and technology-based. Learning must become a part of their lifestyle.

Young teachers demand it
Technology has been implemented in higher education and other professional areas. For new teachers, technology is a standard level and absolutely necessary to work with.

Students can learn at their own pace
Students can learn at their own pace. Today, in traditional classrooms, this makes it difficult to implement. Integrating technology in education, pupils can slow down and go back over concepts and lessons as often as they need. In addition, technology allows teachers to help them more individually.

Young people are digital natives

Children know technology better than most adults do. Since it is an integral part of the life, it has become the easiest way to learn. Utilisation of technology in the classroom helps students acquire multi-tasking skills as well as learn better and faster.

There are no limitations with technology

Analysing the development of technology, it is quite difficult to recognise limitations today. Having access to information outside the school, opens to students various ways of learning a concept. Teachers can support, by coming up with innovative ways of teaching, which keep students engaged. Technology is changing the learning methodology, so learning is becoming more hands-on.

In order to be able to implement the new trends listed above, a development of the existing teaching devices is needed. Nowadays, standard classroom devices like beamers or standard PCs are strongly limiting the ideas of new education. Trends like BYOD (Bring your own device) are reducing the pressure of the schools in buying hardware, which, in a short time, become old-fashioned technology again. If every student is providing their own needed hardware for education, different advantages could be listed. Firstly, each student can work in school as well as at home with the same devices, which eliminates software compatibility problems or individualisation of devices and software. Secondly, the schools are not under pressure of being up-to-date with new hardware and, considering that in a technical higher education school like TFO Max Valier there are eight computer rooms with about 20 stations each, the continuous investment for new computers is extremely high. Of course, the advantage of one is normally the disadvantage of the other. In this case, the effort to buy a high-performance computer is shifted to the family.

4.4.1 Hardware Devices

As explained before the hardware is playing an essential role during the development of Education 4.0 new Software or programs cannot be handled with the traditional hardware we use today. New devices must be developed to be able to go hand in hand with Education 4.0 ideas. The main goals by the new devices are:

- Eliminating books (reducing weight and costs)
- Reducing devices (devices all-in-one)
- Interconnectivity

Thinking about how new devices, there could be considered two different ways of possible strategies for those kinds of technology. The first possible strategy regards more a change on a short term and is the evolution of the classical Smartphone or tablet. Nowadays, the closest trend goes to the BYOD utilising notebooks and working on clouds. These devices are already available and need just a reorganisation of different procedures. The University of Bolzano-Bozen made already the start and could be taken as an example for introducing it also at higher-level schools.

The next step could be the consideration to work with tablets or Smartphones reducing the weight or additional devices. Today, Smartphones are devices everyone carries with them, wherever they are going. Actual technologies are not yet so developed that a tablet or, more so, a Smartphone can replace a notebook. Until new technologies are built in, a Smartphone cannot cover following applications for education:

- Writing or making notes in an efficient way
- Viewing images and texts in an appropriate size
- Conducting researches or other interactive activities for a long time
- Interactivity between devices and user

The development to integrate new technologies in Smartphones is currently underway. A few have already transposed the future features of a commercial Smartphone in relation to the list of applications above [93] is presented in table 18:

Smartphone Features	Technology involved	Writing Efficiency	Appropriate Viewing	Long-Time Interactions	Interaction Devices-User
Eye following system	Camera Recognition Technology and Real Time Data Elaboration				
Smart Holograms	Virtual Reality and Augmented Reality, Camera and Projections Technology				
Flexible Surface/Cover Devices	Nanotechnology and Material Technology				
Drone phone	Self-balancing Technology				
3D Scanning	3D Scanning Technology				

Flipping/Splitting systems of display device	Material Technology				
Battery long life	Battery Management by Material Technology				
Biometrical Analysis	Smart Sensor Technologies and Medical Analysis				
Multitasking ability	Cloud Management				
Construction planning aid	Virtual Reality and Augmented Reality				
Self-learning Software	Artificial Intelligent Technology				

Table 18: Smartphone future features in relation to teaching properties

Some other additional features of future Smartphones, which are not yet relevant for education, are:

- Self-charging mode (device moves autonomously to the docking station)
- Night light by drone (increasing safety by a self-flying drone with light emission)
- Danger recognition (suggesting the admin of prescribed medicines)

All these features are actually already possible to fabricate, but, due to the high production costs not, affordable for mass production.

The second strategy, considering a middle- to long-term development, is leaving aside the Smartphone as a device and considering the trend to miniaturise daily use devices. Future devices could include a ring or glasses. The fewer devices it is necessary to carry with you or the less perceptible devices are to wear, the better. A ring or glasses, once put on, is not so easy to forget and leave somewhere, unlike a Smartphone which could be left on a table or at home. Of course, thinking today of such types of devices needs a lot of fantasy and creative imagination, but the technology is making big steps in reducing production costs and components are becoming ever smaller. Concluding this aspect, making the last step could be the development of a sophisticated lens. These kinds of devices are close to eliminating the perception of wearing objects on the body. Considering health by the utilisation of electromagnetic radiation or other problematics of wearing electrical objects so close to the body will become a great challenge for the future.

4.4.2 Virtual Reality and Augmented Reality

Virtual Reality (VR) and Augmented Reality (AR) will definitely change the education systems. To understand how, it is important to understand what VR and AR are [94].
The Virtual Reality is a digital replication of the real physical world. In this virtual

environment, the user can interact with the system extrapolate relevant data. Augmented Reality is a technology, which is utilizing a device to be able to overlap digital information on a virtual or real world. Devices could be special glasses as well as smartphones.

Possible application fields about virtual reality [95]:

- Virtual fields trips
  VR can motivate students to enter into a world or go to place where normally they would not have the possibility to go. Thinking about geography, the lessons can be made in a completely different way, exploring to see animals or flying into space. Also, history could be more interesting and easier to understand being projected in the relevant year.

- High tech training
  Specialised training in the sector for medicine or Nano-Technology with the aid of virtual reality will give a faster and clearer approach. Moving from simply imagining an object to the possibility of actually seeing it to scale or going into the detail is an important part in considering new technology becoming ever more abstract. Analysing the anatomy of the human body by using, for example, an Oculus Rift headset, is only one of many applications for this technology.

- Internships
  Internships could be changed too. Giving young people the opportunity going to visit different job activities in detail on a virtual tour can help to find the correct study path from the beginning. Students can participate, whenever they want, on a virtual internship to consolidate their learned theories or in studying new topic through practical approaches.

- Group learning
  Team working is one of the most important competences in the future and must also be trained. It should not only be a technology wherein students are working alone, but, by creating avatars, they also can discuss or synthesise about the last lessons during a group session. This gives the students the possibility to learn from each other by working together.

- Distance learning
  A big advantage of distance learning could be the supervision of the individual progress of a learning activity. Students need no longer be inside a classroom; instead,

they could any place which is ideal for them to learn in the best way.

Another technology is Augmented Reality. How this new technology could be used in the education system is explained in the following eight reasons [96]:

1) Harness the impossible

   Students can bring objects into the classroom that would not be possible in reality. Having an image in 3D in front of you allows an undefined number of applications and an opportunity to analyse in more detail objects which could be impossible to have inside a classroom, like a dinosaur or a plane or a space shuttle. The 4D+ Apps from Octagon Studios gives an early impression about this technology

2) Perspective control

   Students can easily view 3D models at any angle, distance and scale within Augmented Reality. Students can view more naturally well-designed Augmented Reality models moving around, for example, the hands, where the object is projected, to change perspective, getting closer or further away. When viewing content like AR shapes, students can examine the relevant properties with more freedom and precision.

3) User Interaction

   Students can interact with AR content to develop a deeper understanding of a topic. Augmented reality creators are speaking about bringing objects to life . Having a certain dynamic movement of an object helps students to understand topics easier in relation to a text or a picture or also a video. The possibility to interact with the virtual world further supports this concept. A good example for this is the app from Visible Body about the amazing Human Anatomy Atlas; this revolutionises completely the study of medicine.

4) Boost Engagement

   Students engage reality with AR content and are motivated to learn independently. Increasing the motivation for a student leads to a deeper understanding of the subject matter. It is easy to imagine that 3D printing can be utilised in almost every situation of student’s life. This integration inside learning scenarios means that students are more engaged to learn the content if it is relevant, not only for school, but also for their private use as well.

5) Enhanced Environment
Students can enhance classroom displays with Augmented Reality content to bring them to life. The utilisation of multimedia inside the classroom is one of the most powerful developments for AR.

6) Stimulate the Senses
Students can engage with a range of multi-sensory learning experience using AR. Sound effects or using touch controls immediately give an object an additional value of interest for the students compared to a static silent object. Interacting by using Smart-Sensors Technology is stimulating the student's senses.

7) The X-Ray Effect
Students are able to look inside objects and discover what they are made from. The curiosity of the students is one of the most important properties a young person can have and must be supported in every possible way. Thanks to tools like VirtualiTee from Curiscope it is possible to have a view inside an object, like wearing X-Ray glasses looking inside a human body. Other applications let you analyse and deconstruct different types of food into protein, sugar, fat or other components. Going inside an object to understand how it is made inside or how it is built together allows students to satisfy a certain thirst for knowledge and gives them many answers to different questions.

8) The Budget Factor
If a certain number of students are able to access the Augmented Reality content , resources will become relatively inexpensive. As is the same problem in every public education entity, the financial resources are strongly limited. For that reason, comparing 3D printing with augmented reality, the second is less costly. Printing an object for each student or for each exercise is connected to a certain cost considering the utilised materials. For that reason, projecting a virtual object is much cheaper, having an initial high investment cost, but it is subsequently possible, via dedicated software, to project each kind of object. On the other hand, technology is rapidly becoming cheaper considering the continuous development in this sector. This will allow, in a few years, to buy devices at an affordable price, especially for schools and, who knows, maybe also open up software to work with this technology.

All those reasons are bringing the education system to a new level, which will definitely change the interaction between students and teachers and also the access to the schools for the students.

4.4.3 3D Printing

3D Printing is, as described before, a technology arising with Industry 4.0. The use of this technology must be considered as a big advantage in the education system. First, the technology itself must be inserted inside the teaching program, because, in many companies of this kind, there will be different types of applications. From construction of a product to the development of small numbers of serial production it will be possible to find that equipment. Second, the 3D printing will lead students to a more practicable teaching approach. Teachers can show and explain by quickly creating a physical object which makes a topic much easier to understand. At a time where students must learn more topics in less time, aids like the 3D technology are helping considerably.

Why could 3D printing become interesting for education?

The increase of interest in 3D printing is down to its versatility. Technicians, for example, are more interested in how the equipment works or in optimising the technique to make the printing process faster. Architects could show a 3D model of a building in a scale that makes it easy to transport in order to give the customer a detailed overview of a project. Chefs in a kitchen could create special objects with eatable materials making a dish something unique and special. Material management is covered in a wide range. Which material today is possible to print, how and which are their properties? Is the printed product only a prototype, or can it afford certain mechanical forces to make it possible to print a final product? What is the economical calculation if a customer prints out a spare part to replace the broken one, in relation to the production on-site, and sends it to the customer? Those and many other questions are making this trend development interesting.

How can 3D Printing revolutionise the classroom? 11 points show the answer [97]:

1. The 3D printer technologies are now since 30 year on the market. New developments and running out of patents makes the devices affordable for school.
2. Printing out complex shapes help students to understand the structures ore assembling possibilities.
3. Use 3d printing technologies in architecture studies open new ideas and concepts, if first prototypes could be created in scale.
4. Artefacts for a history lesson could be exanimate more in detail.

5. Design studying students could create 3D objects of their artworks.
6. Prototypes for engineers are supporting new types of construction application fields.
7. Working on 3D maps in geography helps to understand the topography ore population or demographic developments.
8. Printing food could completely revolutionize the way to create dishes.
9. Classes for car mechanics could learn to fix problems by printing spear parts by their own.
10. Students for chemistry subjects print out important parts or complete molecules to study.
11. Analysing a 3D printed human heart in biology it makes the subject more affordable.

By analysing the points, it is easy to see the huge opportunities standing behind 3D printing. As the technology could find applications in almost every sector, from industry to handicrafts, this would lead to embedding his generation tool at an early stage of education.

Teachers could be supported in many ways in working with a 3D printer:

- Gives students the possibility to feel an object in relation to its size and manageability.
- Provides objects to the teacher, which are not possible to get. If, for example, in biology the heart is threatened, holding in the hand a real copy of that most important organ makes the functional description much more comprehensive.
- Generates excitement and engagement for the students creating something physical from a text or a sketch.
- Encourages creativity for innovations by utilising free software packages to generate an object.
- Promotes critical thinking and problem solving skills if a product does not fit the expectation or could not be assembled as it was planned before.
- Increases the retention degree of a topic if an object can be analysed in real size in relation to a picture or a text description.

Reading all these advantages and opportunities, why is the introduction of this new technology not so easy? Many challenges are associated with 3D printing in education systems. The biggest obstacles to overcome are [98]:

1) Knowledge of teaching staff:

Many teachers have worked for many years in the same way. This especially includes practical applications. Young teachers, coming out from universities, learn this new technology during their study. Older education staff are not so familiar with 3D printing systems and are often afraid of new things, especially technological things. Changing study programmes and attending courses to enable working with a 3D printer could be a big expense, which not every teacher is willing to pay.

2) Support of unfamiliar technology:

Introducing a new equipment is always related to many questions as to possible applications. During this introductory step, it is essential to overcome the fear of doing something wrong or just be supported by different processes. If the use of these devices should become regular during the lessons, the users must be supported very strongly and also to help in bringing new ideas for implementation of the 3D printer.

3) Accessibility to the printer:

Also essential is the consideration of how many devices a school needs and where they should be located. With only one printer in an entire school, good management is needed in order to have efficient use of the device. Is the printer transportable and, therefore, easier to bring it to a class and work on it there, or must the class go to a special laboratory? In each case, this could lead to additional organisation on the teacher's part.

4) Economic considerations:

Printers nowadays are not a big investment because of their 30 years of existence and the fact that many patents are running out. This leads many companies to start a business with future potential in this sector. The more competitors are in the market, the more the price is reducing for the customer. The bigger problem for a school, after the acquisition, is the maintenance and spare part management as well as also the possibility of buying the needed raw materials to allow working with the 3D printer. It does not make sense, given the initial investment to buy the printer, to not then have enough money for the raw materials.

Chapter 5

SUMMARY AND OUTLOOK

Industry 4.0 is becoming a big challenge, not only for industry, but also for the education system. Nowadays, many different approaches are offered to enter into the cyber-physical environment. Looking at the small and middle-size companies in South Tyrol, a big change in introducing technologies supporting Industry 4.0 seems unlikely in the next five years. Nevertheless, schools must think about starting quite soon, teaching young people with new methods, giving them competences which are useful for companies once they finish their education. In fact, competences is the keyword that must be analysed. Defining today futures competences is quite difficult considering the time needed by the Ministry of Education to adopt new education systems. Fast changing technologies need fast reacting process defining and problem solving management. Both of involve a massive bureaucracy that is not so easy to handle. Considering how much time was needed to create the last school reform, it is quite difficult imagine a fast procedure for those activities. Fortunately, "La buona scuola" is giving teachers much more flexibility in building their own education programmes for subjects. Eliminating special topics and introducing descriptions about capabilities and knowledge the teacher can customise the content of a lesson in relation to its geographical, social or economic reality. For example, teaching logistics in the mountain area in South Tyrol has different points of focus than teaching it in Genoa close to the sea. This new model is, for education staff, much more flexible than the old rigid teaching subject instruction plan. Also, the capabilities and the knowledge within Industry 4.0 will also be changing in the coming years, which means that the last education reform must be implemented and actualised.

As a strategy to help companies in becoming part of this new industrial revolution, public entities are helping with a financial contribution in new investments for machines equipped with the new technology [99]. Decisions to invest in new trends for small companies are difficult, considering the limited resources needed for installing, to operate and to maintain the equipment. Courses and detailed trainings are essential to make use of the machine in an efficient way. The research in this paper shows that the possibilities for specialisations in South Tyrol are nowadays restricted. Different study programmes on a higher education level are organised for a broad introduction as well as for a particular topic. In addition, it is possible to attend many technology-related courses. High cost and time consumption accompany this education, which puts companies in a situation whereby it is difficult to understand if the utility has paid off. Hiring young people with competences to handle the new technology will change the entrenched situation considerably.

Students out of university with a backpack full of new knowledge and capabilities, not only give the companies the possibilities of analysing the change in buying new equipment, but also in considering future possibilities and applications. This passes the ball to the education entities. Schools and universities must be the pioneers to this new trend. As can be seen, the development to new teaching systems is already in action. New hardware devices like smartboards or software such as the digital register or Moodle gives an early impression of where the way of education is going. Considering the enormous potential which the technology about virtual or the augmented reality can offer, it is easy to understand that the development will still need a long time in order for these new inventions to be utilised effectively. The role of the education entities becomes essential for the introduction of Industry 4.0. Because of this, if the universities and schools do not receive the necessary resources, then the education development aims will not be possible to achieve. Thinking about the technical upper level school, Max Valier can be considered to be a pioneer in this sector, introducing the digital register without already having a PC in each classroom. Of course, other trends, like BYOD, are going against the acquisition of new computer devices inside school. Despite that, a certain basic equipment is needed inside each classroom if we want to talk about digitisation. The same discussion could be made about equipment like projectors. How can it be possible to leave the old-fashioned frontal teaching method without having state of the art technologies in the classroom? To conclude, the main aspect about providing education institutes with the necessary equipment is the connectivity. On the one hand, the connectivity between devices, utilising clouds or LAN connections, is quite good throughout the education infrastructures around South Tyrol. On the other hand, the problem is the connectivity to the Internet itself (down- and upstream rates of data today are strongly limited). According to the Südtirol Digital 2020 – The guidelines for the digital evolution in South Tyrol devised in 2013 [99]:

- By 2016, a nationwide power supply with connections from 7Mbit/s to 20Mbit/s can be achieved. By 2020, South Tyrol will have met its contribution to achieving the goals set by the European Digital Agenda and the Italian Digital Agenda.

The Italian agenda of 2014 defined, as part of the new Broadband Plan and a Strategy for digital Growth in Italy, the following measures [99]:

- Broadband (Public Connectivity System 30-100Mbit/s) and WiFi for all public infrastructures.

The fact is that, by 2016, all higher secondary level school had a connection to the glass fibre net as it was provided by the South Tyrolean guidelines, but with a limitation. All higher secondary level schools are working utilising a compression package of about 600Mbit/s.

Having 39 high schools, considering all types of schools (technical/economic/social high school and grammar schools), the high amount of 600Mbit/s is dramatically reduced working on a PC inside the school. The connection is enough for working on classical applications, but considering future trends it is surely to low.
The last consideration to do is with the teaching personnel. The way of delivering a lesson must be changed, considering the new competences created by the coming technology. Professors and teachers must be supported in their training to be able to pass the content on, in a correct pedagogical way, in order to motivate and support the students' capabilities. Strictly related conditions, like classroom devices or assessments, are losing their importance. Teaching personnel have to consider investing a certain time for further education in new technologies as well as thinking about how to leave traditional teaching methods and adopt the new approaches. To do this, many more courses have to be organised focusing on different target groups, such as teachers. A possibility could also be a training, organised in collaboration with companies already using technologies for Industry 4.0. In addition, in 2015, "La buona scuola" introduced the necessity of technical students for upper level schools to attend 400 hours of working on practical applications in collaboration with companies ("Alternanza Scuola-Lavoro" [61]). Combining further education for teachers, with projects where students are working with companies, reducing the high number of hours could be one of many ways to embedding new technologies. For example going to the makerspace with a class or treating the 3D printing topic could cover different aspects. The makerspace can show different types of 3D printing systems while teachers and students can be trained to work with the printer as well as analysing possible future applications. The teacher increases their knowledge while the students learn new technologies and can demonstrate the attendance of practical hours.

Finally, to summarise all considerations, the following are the recommendations arising of this paper:

1) Reduction of bureaucracy for public entities to be more flexible and faster in adapting developments and trends.
2) Increase of specialised courses for different target groups in order to focus more on operating topics or education methods.
3) Affordable technologies for education structures to give the teaching personnel the needed tools to be able to teach new and emerging topics.
4) Higher support for education staff in organising courses and managing contacts with companies or entities that are working with new equipment for Industry 4.0.

The recommendations are not only used for one entity or target group, but in considering the entire system. Every element involved inside the education systems must think about changing their usual habits or procedures, from the ministry responsible for the education entities to the teaching personnel and, finally, also to the students. Digitisation by introducing new technologies concerning Industry 4.0, will be a great challenge. It needs time and effort, but must be seen as a great opportunity for everyone.

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