TACCLE AI

Improving skills and competences of VET teachers and trainers in the age of Artificial Intelligence

Artificial Intelligence in the Policies, Processes and Practices of Vocational Education and Training

Co-funded by the Erasmus+ Programme of the European Union

Report

The Erasmus+ funded European project 'Improving the Skills and Competences of VET teachers and trainers in the age of Artificial Intelligence' (Taccle AI) brings together partners from five countries to provide initial training and continued professional development for VET teachers and trainers in Artificial Intelligence.
The project will seek to support VET teachers and trainers in extending and adapting open curriculum models for incorporating AI in vocational education and training. Furthermore, the project will develop an Open Massive Open Online Course in AI in education in English and German, open to all teachers and trainers in VET in Europe.
The course materials will be freely available for other organisations to use for professional development. It follows the tradition of previous successful TACCLE-projects. You can find more information on our website: www.taccleai.eu

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Full Report IO 1

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SUMMARY

Artificial Intelligence (AI) can be defined as a system that has been designed to interact with the world in ways we think of as human and intelligent. It is important to understand the potential impact of AI on learning, teaching, and education, as well as on policy development. AI is particularly important for vocational education and training as it promises profound changes in employment and work tasks. The greatest implications for VET lies in the changing tasks and roles within jobs, requiring changes in initial and continuing training, for those in work as well as those seeking employment. This will require changes in existing VET content, and the introduction of new programmes such as the design of AI systems in different sectors, and adaptation to new forms of cooperative work with AI.

For VET teachers and trainers, there are many possible uses of AI including new opportunities for adapting learning content based on student's needs, new processes for assessment, analysing possible bottlenecks in learners' domain understanding and improvement in guidance for learners.

Introduction and usage of the AI in the VET processes and systems has made different progress in the project partner countries (Germany, Greece, Italy, Lithuania and UK). In Germany the introduction and application of the AI in the VET is progressing strongly due to the overall development of skills and training in the conditions of Industry 4.0 and strong innovative cooperation between the enterprises and VET providers. The practice of establishing learning factories shows strong work process orientation in the introduction of the AI issues in curricula and training practices. In the UK the introduction and usage of the AI in the VET is more focused on the implementation and application of the different AI solutions that foster acquisition of knowledge, basic and key skills by focusing to the enhancing learning capacities of students by applying AI solutions. In the school-based VET systems in Lithuania, Italy and Greece the integration of AI in VET processes is very fragmented and makes initial steps. Here different initiatives of VET teachers, trainers and students play very important role in fostering usage and implementation of the AI.

This report analyses the implications of AI Technologies for vocational education and training, the impact of this process for employment and labour market, as well as implications for work processes in different occupations such as mechatronic occupations, which are crucial for VET curriculum design and organisation of training processes.

The potential impact of the AI for employment, labour market and society is complex and heterogeneous, including both positive and negative implications, such as emerging of the new challenging, interesting and meaningful work tasks and jobs, liberation from the routine and harmful work, but also enhancing digital Taylorism, task encroachment and automation of the high skilled jobs, digital precarization of work and labour market, increasing skills polarization leading to further exacerbation of the income and socio-economic inequalities. AI can both replace the human workers and enable them to perform more and better. It is expected important impact of the AI to the change of the landscape of existing jobs and labour market structures. Subsequently there is expected impact on the demand of knowledge, skills and competencies. Demand for physical and manual skills and for basic data input and processing will decline, while growth will be strong in demand for interpersonal skills, creativity, and empathy. Advanced IT skills and programming alongside complex information processing skills will also see a surge in demand.

AI facilitates redesigning a production environment into a "smart factory", excelling in high flexibility and versatility with new organisational structures and processes. The integration of

intelligent machines and software into the workplace, workflows and workspaces will continue to evolve to enable humans and machines to work together. Artificial Intelligence creates completely new spaces for interaction between machines (e.g. multi-agent systems), as well as between humans and machines. The complementary power of AI and automation through the innovations will increase the performance of humans and could create some new jobs and skill needs, but these trends cannot outweigh the hollowing-out or polarization effect of AI on jobs and skills. It creates the necessity of political intervention and makes the jobs problem a political problem.

AI is at the centre of the different scenarios of the future change of work in the context of digitalization. Gradual upgrading of technologies and work organization including implementation of AI permits smooth and gradual upgrading of skills and qualifications, through involving decentralization and the reintegration of the functions of planning, execution and control of work. AI and related technological solutions also have unlimited (or at least with unknown limitations) capacities for work task encroachment not only in routine work, but also in so called "high-skilled" work processes. It leads to work polarization by erosion of the middle level occupations created by the task encroachment in the related work processes by AI and other technological solutions. AI also becomes an important factor leading to the decentralisation of work organisation and the spread of temporary and project-based forms of work organisation, digitized management of work processes and higher temporal flexibility of work organisation.

One of the key challenges for VET is to identify the work tasks which require complementarity of human work and AI and to provide competencies necessary for handling these tasks. The increasing rate of automation and task encroachment narrows the range of accessible jobs and applicable skills and at the same time decreases the possibilities to obtain new skills needed for the remaining jobs because of fast changing skills needs and intensive competition between the big tech companies, making this know-how and skills an important part of competitive advantage. There is a range of implications of AI for skills needs, starting from rapidly growing demand for advanced technological skills such as programming, increasing demand for key skills and competencies, declining demand for physical and manual skills as well as declining need for basic cognitive skills. The Application and development of AI based technologies challenge the traditional boundaries of disciplines, knowledge and competence areas.

There is also increasing demand for systemic understanding and cognition in work processes and technologies, for their planning and design. The widening of the contents of work processes requires holistic understanding of the work and technological processes and abilities to process the systemic data and information of these processes. Decentralisation leads to the saturation of industrial work processes with data. Employees with qualifications at all levels have to be prepared to deal with real time data from production processes and to react to the requirements of the process management and optimization.

In Germany, where the debate has been heavily focused on Industry 4.0, there is a call for higher level technical skills, for instance in programming or preventative maintenance. In the Anglo-Saxon countries, the discourse suggests we should be teaching the skills and competences that computers (and AI) are not good at: communication skills, teamwork, decision making etc (it is notable that these used to be commonly referred to as soft 'skills).' What does seem likely is that there will be a need for more learning opportunities for those already in work (Lifelong Learning) and also retraining for those whose jobs do disappear as a result of the changing technologies.

Industrial work will need to be redesigned to ensure that workers are sufficiently skilled to work alongside complex machines. Therefore, a shift to advanced technical skills such as programming, quality control and better coordination is necessary. Social, emotional and higher cognitive abstract skills such as creativity and complex information processing will also increase. A change in the curriculum towards an action orientation with high practical application is becoming increasingly important.

AI applications in the vocational education and training concern different forms of learning and training, but their application in the work-based learning is particularly important and interesting. Work based training systems can, for example, make use of AI driven recommender engines to help employees access the training they need when they need it. There is potential for AI to support people throughout their learning life course with 'just-in-time' learning individualised to their needs, accessible through multiple interfaces from voice activated technology, to virtual and simulated environments and physical computing embedded within our world.

At an organisational level, the need for updating existing skills and competences will require more lifelong learning, an increase in blended learning programmes combining online and face to face programmes, closer collaboration between educational institutions and companies in the provision of both course based and workplace learning, and the increased use of data from sensors in the working environment.

AI can also be used in the different fields of VET provision, such as learner engagement and recruitment via chatbot applications, to provide information about the labour market, about jobs and occupations, about qualification requirements and about courses and work experience opportunities. Intelligent tutoring systems and the AI supported provision of online learning can also promote engagement with students, not least because they can be accessed anywhere and at any time. AI enhanced systems can provide nudges to learners to encourage them to complete coursework or to remind them of forthcoming deadlines and tasks. AI can also support the delivery of learning materials, for instance providing answers to frequently asked questions or through stimulating and moderating seminar discussions. The use of AI in assessment can greatly enhance the variety of assessment formats. Automatic marking of assessments reduces the load on teachers, allowing a move towards more formative assessments, rather than reliance on manually marked end testing. AI will free up teachers to act more as coaches for students, and instead of 'teaching to the middle ability', teachers will be able to give greater attention to those students who need it, particularly the higher and lower quartiles in terms of confidence and outcomes.

1. INTRODUCTION

Artificial Intelligence (AI) can be defined as a system that has been designed to interact with the world in ways we think of as human and intelligent. Ample data, cheap computing and AI algorithms mean technology can learn very quickly. The transformative power of AI cuts across all economic and social sectors, including education. UNESCO says AI has the potential to accelerate the process of achieving the global education goals through reducing barriers to accessing learning, automating management processes, and optimizing methods in order to improve learning outcomes (UNESCO, 2019). Education will be profoundly transformed by AI.

Teaching tools, ways of learning, access to knowledge, and teacher training will be revolutionized.

A European Joint Research Council policy foresight report (Tuomi, 2018) suggests that "in the next years AI will change learning, teaching, and education. The speed of technological change will be very fast, and it will create high pressure to transform educational practices, institutions, and policies." They say it is therefore important to understand the potential impact of AI on learning, teaching, and education, as well as on policy development.

The present contribution follows on from this and raises the question specifically:

What impact does AI have on vocational education and training in Europe and how can it be dealt with in practice?

AI is particularly important for vocational education and training as it promises profound changes in employment and work tasks. There have been a series of reports attempting to predict the future impact of AI on employment, producing varying estimates of the number of jobs vulnerable to automation as well as new jobs which will be created (Spöttl et al., 2016; BiBB, 2019; Cedefop, 2019; European Commission, 2020; McKinsey, 2018; Tuomi, 2018; Southgate et al., 2019; UNESCO, 2019). But the greatest implications for VET lies in the changing tasks and roles within jobs, requiring changes in initial and continuing training, for those in work as well as those seeking employment. Cooperative robotics offers new work designs and job scenarios for occupations avoiding repetitive work tasks. This will require changes in existing VET content, and the introduction of new programmes such as the design of AI systems in different sectors, and adaptation to new forms of cooperative work with AI.

If teachers are to prepare young people for this new world of work, and excite young people to engage with careers in designing and building future AI ecosystems, then VET teachers and trainers themselves require training to understand the impact of AI and the new needs of their students. This requires cooperation between policy makers, organisations involved in teacher training, vocational schools and occupational sector organisations, including social partners.

This research report represents a first step to investigate the effects of AI on VET and the future necessary competencies of teachers. First, it sets out how the debate on AI and VET is conducted at European political level and what trends can be observed in the partner countries. In the following chapter, we will first describe the influences AI will have on the professional world and the competences needed in the future. These findings serve as a basis for a more detailed presentation of the impact of AI on vocational education and training and for discussing the ethical debate on AI in general and in schools. In the following chapters, building on the literature and interviews, we summarise which skills and competences are becoming increasingly important for teachers or are new to AI and VET.

2. EUROPEAN UNION AND NATIONAL POLICIES AND STRATEGIES RELATED TO AI AND ITS IMPLEMENTATION IN EDUCATION AND TRAINING

The official strategy paper of the European Commission (European Commission, 2018b) on AI starts by proclaiming that "AI is reality". The question that arises in the context of this report is to what extent this reality already plays a role in education and training and how the link between AI and vocational training is understood, assessed and implemented at the European level.

First, an overview of the European strategy[1] for dealing with artificial intelligence will be given and the importance of education, general or vocational, will be discussed. Then the perspective will be slightly changed and the extent to which AI is mentioned in the strategic orientation of vocational training will be considered.

In April 2018, 24 EU member states agreed to cooperate in the field of AI. The EU seeks cooperation in order to enhance its global competitiveness. It should be taken into account that no one is left behind in the digital transformation and new technologies are based on European values. In the same month the European Commission presented a strategy for artificial intelligence[2] in Europe (European Commission, 2018b). This strategy aims to establish common European values for dealing with AI[3]. Technical, ethical, legal and socio-economic factors should be taken into account. This comprehensive approach to AI should be a unique selling point of European policy. The aim is to promote and establish European AI technologies and applications under the label AI - made in Europe. According to the EU Commission, AI can help to overcome future challenges for humanity and act as an economic driver. Positive effects that can be achieved through AI include fewer traffic accidents, optimized consumption of energy and water resources, lower risk of work-related injuries and more accurate and faster medical diagnoses.

The strategy sets three priorities for the development and promotion of AI in Europe. Firstly, the **EU's technological and industrial capacity is to be promoted**. Secondly, **socio-economic change** must be prepared and accompanied. In addition, an appropriate **ethical and legal framework** for dealing with AI must be created (European Commission, 2018b).

(1) To boost the EU's technological and industrial capacity, public and private expenditure on AI technology is to be increased. For the period after 2020, 20 billion euros per year are to be invested (combined public and private investments) to create a solid basis for AI. A key activity to increase public and private spending on AI technologies is, on the one hand, the stronger networking of European AI research centres. On the other hand, an "AI on demand platform" has been developed, which makes AI resources available in the form of tools and knowledge, for example. The platform should provide a single access point for all users and should also facilitate access to data. Access to data is a key factor to be competitive in the AI field. The Commission has therefore made some recommendations on how to make more data available. They recommend that there should be an updated directive on public sector information, guidelines for the sharing of private sector information in the economy and an updated recommendation on access to preservation of scientific information. In addition, the EU wants to strengthen research and innovation from the laboratory to the market. In this context, the testing and experimentation of AI products is to be promoted in order to make them ready for the market. This should be possible for companies of all sizes. The infrastructure of the Digital Innovation Hubs will be used as a basis for this. Digital Innovation Hubs have already expertise on technologies, testing, skills, business models, finance, market intelligence and networking. The strategy paper gives an example of how companies can cooperate with the Digital Innovation Hubs (European Commission, 2018b):

[1] A visual presentation of the European perspective on artificial intelligence is available at the following link: http://eu-commission.maps.arcgis.com/apps/Cascade/index.html?appid=f0403ce4dcb54d39bfbe4a7db71cd514

[2] The call for a European AI strategy was already made by the European Council in October 2017.

[3] Artificial intelligence is defined in the European strategy as follows: „Artificial intelligence refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals. (…)" (European Commission, 2018b).

"For example, a small company that produces metal parts for the automotive industry could consult the regional hub (which can be a science park for example) and ask for advice on how to improve the manufacturing process with AI. Experts from the hub would then visit the factory, analyse the production process, consult with other AI experts in the network of hubs, make a proposal and then implement it. These activities would be partially financed with EU money."

These and other activities are intended to ensure that the EU can keep pace with technological developments and involve European actors.

(2) New technologies like AI change the labour market by replacing existing jobs, creating new jobs or changing tasks within jobs. Therefore, especially in the field of labour and education policy, care must be taken to ensure that the EU Member States are prepared for and react to the socio-economic changes caused by AI[4]. Already in 2016, the European Commission published a paper (*New Skills Agenda for Europe*) in which it makes recommendations on how to respond to the changes in the labour market through upskilling (European Commission, 2016). In this context the paper specifically states **"Making VET a first choice"**. The aim is to get more young people interested in an apprenticeship (European Commission, 2016, p.6). In the field of education policy, the Digital Education Action Plan was presented, through which the technology use and the development of digital competences in education should be supported (European Commission, 2018d). In the AI strategy paper, the European Union builds on both the *New Skills Agenda for Europe* and the *Digital Education Action Plan* to ensure that no one is left behind in the transformation, but rather that everyone is taken forward.

In addition to the aim of bringing everyone into the transformation, it is also specifically intended to keep more people who have knowledge of AI in the EU. Particular attention should be paid to promoting interdisciplinary knowledge. This means in detail to involve more women, people with different backgrounds and disabled people in the development of AI. This is to ensure that AI is non-discriminatory and inclusive. In order to arouse interest in AI topics among young people, a traineeship "Digital Opportunity Traineeship"[5] was designed by the Commission to increase the number of digital experts with skills in fields like cybersecurity, big data and machine learning. In order to build a pool of talented people in the field of AI, the European Institute of Innovation and Technology integrates AI into the curricula of its educational courses.

Besides the considerations already mentioned, the EU would like to promote networking between companies and educational institutions. In the context of this report, the EU goal of motivating member states to modernise their education and training systems is particularly noteworthy. Special investments are to be made in upskilling, i.e. the further education and qualification of employees for the new world of work. This idea is based on the European goal of implementing a people-centred implementation of AI.

(3) Examples of how the EU is shaping the ethical and legal framework for dealing with AI are the draft ethical guidelines published in December 2018 and the General Data Protection Regulation, which regulates, among other things, the processing and

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[4] The EU takes a supportive rather than an active position in this task, as the authority to act in these policy areas lies with the member states.

[5] https://ec.europa.eu/digital-single-market/en/digital-opportunity-traineeships-boosting-digital-skills-job

> dissemination of personal data. The development of an ethical and legal framework requires a broad and open exchange at all levels of society, whether national or international, in order to develop ethical AI standards that reflect European values.

A few months after the publication of the AI Strategy a High Level Expert Group on AI, established by the European Commission, was set up with the aim of promoting the implementation of the European AI Strategy by discussing ethical, legal, economic and societal issues related to AI and making policy recommendations. This expert group also acts as a steering group for the so-called European AI Alliance, which is a broad multi-stakeholder platform. As a member of this AI Alliance, you can interact with the experts of the High Level Expert Group on AI in a kind of forum.

In December 2018, a common and coordinated plan for dealing with the European AI strategy was also agreed at member state level. The aim behind this is above all to strengthen the label AI - made in Europe. In the context of this report, the chapter "Adapting our learning and training programmes and systems to better prepare our society for AI" is of particular interest (European Commission, 2018c, p.5). In the coordinated plan, the member states agree that the teaching of digital skills should be included in all education and training curricula. However, it is not specified which competencies are required. But it is expected that these digital skills in general will promote and facilitate the development and use of AI (European Commission, 2018c, p.6). Europe must therefore, on the one hand, equip more people with knowledge about AI. On the other hand, these trained people must also be kept in the EU. The countries' coordinated plan states that almost all Member States are facing shortages of information and communications technology professionals (European Commission, 2018c, p.5).

The Expert Group on AI, the European AI Alliance and the coordinated plan with the member states show that the bundling of European forces is at the focus of the AI strategy, because only in this way, according to the European Commission, is it possible to use the full potential of AI and to keep pace with technological progress on a global scale.

In February 2020 a new paper on AI was published, which provides policy options for a trustworthy and secure development of AI in Europe (European Commission, 2020). On the one hand, an 'ecosystem of excellence' should be created in the future. This will be based on shared public and private resources. On the other hand, an ‘ecosystem of trust’ should be established. This requires clearer rules for dealing with AI. Six recommendations for action are given in order to establish the ecosystem of excellence. Among other things it is about skills. The section states that AI technologies can be used, for example in the form of learning analytics, to improve education and training systems. It is also suggested that ethical guidelines can be integrated into the curriculum of vocational training so that training institutions can train future employees in the use of AI. Vocational education and training is thus addressed, but ignored in the concrete recommendation for action (Action 3), instead only higher education is highlighted: "Action 3: Establish and support through the advanced skills pillar of the Digital Europe Programme networks of leading universities and higher education institutes to attract the best professors and scientists and offer world-leading masters programmes in AI"(European Commission, 2020, p.7).

This current Commission paper takes up broadly similar points to the AI Strategy published in 2018. It seems that there is a lot of discussion on the subject, but not much has been implemented in the last two years, as the 2020 report also states that Europe is lagging behind other countries in terms of technology and AI.

In addition to the efforts of the EU on a supranational level, it must not be forgotten that the citizens must be taken along. This also means that the citizens of the individual member states must have confidence in AI and be open to applications with this technology. This can be achieved in particular by imparting knowledge, because this way the involvement of the population in the topic can be increased and the discourse on it can be more differentiated[6]. An example of the involvement of the population is given below.

Elements of AI - Case study from Finland

In Finland an online course (www.course.elementsofai.com) has been developed to give citizens a basic understanding of artificial intelligence: What is AI? What can and what can AI not do? How are AI methods created?

The course was developed by the University of Finland and the consulting company Reaktor. The current goal is to educate 1% of European citizens in the basics of AI by 2021. Thus, theoretical concepts are taught as well as practical applications. The following table gives an overview of how the online course is structured and which topics are covered.

Chapter	Chapter Sections
What is AI?	I. How should we define AI? II. Related fields III. Philosophy of AI
AI problem solving	I. Search and problem solving II. Solving problems with AI III. Search and games
Real world AI	I. Odds and probability II. The Bayes rule III. Naïve Bayes classification
Machine learning	I. The types of machine learning II. The nearest neighbour classifier III. Regression
Neural networks	I. Neural network basics II. How neural networks are built III. Advanced neural network techniques
Implications	I. About predicting the future II. The societal implications of AI III. Summary

Table 1: Structure of online course

[6] The knowledge service AI Watch was set up by the European Commission. It provides an overview of the introduction and impact of AI in Europe. https://ec.europa.eu/knowledge4policy/ai-watch

The chapters do not have to be worked on in a fixed order. This allows you to learn very individually. To test the acquired knowledge there are either multiple-choice questions, quizzes, open questions, numerical exercises or other tasks at the end of the sections. After you have worked through all the chapters you will receive a certificate of completion of the course. Successful completion of the course requires at least 90% completed exercises and a minimum of 50% correct answers. You can get credit for this course as a student at the University of Helsinki.

Competences that should be acquired at the end of the course[7]:

- Identify autonomy and adaptivity as key concepts of AI
- Distinguish between realistic and unrealistic AI (science fiction vs. real life)
- Express the basic philosophical problems related to AI including the implications of the Turing test and Chinese room thought experiment – Formulate a real-world problem as a search problem
- Formulate a simple game (such as tic-tac-toe) as a game tree
- Use the minimax principle to find optimal moves in a limited-size game tree
- Express probabilities in terms of natural frequencies
- Apply the Bayes rule to infer risks in simple scenarios
- Explain the base-rate fallacy and avoid it by applying Bayesian reasoning
- Explain why machine learning techniques are used
- Distinguish between unsupervised and supervised machine learning scenarios
  Explain the principles of three supervised classification methods: the nearest neighbour method, linear regression, and logistic regression
- Explain what a neural network is and where they are being successfully used
- Understand the technical methods that underpin neural networks
- Understand the difficulty in predicting the future and be able to better evaluate the claims made about AI
- Identify some of the major societal implications of AI including algorithmic bias, AI-generated content, privacy, and work

The various competence goals show that the course does not only deal with the topic of AI superficially, rather it goes into depth. On the one hand, it will probably only address an academic audience. However, the aim should be to address other socio-economic groups. On the other hand, a complex topic like AI is not broken down to the absolute basics, instead it allows the learner to gain a more profound knowledge of AI. This is a very positive aspect of the course. In early 2020, this course will be available in all official EU languages.

The previous consideration in the Finnish example, i.e. to intensify the discourse on AI through education, is also reflected in the paper "Ethics Guidelines for trustworthy AI"[8] published in April 2019[9] by the 52-strong group of experts (European Commission, 2019). An important argument in this paper is that the trustworthy and credible handling of AI cannot be assumed, but must be actively trained and communicated. Thus, on the one hand, it calls for training and education to be provided in order to inform all stakeholders about AI and thereby raise awareness of AI (European Commission, 2019, p.3). On the other hand, in addition to theoretical education formats, practical contact with AI must be promoted and public discussions about AI must be

[7] https://www.cs.helsinki.fi/u/ttonteri/elements/elements_objectives.pdf

[8] The following aspects should be considered for trusted AI: Human agency and oversight, Robustness and safety, Privacy and data governance, Transparency, Diversity, non-discrimination and fairness, Societal and environmental well-being, accountability.

[9] The first draft of the ethics guidelines was published as early as December 2018. There were numerous comments on this draft, which were taken into account when the final Ethical Guidelines for Trustworthy AI were published.

stimulated. This is the way to establish an ethical culture and way of thinking for a trustful handling of AI (European Commission, 2019, p.9). Educational institutions, along with governments and leading industry representatives, have the responsible task of leading citizens into the new age and ensuring that they have the right skills to operate in the labour market (European Commission, 2019, p.33).

2.1. AI in European strategy papers for education and training

Digital Education Action Plan

In 2018, the Digital Education Action Plan was presented by the European Commission, which makes proposals on how to promote the use of technologies and the development of digital skills in education (European Commission, 2018d). In the Digital Education Action Plan three priorities are proposed:

Priority 1: Making better use of digital technology for teaching and learning
Priority 2: Developing relevant digital competences and skills for the digital transformation
Priority 3: Improving education through better data analysis and foresight

One way to make a better use of digital technology for teaching and learning (Priority 1) is to "Tackle the connectivity divide between EU Member States regarding the uptake of very high capacity broadband in all European schools (…)" (European Commission, 2018d, p.6). In addition, the strengthening of digital skills is intended to promote the willingness of general and vocational schools to deal with the changes in the world of work. In parallel, the question of how digital competences can be certified should be raised. Within the second priority, five further actions are recommended to develop digital competences: Higher Education Hubs, Open Science Skills, EU Code Week in schools, Cybersecurity in Education and Trainings in digital and entrepreneurial skills for girls (European Commission, 2018d, p.9). One action to improve education through better data analysis and foresight (Priority 3) is by using artificial intelligence and analytics. AI could be used to help address specific problems and improve implementation and monitoring of education policy (European Commission, 2018d, p.10).

European Vocational Training Agreement

New technologies such as AI are not explicitly mentioned in the European Vocational Training Agreement[10] for the years 2015 - 2020. However, due to this period coming to an end, a committee has already been dealing with the question of how future vocational education and training should look like in a post-2020 era (European Commission, 2018a). In the position paper, the committee puts together some recommendations for the coming years, which also address the topic of AI. In order to cope with the structural change caused by new technologies such as AI, it is necessary to integrate vocational training policy into future-oriented economic, competition and innovation policy, since vocational training plays a key role in qualifying people for the labour market, according to the position paper (European Commission, 2018a, p.4).

[10] The agreements for European cooperation in the field of vocational education and training have been extended by "The Bruges Communiqué on enhanced European Cooperation in Vocational Education and Training for the period 2011-2020" and "RIGA CONCLUSIONS 2015". https://www.eqavet.eu/Eqavet2017/media/Documents/brugescom_en.pdf
https://www.izm.gov.lv/images/RigaConclusions_2015.pdf

Digital Education: Learning, Teaching and Assessment

The working group on digital Education: Learning, Teaching and Assessment met in Ljubljana in 2019 to discuss AI and its implications for education[11]. The main conclusion of the meeting was that AI and education are not yet high on the list of priorities in all countries. This is partly due to the fact that it is not clear how AI and education should be dealt with in concrete terms. A framework for Education for AI and AI for Education is considered helpful and necessary by the participating countries of the working group. The working group distinguishes between two central points when it comes to AI and education: 'Education for AI' and 'AI for education'. Education for AI is about equipping students and teachers with knowledge about AI. AI for Education focuses on AI applications that can be used to improve education and thus learning and teaching. Particular potential is seen in the areas of personalisation of learning, automation of domain-specific knowledge, tackling learning difficulties and automation of assessments. Whether AI for education or the other way round, teachers are in the focus of attention, because they have to be trained to be able to use AI in educational institutions. There is a demand for more concrete consideration of which topics should be trained in schools and educational institutions in the context of AI. In general education, these could be topics such as computing, coding and computational thinking.

In summary, although the topic of AI is mentioned in the strategy papers on vocational training, there are rarely concrete proposals for implementation. The working group on Digital Education: Learning, Teaching and Assessment came to a similar conclusion at a meeting in summer 2019. However, it is necessary to be more specific because when it comes to the use of AI in educational programmes, this can be done in a variety of ways. In the following chapters of this report, it becomes clear that AI could, for example, be included as a topic in the curriculum. In this case, one would become familiar with AI technology in a theoretical and practical way. It is also possible to use AI as a pedagogical tool to achieve better learning outcomes, e.g. through intelligent tutoring systems. European papers rarely really differentiate the use of AI in education. It is only recommended that AI should be integrated into education, but without mentioning in what way. A positive example of a differentiated analysis of the use of AI in education is the UNESCO report about Artificial Intelligence (Pedró, F. et al., 2019). The structure of the report already shows that the different dimensions were taken up. The first topic is how AI can improve learning success. On the one hand, it is considered how AI can be used pedagogically, for example through personalised learning offers. On the other hand, it is considered that AI can be used for the management of educational provision and systems. This provides a systematic approach to the question of improved learning success. The report provides examples of implementation (Pedró, F. et al., 2019, p.14):

Example 1: “In Brazil, the federal government created Mec Flix as a state educational platform. It is a video content platform designed to prepare students for the national higher education examination (ENEM). It has some emergent elements of AI: students have to log in and they can create personalised playlists of video-lessons and get recommendations based on their preferences.”

Example 2: “M-Shule was launched in Kenya in 2016 as a mobile platform with lessons based on national curriculum standards delivered via SMS that adapt to each student’s skills and abilities using AI technology. As students use the platform, M-Shule tracks and analyses learner performance to empower parents and schools with insights and recommendations.”

[11] https://ec.europa.eu/social/vocational-skills-week/sites/evsw/files/ai_key_messages_final_and_es.pdf

In the following chapters of the UNESCO report, many examples are given to illustrate different possible applications of AI. The examples presented above show that there are already concrete ideas and implementation for AI in education.

Individual countries must now consider how to deal with AI in their education systems. A research group from the Australian Government Department of Education concluded that AI in Australian schools is still in its early stages. AI will only enter the education sector if teachers understand the enormous economic and social changes that have been and will continue to be brought about by the use of new technologies. Therefore, trainers need basic knowledge about AI and the handling of AI (Southgate et al., 2019, p.10). The Australian study also identified the need for independent expert advice for schools and policy makers. Furthermore, they have found that it may take a long time to come up with concrete ideas on how AI can be incorporated into existing curricula.

Introduction and usage of the AI in the VET processes and systems has made different progress in this project partner countries. A first overview is given below on the basis of the interviews conducted or additional information in the project countries.

On the one hand, the German AI strategy states that the understanding of AI for vocational education and training needs to be promoted among young people in a new kind of way. Concrete projects in this context are the establishment of learning factories at vocational schools (BMBF, 2018, p.30) in circa 11 industrial occupations. These could help to improve technical skills by topics related to AI. These Learning Factories provide a professional learning environment to allow project-based and work process-oriented learning. Within the Erasmus+ project three learning factories in Lower Saxony were analyzed and studied to make clear how VET teachers and trainers can act best by challenging work and learning tasks for their students such as apprentices. On the other hand, the German AI strategy points out the value of AI-based applications for learning and teaching (BMBF, 2018, p.31). According to a survey on the topic of "Artificial Intelligence and Learning", technology learning experts expect that "Learning Analytics" and "Adaptive Learning" will gain more importance in Germany in the future (mmb, 2020, p.12). How speech-supported assistants (a VET related kind of Alexa) bring an additive value to learning has to be found out by concrete assessment project. The programming of robots already has practical relevance for mechatronic occupations because of an increased interest of the industry into automation. According to the first investigations within the ERASMUS+ project, however, AI-based learning tools are not yet undertaken on a large scale in vocational schools and company trainings.
Introduction and usage of the AI in the VET in UK is more focused on the implementation and application of the different AI solutions that foster acquisition of knowledge, basic and key skills. A lot of attention is paid to the enhancing learning capacities of students by applying AI solutions. Another key target of the implementation of the AI is the improvement of the teaching and learning processes in the vocational colleges and development of teachers' didactic competencies.
In the school-based VET systems in Lithuania, Italy and Greece the integration of AI in VET processes is very fragmented and makes initial steps. Here different initiatives of VET teachers, trainers and students play very important role in fostering usage and implementation of the AI. In Lithuania some knowledge and skills related to the AI are integrated in the training modules, but there are no specific modules dedicated to the AI application. The usage of AI applications in the training process also has not yet come to the training practice. Usually AI is not provided as separate competence or discipline in the curriculum, but it can make integral part of the VET curriculum in the fields related to engineering, machinery production and metalworking. For

example, some elements of AI application knowledge and skills can be found in the modular curricula of mechatronics, especially in the modules related to programming of controllers, running and controlling of the fully automated production systems. There are established some relevant institutional preconditions for the future development in this field, such as sectoral practical training centres, equipped with the up-to date equipment and technologies of work typical for different sectors of economy. There are also some examples of successful cooperation between innovative VET centres and enterprises, which involve development of AI related skills and competencies in the apprenticeship programmes.
In Italy the main interventions in the application of the AI in VET are focused on the modification of some curricula and didactic modules, especially in the fourth years. Similar interventions have been made in the post-diploma VET courses. The VET teachers in general feel the need to be involved in training courses on the AI topic. Some general preconditions are not favorable for the development in this field, such as low level of didactic innovations in the field of VET and decreasing attention to the there-year VET curricula involving subjects potentially related to the application of AI.
In Greece, the anaemic growth and the low digital adoption rates set as an imperative the need to transform. AI is a key transformation accelerator and a "game-changer" that we believe deserves the country's attention. All stakeholders interviewed do recognize the strategic importance of AI and acknowledge it as a critical centerpiece for moving forward. It is seen as an "agent for change", yet, they appear to be reluctant to actively invest in it. Several challenges are claimed to slow down their AI efforts: limited skills for implementing and using AI, IT infrastructure and low data quality being identified as the three top of-mind ones. To fill the new and reconfigured roles, organizations will need to make radical changes to their training strategies. "New Skilling" programs must be rapid, flexible, tailored and large-scale to maximize the value humans and machines can create together. "New-Skill" shall also foster a culture of lifelong learning, much of it enabled by technology.

3. UNDERSTANDING ARTIFICIAL INTELLIGENCE AND ITS TRANSFORMATIVE POWER

This chapter discusses the understanding of Artificial Intelligence and what is and what it is not. This understanding should serve as a basis for the present report.

3.1 Understanding of the term Artificial Intelligence

Artificial intelligence is not a completely new topic, instead it has been occupying computer science since the early 1950s. The term was first coined during the Dartmouth Workshop on artificial intelligence in 1956. The topic has been particularly high on the agenda in recent years, as recent technological advances push the limits of what machines can do (McKinsey, 2018). This is particularly due to the expansion of the Internet, the availability of data and more powerful computing and algorithms. A uniform definition of what artificial intelligence is, however, does not yet exist, since AI combines a multitude of technologies. Artificial intelligence is therefore to be understood as a kind of 'umbrella term' (Southgate et al. 2019, 17). On the other hand, the challenge of a term definition lies in the fact that it cannot be conclusively determined what is considered "intelligent". Nevertheless, there are some attempts at definition, for example the following one on the German online platform for AI[12]:

"The term AI stands for systems that exhibit behavior commonly assumed to be human intelligence. The goal of modern AI systems (learning systems) is to enable machines, robots and

[12] https://www.plattform-lernende-systeme.de/glossar.html

software systems to independently process and solve abstractly described tasks and problems without each step being programmed by humans. At the same time, the systems should also be able to adapt to changing conditions and their environment".

In the European Artificial Intelligence Strategy the following somewhat condensed definition is given (European Commission, 2018b):

„Artificial intelligence (AI) refers to systems that display intelligent behaviour by analysing their environment and taking actions – to achieve specific goals. AI-base systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications). (…)."

The EU definition is quite helpful in that it shows that AI is used in different forms and that most people deal with AI-based applications on a daily basis, e.g. to translate languages, when using navigation systems or when using Alexa, Siri etc.. Depending on the respective scientific discipline, there are different ways to categorize the various forms of AI application. In computer and mathematical science, the focus is on various applications or fields of activity of artificial intelligence. Another classification of AI, which is also more widely used by the public, provides for the following subdivision (Southgate et al., 2019):

Artificial narrow intelligence (ANI): refers to AI systems that focus on solving concrete application problems, which have been developed and trained specifically for them. In performing the tasks, the system may outperform human performance, but they do not have the general scope of intelligent behaviour that humans have. All systems that exist today fall into this category of weak AI.

Artificial general intelligence (AGI): Refers to AI systems that have the same intelligence as humans. They would act on their own initiative. These systems exist only in science fiction movies.

This overview is intended to make it clear that the term artificial intelligence is not unambiguously defined, since on the one hand the word intelligent cannot be unambiguously defined and the term AI combines many technologies.

In the context of this report we understand AI as follows:

Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems, which includes expert systems, natural language processing, speech recognition, machine vision and other operations programmed on the basis of machine learning, reasoning and self-correction.

These many facets of AI mean that the transformative power of AI is very high and will affect many areas of life. Therefore, there is a debate over the social and organisational implications of AI. Schwab and Nadelia (2018) claim that there is a lack of information on how machine learning algorithms function and often the algorithms cannot be understood even by expert technicians. Susskind and Susskind (2015) criticize similar attitudes, which ascribes the weakness of the AI to replace the humans in the different activities by its inability to replicate the human brain together with consciousness (the so called "AI fallacy"). Susskind (2020) claims that AI has a high potential for substitution of humans leading to a world without paid work in the longer term perspective.

To broaden the understanding of the AI term, we want to clear up some myths that exist around the term and the topic, in the following subchapter.

3.2 The myths of AI: What AI is and what it is not?

Why are statements about the present and future potential of AI often contradictory and unclear? Some statements lack scientific evidence or proof of practical use in concrete applications in industry and/or research. This is why initiatives towards the general public are particularly valuable (see, for example, Finland's open public campaign, p. 14), as they provide learning for many people to understand what we can expect from AI technologies including its use, the risks and the challenges. It also allows us to explore our role as citizens, job seekers and teachers in the development process. In the following section, we summarise interviews with experts who see the use of AI as positive but who want to inform the general public about AI-related design options and to promote a discussion with the population about the consequences of this technology[13].

Why will artificial intelligence still have to overcome major challenges in the future? According to Peter Schicht, an AI expert on autonomous driving at Volkswagen AG, the robustness, hardware security and understandability of AI applications are among the greatest challenges. The first time these goals are completely and continuously achieved, we can speak of a functioning AI. The goal is achieved when a reliable, robust and energy-efficient AI has been created. At present, AI is not really intelligent, but is very good at processing large amounts of data.

Does AI recognize things and connections? It cannot. AI can only detect correlations, not causalities. Real knowledge, like the ability to understand things from inside - is beyond the reach of artificial intelligence. False correlations, as have been experienced in autonomous driving, are therefore not faults of AI, but intrinsic to AI and show its clear limitations. In addition, AI is always related to the past, AI can only recognize what is already there on the basis of existing data. It is blind to really new things (e.g. "Newton's apple"). AI cannot and should not generate hypotheses.

Is AI hardware dependent on a green energy supply? AI needs a relatively large amount of power, because powerful and efficient computers require a relatively large amount of electricity. If every German household were to operate a small computer with AI, this would result in a one-fifth increase in electricity consumption. Energy efficiency and green power generation is necessary to operate AI systems and equipment sustainably, which means that AI algorithms and hardware have to be well designed.

AI solutions and instruments have clear limitations and are still yet not as robust and secure as promised with machine learning or deep learning. Implementation and use of AI involves a wide range of risks of human privacy, and the security and safety of personal data. (Zuboff, 2019, Marcus & Davis, 2019).

[13] https://www.plattform-lernende-systeme.de/startseite.html

4. ARTIFICIAL INTELLIGENCE AND EMPLOYMENT, THE LABOUR MARKET AND SOCIETY

Despite alarming forecasts of the occupations and jobs that could disappear as a result of the introduction of AI and automation, and counter claims that the new technologies will lead to the creation of jobs, the reality may be more nuanced. It is likely that AI will have greater impact in changing the tasks within individual occupations and jobs, with some tasks becoming automated while new tasks emerge. This is already being seen in occupations within the legal and retail sectors and in engineering. Digital technologies are also leading to the emergence of new companies acting as intermediaries between producers and consumers of goods and services (Stanev, 2020), leading to what is popularly known as the 'gig economy'. Stanev says: "Globalisation of the economy has drastically increased competition and caused the number of atypical labour forms to grow. The expansion of these new forms of employment entails the creation of new kinds of contracts, and in many cases the circumvention of employment law, as workers are turned into 'entrepreneurs'."
Based on the literature research, we will present and discuss possible effects of AI on Employment, the labour market and society.

4.1 Will machines complement or replace humans in the workplace?

Literature on the implications of AI for work and employment distinguish between the replacement of human workers and the use of AI to assist human performance.

Schwab and Nadelia (2018) claim that there is a lack of information on how machine learning algorithms are functioning and how they reflect existing social deviations. AI will transform work tasks, but will not make human activity completely obsolete. With a few exceptions, only parts of jobs can be completely automated.

Susskind and Susskind (2015) criticize this idea based on the failure AI to replace the humans due to its inability to replicate human brains and consciousness (AI fallacy). They claim that "increasingly capable machines (whether using AI, Big Data techniques or techniques not yet invented) will arrive at conclusions and offer guidance that in human beings we would regard as creative or innovative." In discussing the potential of technologies and AI to replace human activities (including education), they focus on three main questions:

1) What is the new quantity of tasks that have to be carried out?
2) What is the nature of these tasks?
3) Who has the advantage in carrying out these tasks?

Tuomi (2018) differentiates the implications of AI for work by distinguishing between the level of operations the level of actions and the level of activities. At the level of operations, the AI augments and complements them by increasing the efficiency and effectiveness of current ways of doing things, at the level of actions, AI replaces, substitutes, and automates actions that were previously done by humans, whereas at the level of activity, AI transforms the system of motives, making current activities and specializations redundant and obsolete.

The McKinsey report (2018) indicates that by 2030 there can be expected to be significant transitions accompanying automation and AI adoption – changing the mix of occupations, skill and educational requirements. Around 3 percent of the global workforce will need to change occupations by 2030, though scenarios range from 0 to 14 percent. Occupations made up of physical activities in highly structured environments or in data processing or collection will see declines. Growing occupations will include those with difficult to automate activities such as managers, and those in unpredictable physical environments such as plumbers. Occupations that will see increasing demand for work include teachers, nursing aides, and technical and other professionals.

Research literature indicates that current ICT systems show increasing ability in language, vision, movement and even reasoning. "IT capabilities that have been demonstrated in research settings could provide the reasoning, vision and movement skills required in most current jobs, only for language skill does the analysis suggest that a substantial number of current jobs have skill requirements that clearly outstrip the IT capabilities demonstrated in research literature. (…) Occupations representing 82 percent of current employment will be potentially vulnerable to displacement by IT over the next few decades" (Elliott, 2017, p. 604-624). Demand for physical and manual skills and for basic data input and processing will decline, while growth will be strong in demand for interpersonal skills, creativity, and empathy. Advanced IT skills and programming alongside complex information processing skills will also see a surge in demand. In highly automated plants, the software is the interface for all technical solutions. In this case, all tasks, especially service, maintenance and repair, have been structured around software tasks. Highly qualified technicians are necessary to maintain this software, while programming is left to the engineers (Spöttl et al, 2016).

The shift of work demanding high-skills to lower-skilled workers is enhanced by digital Taylorism. In the McKinsey survey, 40 percent of companies describing themselves as extensive adopters of automation and AI expect to shift tasks currently performed by high-skilled to lower-skilled workers. This is also related to the emergence of new middle-skilled, "new-collar" jobs. For example, registered nurses and physician assistants now do some of the tasks that primary care physicians once carried out, such as administering vaccinations and examining patients with routine illnesses.

There is also seen to be a "liberating effect" of AI in different work processes, for example, AI driven educational systems complement teachers, so teachers with the help of AI can focus on the teaching and mentoring that cannot be automated through AI. Kreinsen and Ittermann (2017) claim that automation and the increasing flexibility of production (where AI contributes) help to optimize value chains and to develop business models based on the highly intensive involvement of customers. It can lead to an improvement of the quality of work and better opportunities for human-oriented shaping of work organisation, as well as a better fit between work and private life.

4.2 The role of AI in the Industry 4.0 and it's socio-economic implications

One impact of AI on the working and professional world is the establishment of smart factories. AI facilitates redesigning a production environment into a "smart factory", exceling in high flexibility and versatility with new organisational structures and processes. One effect is a considerable reduction in the processing time (Brynjolfsson, E., & McAfee, A., 2014). The integration of intelligent machines and software into the workplace, workflows and workspaces will continue to evolve to enable humans and machines to work together. For example, cashiers become checkout assistance helpers, who can help answer questions or troubleshoot the machines. Warehouse design may change significantly as some sections are designed to accommodate robots and others to facilitate safe human-machine interaction.

Research undertaken in 2016 into the implications of Industry 4.0 for the mechanical engineering and electronic sectors in the German State of Bavaria revealed that the mastering of networked systems with decentralized intelligence, handling data and analysis as well as the ability to safeguard flawless operation of plants are among the most important requirements for work on production sites, together with the management and mastering of traditional skills in the workplace (Spöttl et al., 2016). Workflow design will have to be adapted to the closer work of humans with machines by creating a safe and productive environment, which would also make the work more collaborative and increase the agility of companies through non-hierarchical management structures[14].

According to Becker and Spoettl (2016), Artificial Intelligence creates completely new spaces for interaction between machines (e.g. multi-agent systems), as well as between humans and machines. Pfeiffer (2017) also notes a significant increase in active labour in the field of complex maintenance processes in heavily digitalized production environments. The increasing complexity of work tends to increase the significance of non-routine activities in highly automated production processes and requires holistic, explorative and dialogical approaches, intuition and empathy (Pfeiffer, 2017).

It is also expected that the next wave of automation and AI in manufacturing will disrupt production functions in factories through better analytics and increased human-machine collaboration. It will also have an impact on product development and on marketing and sales. The share of predictable manual jobs, such as driving, packing, and shelf stocking, will substantially decline (McKinsey, 2018). Jobs that remain will tend to be concentrated in customer service, management, and technology deployment and maintenance.

Joseph Stiglitz (2019) draws attention to the threat of secular long-term economic stagnation due to the lack of demand caused by the replacement of humans with robots and AI in the workplace, as well as risks of lowering of wages and deterioration of employment quality (precarization). Stiglitz doubts whether education can really meet the challenge of AI outperforming people in the increasing share of jobs, rather than offering short-term adjustment solutions. Of course, the complementary power of AI and automation through the innovations will increase the performance of humans and could create some new jobs and skill needs, but these trends will not outweigh the hollowing-out or polarization effect of AI on jobs and skills. It creates the necessity of political intervention and makes the jobs problem a political problem. One possible solution is a policy helping to restructure the economy and labour market by orienting to the development of the service sector and other sectors, where the advancement of task encroachment by AI and automation is slower due to economic, cultural and other reasons. It would also require re-orienting education including VET to the skills needed in these sectors.

How do the stakeholders and policy makers respond to these challenges posed by the new skills needed related to digitalization and introduction of AI? On the national and sectoral levels there is a trend towards “clustering”, when the interested stakeholders (innovative enterprises, employers’ organizations, research institutes, universities and VET learning providers, etc.) establish and develop different “clustered” units targeted to improve strategic cooperation and to create a space for experimentation, testing, competence development and targeted sharing of know-how. The ideas and plans of such clusters and competence centres (Smart Factories) are being suggested and implemented by the sectoral bodies and organizations, social partners

[14] Case studies on Smart Factory Models in VET schools show how vocational schools are reacting to this industry trend. (See Appendix for more information on the case studies).

and governments. National strategies related to the advent of Industry 4.0 are being introduced in many countries including Germany, Italy, France, Netherlands and Estonia.

In Italy, the National Plan Industry 4.0 foresees establishment of the national technological cluster "Fabbrica Intelligente" (Smart Factory), which amongst other priority fields of activities, foresees to develop big data solutions and apply AI for decision making processes in industry, development of advanced robotics and automation and the implementation of the Internet of Things through the use of intelligent sensors (Confindustria, 2019). This plan foresees different measures of competence development implemented by the cluster, such as tax credits for the training of employees related to Industry 4.0, and the funding of competence centres dominated by the universities and specialized in the field of digitalization and Industry 4.0. Other measures include the provision of counselling, experimental technological solutions, the establishment of the Digital Innovation Hub for supporting enterprises in the opportunities provided by the 4.0 and supporting their investments in this field (Confindustria, 2019).

In Germany smart factory concepts have in common the integration of different technologies and implementation possibilities in a new kind of learning infrastructure with profound implications for learning processes for VET apprentices. The Smart Factories are mostly located at vocational schools or industrial training centres and work in close cooperation with local industry. Young people including apprentices and technicians are to be prepared for the future world of work and the changes due to new industry 4.0 developments. Not every small and medium-sized industrial enterprise has the opportunity to provide such new qualifications without external support. Thus, helping to ensure that, regardless of the size of the company providing training, all trainees or apprentices can obtain employment at the end of their training commensurate with qualification and occupational profile is important (DIHK, 2018).

4.3. Trends and scenarios of the future development of work

Kreinsen and Ittermann (2017) distinguish four possible scenarios for the future development of work in the context of digitalization.

The scenario of the upgrading of work and qualifications in all occupational fields can occur through the spread of intellectual skills and theoretical understanding of the developing and new work processes together with the growth of the complexity of work. Gradual upgrading of technologies and work organization including implementation of AI permits smooth and gradual upgrading of skills and qualifications, through involving decentralization and the reintegration of the functions of planning, execution and control of work. This scenario also forecasts the development of the lean work organisation based on networked and project work. AI in such a scenario becomes a factor of technological change, which enables and empowers improved and more productive (effective) execution of work.

Another scenario presents the *increasing automation* of work, leading to a high rate of substitution of routine work by delegating execution of these functions to AI and cyber-physical systems. This scenario echoes with the vision of the widening task encroachment by AI proposed by Susskind (2020). The main idea is that AI and related technological solutions have unlimited (or at least with unknown limitations) capacities for work task encroachment not only in routine work, but also in so called "high-skilled" work processes.

Similarly, the third scenario is related *to work polarization by erosion of the middle level occupations* created by the task encroachment in the related work processes by AI and other technological solutions. This trend is already noticed in the labour market of many countries, for example, in Italy, where there is noticeable increase of skills polarization of employees and hollowing-out of middle skill jobs in recent years (Confindustria, 2019; Alleva, 2017). These jobs are more susceptible for task encroachment because of containing some share of routine tasks from the one side, and because of higher economic interest to replace better paid workers with AI and automation.

The *scenario of work flexibilization and delimitation*, from the point of view of time, organization and space, involves wide and long-term planning and management of value creating chains and processes enabled with access to a wide range of data and information, processing, networking and communication. Here AI becomes an important factor leading to the decentralisation of work organisation and the spread of temporary and project-based forms of work organisation, digitalized management of work processes and higher temporal flexibility of work organisation. One of the important challenges which occurs in all these scenarios is related to the emergence of a requirement for workers to be ready to assume responsibility for the use and control of autonomous technological systems driven by the AI.

Lee and Pfeiffer (2017) raise the problems of technological determinism of the scenarios of digitalization for work: 1) the structural changes of work process and employment cannot be linearly derived only from the change of technologies; 2) ignoring the social context of the Industry 4.0 change and innovations, where VET and qualifications can play a significant role. They derive several alternative future scenarios.

In the scenario of the *growing gap*, as a smart system capable of reacting to the change of environment, AI plays the central role. AI increases the performativity, quality and productivity of work, thus reducing the quantitative demand for new workers and specialists, but at the same time raising the requirements and needs for skills and competencies in such fields as maintenance, monitoring and repair. These competence needs concern technical and physical characteristics of the equipment, digital working and other fields. There is expected to be an increase in demand for knowledge and skills needed to identify specific complex and difficult to detect faults in AI driven systems driven by the, which would also require in-depth and systemic understanding of technologies and work process knowledge related to the networked production systems. In general, the demand for vocational skills and competence may decrease, which would require the revision and shortening of the volume of VET curricula and duration of training. Increasing demand for competencies and qualifications in the planning, monitoring and maintenance of digitally networked production systems cannot be satisfied with the current VET curricula. It requires revising both the structure and contents of VET curriculum with preferences towards modularized and lean models of VET. Modularized curriculum can react to the technological change of Industry 4.0 by just in time and cost-effective implementation of needed competencies and units of qualification.

The General Upgrade scenario describes employees work in the whole process chain becoming more transparent with higher transparency of data (the use of AI also significantly contributes to this), but at the same time increasingly complex and requiring higher responsibility. It requires wide work process knowledge, customer orientation, project work skills and communication skills. Although this scenario foresees a general improvement in productivity and the quality of work in most sectors due to the application of digital innovations and automation technologies, in some sectors enterprises will have their own specific developments. For example, automation and digitalization of the "craft" work processes in the SMEs can lead to more supplementary application of the digital technologies, including AI, in the production process, rather than to the substitution of human work by AI (Checcucci, 2019). The domination of SMEs in a sector can create specific conditions for the implementation of digital innovations and technological solutions, requiring ways to make digital technologies, including AI, more accessible for SMEs in terms of cost, demand for investment and skill requirements (Alleva, 2017).

The Central Link scenario focuses on networking between physical and digital systems – Cyber-physical systems (CPS) which integrate production processes in holistic digitized business structures. AI plays a crucial role in the control of such systems. Intensifying the use of CPS would require experience and know-how in the interface between the cyberspace and physical world. This would also increase the demand for skilled workers and technicians in the field of mechatronics with competencies to translate the IT solutions and systems in the language of the production process. This trend would also foster the integration of different occupational fields and thus increase the demand for hybrid qualifications. This scenario also foresees new requirements for interface management in cross-process and domain-wide coordination between: 1) the process of production and planning, control, installation of equipment, logistics and procurement, and 2) professional-technical and information fields. Such specific competencies related to interface management in the digitalized value creation processes can be integrated in the existing VET curricula and developed by using work-based learning and training with strong focus on the moderation and interaction of interfaces.

Susskind (2020) indicates that development of AI and automation and their work technologies change the basic qualities of work, such as remuneration, employment safety, working time and the contents of working tasks. Computational rationality in Narrow Artificial Intelligence, which can handle very particular assignments, contributes to the development of substitution and complementarity. Task encroachment by AI reduces the demand for manual cognitive and affective capabilities in the production process, because these abilities are needed only when the work tasks are performed by humans. Structural technological unemployment and precarity of work tend to be driven by the skill mismatch, worker's identity mismatch (when a worker cannot accept new professional identity offered by the precarious work or job position) and place mismatch, occurring due to the lack of geographical mobility of workers and "mobility" of workplaces. The last mismatch is particularly pronounced and presents an important challenge for labour market policy in some countries, like in Italy, where the limited geographical mobility of workforce is combined with the ageing and insufficient provision of the middle level vocational skills needed for implementation and handling of new digital solutions, including AI (Checcucci, 2019).

Task encroachment tends to increase the substitution power of AI and reduces the need for its complementary power (Susskind, 2020). AI also enhances the uneven distribution of human capital in society by strengthening the market power of large hitech companies and professionals involved in the design and application of AI solutions from and resulting in the human capital of the remaining workforce becoming less valuable than traditional capital because of the substitution effect (Susskind, 2020). Here one of the key challenges for VET is to identify the work tasks which require complementarity of human work and AI and to provide competencies necessary for handling these tasks. The increasing rate of automation and task encroachment narrows the range of accessible jobs and applicable skills and at the same time decreases the possibilities to obtain new skills needed for the remaining jobs because of fast changing skills needs and intensive competition between the big tech companies, making this know-how and skills an important part of competitive advantage.

One of the significant trends of the development of work processes and technologies under the 4th Industrial Revolution and AI is the increasing volume of autonomous self-control of the production processes executed by the production technologies, like automatization of the production and transport chains. Such a trend towards self-management of production processes means decentralized control of the autonomous objects of logistics and production in hierarchical organizational structures (Gorldt et al, 2017). Such trends reduce the importance and demand of skills and competencies in the work organization and execution. Despite that, the human work force plays an important role in the introduction, launching, maintenance and functioning of technological solutions and innovation for Industry 4.0 (Hirsch-Kreinsen & Ittermann, 2017). While production automation follows the logic of technological rationalization and leads to the reduction of the dependence of work execution on the human workforce (and on related skills and competencies), the informatization of work indicates increasing access to and consumption of information and data in the work processes, thus opening new fields of activity for humans and new roles for their competencies (Hirsch-Kreinsen & Ittermann, 2017).

The scenario of an automated factory stresses the loss of routine and low-skilled jobs. Substitution of human work by automation concerns not only low-skilled, but also skilled and high-skilled work, in such fields as planning and management, product development and administration, where AI based technological solutions, such as cyber-physical systems (CPS) can be applied to execute these functions. Therefore, this scenario expects a decrease in demand for competencies and qualifications in industry and other sectors of economy. The scenario of work polarization examines the macro-structural development of the labour market, claiming, that the development of Industry 4.0, especially the interplay between work automatization, informatization and digital taylorism tend to reduce the importance and need for middle level skills (Spöttl et al, 2016; Hirsch-Kreinsen & Ittermann, 2017).

5. THE SKILLS AND COMPETENCES NEEDED IN THE AGE OF ARTIFICIAL INTELLIGENCE

Research literature identifies a range of implications of AI for skills needs (McKinsey, 2018):

- Demand for advanced technological skills such as programming will grow rapidly. There is also a lack of sufficient understanding of technologies to lead the organization through the adoption of automation and AI.
- Increasing demand for key skills and competencies: social, emotional, and higher cognitive skills, such as creativity, critical thinking, and complex information processing, basic digital skills.
- Demand for physical and manual skills will decline but it still will remain the single largest category of workforce skills in 2030 in many countries.
- There are expected declines in the need for basic cognitive skills, particularly the basic data input and processing skills used by data entry clerks and typists and in a range of back-office functions.

The Application and development of AI based technologies challenge the traditional boundaries of disciplines, knowledge and competence areas. For example, the application of sensors and the networking of cybernetic-physical systems (CPS) increases productivity but at the same time requires interdisciplinary individual and collective competencies that integrate knowledge and skills from the fields of machinery production, electronics and information and communication technologies (Gorldt et al, 2017). Such erosion of the disciplinary and occupational boundaries of competencies is also enhanced by changing industrial production, including virtualisation, individualisation and flexible production processes as well as the integration of digital, virtual and real dimensions of production processes and the increasing transparency of the production processes (Gorldt et al, 2017).

The decentralized intelligence linked to Industry 4.0 leads to an increased availability of data that is highly process relevant to skilled workers. Maintenance still requires traditional manual skills as well as the mastering of SPS, robotics, pneumatics, hydraulics, drive technology etc. These, however, are no longer sufficient. Simply amending occupational profiles will not be enough. The authors of the Bayme VBM study (Spöttl et al, 2016) call instead for a massive amendment of process orientation in occupational profiles. Maintenance processes will be based on informatization. Occupational and advanced training profiles must focus on these central developments. The Baymee study (Spöttl et al, 2016) claims that if future development of production technologies will focus on assistance/support systems and if skilled workers at the shop-floor level are given the chance for co-shaping, Industry 4.0 can be used as an "assistance system", where skilled workers and technological applications would thus control and influence one another, whilst decision making power remains in human hands. At the same time, skilled workers have to deal with increasing demands in terms of interpreting system data. Analytic capability and thinking in networks are prerequisites in order to deal with abstract information and to gain a swift overview of the production process.

AI cannot replace the skilled workers in automated control of plant conditions, where skilled workers undertake troubleshooting, assessing damage and analysing causes. Work processes like maintenance also need skilled workers who act as decision makers, controllers, maintenance staff, co-shapers and experts.

5.1. The bifurcation hypothesis

Some researchers have postulated a bifurcation in employment and skill patterns, with increasing demand for high skilled workers, a decline in demand for low skilled workers and a rapid decline in opportunities for middle skilled workers: the so called "hollowing out" of the labour market. Some political commentators have even attributed this trend to the rise in populism in Europe (Bender, 2020).

However, new research has challenged this hypothesis. In an article in Social Europe by German Bender entitled 'The myth of job polarisation may fuel populism' (2020), German Bender explains "It has become conventional wisdom since the turn of the century that labour markets are rapidly becoming polarised in many western countries. The share of medium-skilled jobs is said to be shrinking, while low- and high-skilled jobs are growing in proportion." But as German points out: "In a research report published last May by the Stockholm-based think tank Arena Idé, Michael Tåhlin, professor of sociology at the Swedish Institute for Social Research, found no job polarisation: rather, a continuous upgrading of the labour market."(Thalin, M., 2019).

Bender goes on to explain: "The main reason is that the research, as is to be expected from studies rooted in economics, has used wages as a proxy for skills: low-paying jobs are taken to be low-skilled jobs and so on. But there are direct ways of measuring skill demands in jobs, and Arena Idé's report is based on a measure commonly used in educational requirements as classified by the International Labour Organization's ISCO (International Standard Classification of Occupations) scheme. Using this methodology to analyse the change in skill composition yields strikingly different results for the middle of the skill distribution.". The study found that while jobs with relatively low skill demands but relatively high wages—such as factory and warehouse workers, postal staff and truck drivers—have diminished, others with the same or slightly higher skill demands but lower wages—nursing assistants, personal-care workers, cooks and kindergarten teachers—have increased. The reason is that the former jobs are male dominated whilst the jobs which have grown have a majority of female workers. Research in most countries has shown that women (and jobs in which women are the majority) are lower paid than jobs for men, regardless of skills levels. "Put simply", says Bender: "wages are a problematic way to measure skills, since they clearly reflect the discrimination toward women prevalent in most, if not all, labour markets across the world."

A further review of two British studies from 2012 and 2013 (Holmes, Craig and Ken Mayhew (2012) and McIntosh, Steve (2013)), showed a change in the composition, but not the volume, of intermediate-level jobs. "Perhaps the most important conclusion", Bender says "was that 'the evidence shows that intermediate-level jobs will remain, though they are changing in nature'.". The implications of this interpretation of the data are profound. If lower and medium skilled jobs are declining there is little incentive to invest in vocational education and training for those occupations. Furthermore, young people may be put off entering such careers and similarly careers advisers may further mislead school leavers.

There has been a trend in some European countries, e.g. Germany, UK towards higher level apprenticeships or dual oriented studies at level 5, rather than providing training with the skills needed to enter such medium skilled jobs. But even a focus on skills, rather than wages, may also be misleading. It is interesting that jobs such as social care and teaching appear more resistant to automation and job replacement from technologies such as Artificial Intelligence. But those who are arguing that we should be teaching so called soft skills such as team building, empathy and communication are talking about the very skills increasingly demanded in the female dominated low and middle skilled occupations. It may be that we need not only to relook at how we move away from wages as a proxy for skills, but also look at how we measure skills.

German references research by Daniel Oesch and Giorgio Piccitto (2019), who studied occupational change in Germany, Spain, Sweden and the UK from 1992 to 2015, characterising good and bad jobs according to four alternative indicators: earnings, education, prestige and job satisfaction. They concluded that occupations with high job quality showed by far the strongest job growth, whereas occupations with low job quality showed weak growth regardless of indicator used.

A further issue is the uneven adoption of AI and automation. While in some industries, sectors and economies there is widespread adoption, in others the speed of development and uptake is much slower. To some extent this is due to regulation and the interests of different social partners. It may also be influenced by the availability of capital for investment and by productivity. In those industries and countries with low wages, it may be simply cheaper to pay staff to undertake tasks rather than adopt new technologies. It has also been suggested that the chronic low productivity increases in countries like the UK (the reasons for which are the subject of a complex debate between economists) may inhibit the adoption of AI and automation.

5.2 Cognition in work processes and the intersections between cyberspace and physical world

There is also increasing demand for systemic understanding and cognition in work processes and technologies, for their planning and design (Spöttl et al, 2016). The widening of the contents of work processes requires holistic understanding of the work and technological processes and abilities to process the systemic data and information of these processes. Decentralisation leads to the saturation of industrial work processes with data. These trends, especially process orientation, networking and data analytics become new objects to be integrated in the vocational education and training processes and practices, especially in the VET curricula. Spöttl et al. (2016) outlined and described general occupational and professional fields that are influenced by Industry 4.0 and related new competence requirements: the design and simulation of equipment, the installation of networked equipment, the exploitation and maintenance of equipment by applying process data management in production systems, the monitoring of equipment by applying real-time data monitoring, analysis and assessment, and process management for safety safety through monitoring, diagnostics and repair of faults, production data management and optimisation of production processes.

While networking of production increases the volume and contents of the processed data and CPS and Big Data provide solutions to cope with these challenges, the meaningful interpretation and evaluation of data contents is reserved for humans (Pfeiffer, 2017). Employees with qualifications at all levels have to be prepared to deal with real time data from production processes and to react to the requirements of the process management and optimization. Skilled workers become more responsible executors, problem solvers and operators of production processes also taking responsibility for planning and project-based work.

AI based technological innovations in the field of networking of physical and virtual digital worlds, and the integration of mechanical-electronic production processes into unified digitalized business structures and digital networking through an Internet of Things and Services would require skilled people with different backgrounds and competencies to deal with these intersections between cyberspace and physical world (Pfeiffer, 2017). These functions will be executed by master craftsmen and technicians playing the role of mediators by linking mechatronic processes and plant engineering with information technology. It pushes towards greater integration of various professional fields in the hybrid occupational profiles, leading to enrichment of the existing training curricula with the ICT related knowledge (Pfeiffer, 2017).

5.3 The need for new learning opportunities

There are different views on what skills and competences will be needed to respond to the rapid developments in the use of Artificial Intelligence and automation in the workplace. In Germany, where the debate has been heavily focused on Industry 4.0, there is a call for higher level technical skills, for instance in programming or preventative maintenance. In the Anglo Saxon countries, the discourse suggests we should be teaching the skills and competences that computers (and AI) are not good at: communication skills, teamwork, decision making etc. (it is notable that these used to be commonly referred to as soft skills). What does seem likely is that there will be a need for more learning opportunities for those already in work (Lifelong Learning) and also retraining for those whose jobs do disappear as a result of the changing technologies. Chris Percy (Attwell, 2020a) suggests that AI may take over routine (and often boring) tasks freeing up staff to undertake more complex and interesting work. He points as an example to the work of interns and students in legal companies who have regularly has to undertake legal searches for due diligence for companies. Equally although tills in supermarkets have been largely automated, many retail workers are now employed in assisting customers. This work can now largely be undertaken by AI freeing the workers or students to progress their learning. In terms of retraining, the UK government has launched a programme targeted at those earning less than £34000, without a degree and working in occupations threatened by technology.

5.4. Pressure for occupational changes: mechatronics

While nearly all occupations will be affected by automation, only a few occupations (5%) can be fully automated. Two scenarios are discussed below: firstly, that machines substitute for human work or secondly, machinery and systems support or assist working people, for example "cognitive robots" which can cooperate with professionals from mechanics to nurses (BiBB, 2019, p.7). These scenarios have a serious impact on industrial electrical and machine occupations, including the Mechatronics occupation (McKinsey, 2018, p.3). The changes in the technical, social and organisational qualifications of technical specialists, such as skilled workers, technicians or engineers, are driven primarily by the digitisation of industrial production processes, including the use of AI-supported technologies, such as wireless, digitally networked data transmission, technical processing stations, and robotics, which has been advancing at an increasing rate for several years (Becker & Spoettl, 2018; Aunkofer & Benjamin, 2017; Heinemann & Deitmer, 2019). As a result, there are far-reaching changes in work and technical processes for employees in various professions. The changes are different in that repetitive work activities are sometimes completely automated. Other activities for some technical occupations, such as mechatronics technicians or industrial electrical and metalworking occupations, remain important, but change decisively in terms of the content of the activity such as in maintenance, conversion or reprogramming of automatically operating plant systems in industrial production (Pfeiffer et al., 2017; McKinsey, 2018).

Industrial work will need to be redesigned to ensure that workers are sufficiently skilled to work alongside complex machines. Therefore, a shift to advanced technical skills such as programming, quality control and better coordination is necessary. Social, emotional and higher cognitive abstract skills such as creativity and complex information processing will also increase (DIHK, 2018, p.20-30). A change in the curriculum towards an action orientation with high practical application is becoming increasingly important. An example of what a redesigned curriculum and a shift towards an action orientation can look like is illustrated below using the job description of a Mechatronics Technician in Germany.

5.5. The changing curriculum for mechatronics

Mechatronics is a relatively new technical occupation created through a legally regulated process in 1998. Mechatronics are employed in mechanical and plant engineering, automation technology, and in vehicle, aircraft and medical technologies. They build, maintain and repair complex mechatronics systems from mechanical, electrical and electronic assemblies and components.

Advanced industrial automation technologies, as in Industry 4.0 are based on complex mechanical and electronic systems which are now integrated through digitisation to allow self controlled automation. With the creation of the mechatronics occupation different mechanical, electronic and electrical occupations were brought together.

As with many other technical occupations in Germany, the mechatronics occupation is structured in a dual training format. This is provided mostly in industrial enterprises plus VET schools in a three-and-a-half-year course. The curriculum for mechatronics, has been amended twice in 2011 and 2018 in due to changes in industrial technology. In the latest version of the curriculum, particular attention is paid to the impact of computer integration and the increased use of AI, such as physical cyber systems and digital twins, leading to changes in the activities of maintenance staff at production plants. Under the new training regulation, trainees have the opportunity to obtain additional qualifications in the following subjects: *Digital networking, Programming, IT security and Additive manufacturing processes*. The time frame is eight weeks per additional qualification. What the trainees have to be able to do to acquire the additional qualifications is briefly described below (BIBB, 2018, p.38).

Digital networking:
The trainee should prove that he/she is able to

- analyse systems, processes and technical conditions, determine network requirements and develop different solutions,
- select, install and configure network components; integrate into existing infrastructures and document system data/conditions,
- test systems and propose optimizations; analyse errors, malfunctions and bottlenecks; evaluate data throughput and error rates and correct errors.

Programming:
The trainee shall demonstrate that he/she is able to

- analyse systems, processes and technical conditions, determine requirements for software modules,
- adapt software modules and integrate them in existing systems and document the software
- create test plans and test data, simulate environmental conditions, test the systems and correct errors.

IT security:
The trainee should prove that he/she is able to

- develop and coordinate technical and organisational IT security measures based on legal and operational regulations,
- implement IT security measures
- monitor the implemented IT security measures.

Additive production processes leading to Industry 4.0:
The trainee should demonstrate that he/she is able to

- create and apply 3D parametric datasets,
- set up and operate additive production facilities,
- check and ensure the quality of the products.

These additional qualifications provide the skills and knowledge for apprentices to perform highly skilled mechatronics, and qualify them to set up and operate of new industrial production facilities. They should be able to analyse, plan, prepare and implement operational services for new manufacturing systems. The occupational competence of the mechatronics relies on advanced knowledge and high-level practical skills.

6. VOCATIONAL EDUCATION AND TRAINING AND ARTIFICIAL INTELLIGENCE

In an interview with Graham Attwell, Paul McKee, Head of Further Education and Skills at the UK JISC (Attwell, 2020b) explained that JISC[15] are looking at what the Fourth Industrial Revolution means for education - including buildings, spaces, pedagogy, curriculum, student experience etc.

[15] The Joint Information Systems Committee is a UK non-profit organisation that promotes digital technologies in research and education. It provides digital services and solutions for universities and educational institutions.

This, says Paul McKee, can be translated into Education 4.0. Checkout type activities including registration and form filling will be undertaken by machines freeing up practitioners to teach. Adaptive technologies can automate formative assessment. This can include logic questions, ranking schemes and feedback. This potentially releases practitioners from teaching didactically to the middle ability and focusing on the top and bottom groups of learners.

AI tools will be important in VET because there is a lot of knowledge requirement in VET subjects for example hairdressing which not only requires knowledge about chemicals, but also knowledge about business, for instance running a salon.

Personalisation of learning is needed as VET students have a broad distribution in terms of their ability and prior knowledge. It is the same in engineering where what is needed is the application of knowledge. Paul McKee says much more support is needed for students and at present teachers in VET do not have enough time for that support.

6.1 The implications of AI for vocational education and training

The development and deployment of Artificial Intelligence has profound implications for Vocational education at a number of different levels including the organisation of VET, the curriculum for VET subjects and occupations, teaching and learning in VET and the role of VET teachers and trainers.

According to Tuomi (2018), vocational education has traditionally focused on the level of operations and acts by teaching vocational students, such as apprentices how to use tools and domain-specific knowledge to be able to deal competently with work situations. The recent calls for competence-based education, in turn, emphasize problem solving, critical thinking, decision-making and analytical skills, focusing on the cognitive level.

According to Susskind and Susskind (2015) AI helps to transform the education process by making it more flexible, individualized, and updated with the high volume of new information technology change requires. Intelligent tutoring systems permit to monitor and manage education and teaching process effectively by using individual learning performance data to tailor the contents and methods of teaching and alerting the teacher if an individual student requires particular attention. AI can also help to computerise the assessment of learning by applying a machine-grading approach, where algorithms computerise the marking process entirely.

According to Spöttl, the application and development of the AI in the work processes fosters an increase of the focus of VET curricula and modules to the technological work processes (Spöttl, 2016; Die berufsbildende Schule 2016). For example, the complexity of maintenance and the repair of automated technologies and solutions require wide and more basic initial training, either through the companies or in classroom and other institutional settings as additional learning environments for effective training, typical of the "dual" system of training (Spöttl et al, 2016).

AI based tutoring systems for students can be used in the well-defined subject areas, including the vocational education and training subjects (McKinsey, 2018). AI can also help teachers and trainers to construct stepping stones for understanding knowledge. AI can also help students to develop the skills and capabilities they will need in the AI augmented workplace. For example, AI can support humans to learn to be better at working together to solve problems through (McKinsey, 2018). AI applications in the vocational education and training concern different forms of learning and training. Work based training systems can, for example, make

use of AI driven recommender engines to help employees access the training they need when they need it. There is potential for AI to support people throughout their learning life course with 'just-in-time' learning individualised to their needs, accessible through multiple interfaces from voice activated technology, to virtual and simulated environments and physical computing embedded within our world (for example, application of virtual labs in the field of mechatronics and other similar work processes).
AI brings significant changes to the learning and teaching environment - the distributed, networked, virtual reality classroom, which permits intensive real time measuring of learning success in an AI-based educational process, in the same time posing the risks to be left behind for the students who are already falling behind, thus creating greater educational inequalities (Allen, 2018). Instead of focusing on specific work-related skills in the future, education needs to create competence platforms that enable effective lifelong learning (Tuomi, 2018).

AI can help to monitor behaviour and learning of students in great detail through intelligent tutoring environments. There is a focus on the problem of using AI and machine learning to generate teacher interfaces for student and learning monitoring, and learning diagnostics, commonly known as learning analytics and educational data mining (Tuomi, 2018).
Many projects are trying to explore the use of AI for automatic test generation and assessment by focusing on automating summative assessment, with a promise of reducing teacher workloads. Due to that high-stakes testing will be increasingly displaced by frequent low-stakes formative assessment, as the effort and cost required for assessment decreases. Current AI systems can relatively easily check and diagnose students homework and support accumulated formative assessments (Tuomi, 2018).

AI could be used to objectively assess student learning by scoring test results without teacher bias. As Neural AI strongly prefers large datasets and standardized testing it is suitable for learning models that view learning as transfer of knowledge to the student's mind. If learning is understood as the development of skills and competences, AI may need to be incorporated in learning processes in different ways. AI supported assessment can be used to help learners to develop their skills and competences and keep students on effective learning paths, by making high-stakes testing redundant, and using broader evidence for assessing skills and competences.

6.2 Robot teachers?

Bosede and Cheok (2018) claim that robot teachers hold many advantages over human teachers and the economic implications of these factors, coupled with developments in AI, robotics, and machine learning, suggests that in the future, the teacher's job could be performed more effectively by robots. Physically embodied robots can play diverse roles as classroom assistants, educational technologies, and teaching support systems in current classrooms. Manyika et al. (2017), imply that due to the need for skills like emotional intelligence, creativity, and communication, for which human teachers are naturally endowed, good (human) teachers will continue to be needed in the future classroom, while many routine skills, like scheduling and lesson planning will be performed with AI assistance. Bosede and Cheok (2018) conclude that an independent robot teacher will require some capabilities, such as:

- exhibit characteristics expected of a social agent (agency and social presence)
- deliver instruction by selecting and employing appropriate pedagogy
- manage and engage in social interaction in the classroom.

They also predict, that "even the most clearly traditional educational roles like curriculum development, instructional design, lesson planning, summative assessments requiring some open-ended approaches, school management, establishment of schools, and similar duties will not remain human preserves for too long." (Bosede & Cheok, 2018).

6.3 New models of education and training

At an organisational level, the need for updating existing skills and competences will place a renewed focus on lifelong learning. Referring to the increasing rate of technological change, Chris Percy poses possible new models of employment and training, for instance one skilled workers spending one year in every seven updating their qualifications or alternatively undertaking courses lasting one week in a three-month period (Attwell, 2020d). It is also likely to require an increase in blended learning programmes combining online and face to face programmes. AI may also facilitate closer collaboration between educational institutions and companies in the provision of both course based and workplace learning, and the increased use of data from sensors in the working environment providing evidence of competence and feedback to learning (Internet of Things). Equally the increased use of online learning linked to the need for updating competences and knowledge may accelerate the trend towards micro credential, certification short units of learning.

7. ARTIFICIAL INTELLIGENCE AS A 'TRIGGER' FOR THE RE-DESIGN OF VET

When we talk about the integration of AI into VET, this can be done in two ways. One is as a topic in the curriculum. It is about preparing the learners for a future AI driven working world. Secondly, the integration of AI into VET can be done by using AI tools. This is to improve and support learning and teaching. The following chapter will deal with the former and thus the question of how AI can be integrated into the curriculum at vocational school.

7.1 Integration of AI related learning topics into the design of work oriented curricula

Through the specific design of the curriculum a new kind of coordination under teachers and trainers in relation to the learning and working programme of the school, training centre or training company can be envisaged. The current re-design of a curriculum is a complex educational and training oriented activity by trainer and teachers. It has to cover the professional work and learning tasks of an occupation in all its dimensions: work process knowledge covered in practical work skills from the work process in the company but also more explanatory in depth and/or reflexive knowledge which could be addressed more clearly in a VET school or special course

For actual, advanced and timely curricula, work process changes are the basic impulse to form new vocational learning programmes (VLP) which include work and learning tasks (WLT). Curricula are a key framework to say what kind of technical and organisational skills are to be followed and which of the learning tasks get priority and in which order they can be grouped and systemised. The skills spectrum starts from beginners' tasks, advanced beginners' tasks, advanced task sand very advanced expert tasks (Rauner & Haasler, 2009).

7.2 Curricular structures in mixed VET systems

In principle, several curriculum structures can be distinguished (Arnold, R. et al., 1998):

1. In the **synchronous curriculum** type the theoretical knowledge in the vocational school and the practically imparted learning content of the company can be clearly assigned to both locations. The theoretical and practical learning content are apart from each other and shall be taught by teachers and trainers in a synchronous way. For this purpose, the curriculum is broken down into learning units which will be trained in parallel in school and company, here the practical action knowledge and here the explanatory and in depth knowledge. The problem with this curriculum is that it requires a close coordination under teachers and trainers; but this is difficult to get organised because the business character at the company does not allow coordination with the school curriculum. The experiences with this approach show that the learning processes at the company are too much depended on work orders.

2. The **autonomous curriculum** is characterized by the independence of the company and school education mandate. The autonomous curriculum is characterized by a relatively weak cooperation between the learning locations; here the company and their the school. Both the school and company teaching / learning content are conveyed relatively detached from one another. This curriculum does not encourage ongoing and substantive work and learning process cooperation e.g. design common projects between trainers and teachers.

3. The **learning arena curriculum** tries to encounter the advantages and disadvantages of the different curriculum types shown (especially overcoming weaknesses such as little mutual reference to the work processes of the skilled occupational work to be done and overcoming problems that the curriculum does not start from practical or real work problems: missing work orientation). With the introduction of the learning field concept, a fragmentation of related practical actions into individual aspects and their treatment in separate subjects, such as mathematics, professional theory, is overcome in a way that mathematical operations are integrated into the different learning arena's.
This pursues through its concept of structuring the curriculum in form of work-related and work-related learning fields that are translated into a system of learning and work tasks (Lern- und Arbeitsaufgaben), a more integrative course between company training practice and vocational school teaching (Deitmer, 2007; Deitmer & Gerds, 2004).

This curriculum classification debate refers indirectly to the debate on how to deal with AI in VET, insofar that the learning arena curriculum type 3 is the most advanced option under possible curriculum designs. The learning arena curriculum preparing well for new kind of learning world of AI: more work based industrial reality, more student centeredness, more project and work task oriented.
By this curriculum concept the vocational school lessons are didactically structured by means of learning and work tasks and learning projects, which can increase in their learning complexity in which the learning and work tasks are carried out first in an ground and starting level forms for VET students (apprentice etc.) who are the beginning as well as getting later on in a more advanced level tasks or work topics with a direct reference to the professional work or operational order processes of the industrial and manual work economy. This means young technicians or apprentices of a higher kind get prepared to deal competently with all the questions and problems related to cyber physical systems.
This curriculum replaces old ways of learning as typical in the curricula types 1 and 2 by an integrated processing structure in the sense of coherent learning and tasks in successive "work related projects". With this, the curriculum of the vocational school with its framework curriculum approaches is oriented more towards real work related operational processes and is preparing the VET students for the world of AI related work task as been illustrated more concretely in the case studies in the appendix.

The complexity of operational work process, such as the one that comes to light when processing a customer order in times of digital production, is dealt with in a reciprocal manner in the learning field-structured lessons, both from an application-oriented as well as a theoretical or in-depth knowledge-oriented perspective. The trainees are to learn how existing work and action situations in company professional practice can be processed through a set of work and learning tasks.

7.3 AI and designing VET curricula

The developments in the world of work in the AI era can thus also be found in the facets of the learning field concept, through the:

- interdisciplinary, project topics,
- addressing professional, organizational and social skills,
- direction towards operational processes and real company action and business reality situations,
- orientation towards systematic, holistic training processes and
- a decreasing, purely techno centered orientation towards more organisational real problem oriented settings such as team building, project management and other forms of stronger cooperation and communication (Deitmer & Gerds, 2004; Deitmer, 2007; Deitmer, 2019).

The design criteria for a learning arena curriculum can be summarized:

- Work based curriculum is in favour in the context of AI technology because disruptive change will have a massive effect on the design and content of different technical, social and business occupations.
- Curriculum changes occur from the industrial labour market which will delete low skilled jobs and occupations but on the same side will enhance existing non routine job tasks such as to be found in technical occupations, for example industrial electronic and mechatronic occupations.
- The curricula can cover all learning places: company, training centre, vocational education school.
- Curricula follow an open content approach which is demonstrated by a continuous openness to new knowledge like new AI tools; system elements and methods.
- Supports the integration of different kind of knowledge domains, practical experience and theoretical knowledge gained by implementation of AI devices into real production facilities and
- work based curriculum is a thematic framework which gives direction, advice and thematic input for trainers and teachers in organising work and learning processes at different levels for apprentices, trainees and students as well as pupils.

8. USING AI IN PROVISION OF VOCATIONAL EDUCATION AND TRAINING

Donald Clark (Attwell, 2020c) summarises the different components of AI impacting on Vocational Education teaching and learning as follows:

Learner engagement and recruitment: Engaging with potential students is an issue for vocational education and training organisations in many countries. Higher education has greater prestige whilst careers advisers may not have an in depth knowledge of different occupations and vocational education opportunities. AI can be used, for instance in chatbot applications, to provide information about the labour market, about jobs and occupations, about qualification requirements and about courses and work experience opportunities. This provides much greater opportunities for in depth engagement than is possible for organisations to currently provide face to face.

Learner engagement and support: Intelligent tutoring systems and the AI supported provision of online learning can also promote engagement with students, not least because they can be accessed anywhere and at any time. Students can access information about their learning and learning progress, about forthcoming assignments and about requirements for completing parts of their course. Information and replies to queries are available in real time through chatbots.

Nudge learning: The use of the Experience API and a Learning Record Store means all of a learner's records and progress can be brought together. Perhaps more importantly the system can provide nudges to learners to encourage them to complete coursework or to remind them of forthcoming deadlines and tasks.

Creation of Content: AI and Natural Language Processing can be used to develop multimedia learning materials and Open education Resources in less time and at less cost than traditional development processes (see section on Educational Materials, below).

Delivery of content: AI can also support the delivery of learning materials, for instance providing answers to frequently asked questions or through stimulating and moderating seminar discussions.

Assessment: One of the biggest short term uses of AI in teaching and learning may be in assessment. Although e-Assessment has been around for some time, the use of AI can greatly enhance the variety of assessment formats. Automatic marking of assessments reduces the load on teachers, allowing a move towards more formative assessments, rather than reliance on manually marked end testing. The Wales government is exploring moving all exams in schools to e-Assessment in the near future.

The role of teachers and trainers: Teachers are understandably concerned that 'robots will take over their jobs.' Yet this seems unlikely. Teachers have a key role to play in supporting learning in ways that cannot be undertaken by either AI or machines.

More optimistically, AI will free up teachers to act more as coaches for students, and instead of 'teaching to the middle ability', teachers will be able to give greater attention to those students who need it, particularly the higher and lower quartiles in terms of confidence and outcomes. Many of these ideas are explored in more detail in this section.

8.1 Intelligent tutoring systems

An Intelligent Tutoring System (ITS) is defined as an IT tool capable of helping a student in the same way (or almost) as a human tutor. Specifically, the functions it should perform are the following:

- presenting learning contents;
- evaluating the efficacy of student learning process (what and if the learner is learning);
- promoting learner motivation;
- helping learners to cope with difficulties, to bridge learning gaps by getting examples and extra explanations.

An excellent ITS can interact with the learner through instant feedback, on-demand, corresponding to the requests, appropriately to the situation. To answer students' questions, it is also able to store, represent and retrieve information (Jia, 2015).

Most of the authors conceive the ITS architecture as composed of 4 parts (Mousavinasab et al., 2018; Nkambou, Bourdeau, & Mizoguchi, 20109) 1) domain knowledge, 2) student model, 3) pedagogical module and 4) user interface. The *domain knowledge*, or expert model, contains the explicit representation of the knowledge to be provided to the student, expressed in the form of a model, capable of both communicating the concepts and properties of the application domain externally, and equipping the system with dynamic skills for the elaboration of expert knowledge. The *student diagnosis model* is the ITS component that record in the system the student's cognitive status information, i.e. responses, behaviour, activities, knowledge deficiency, learning styles. The *pedagogical model uses* the information contained in the student model to determine which aspects of the knowledge domain must be presented to the user. It also focuses on teaching strategies and methods useful to compensate the student's gaps (e.g. adaptive feedback, adaptive educational content presentation, etc.) The *user interface*, the communication part of ITS, controls the interaction between the system and the user, making the experience more effective.

ITS were being used by the 1970s, a period in which the potential offered by AI was small compared to today. The development that AI has seen in recent years has fostered its use for particular purposes in the context of ITS. In particular, it has been used for generating adaptive feedback, hints or recommendation, defining, classifying and updating the student diagnosis model, for student evaluation, for presenting adaptive learning material or content; and for adapting navigations of learning pathways (Mousavinasab et al., 2018).

ITS, in general, has been recognized as an effective method by several studies. In particular, a meta-analysis conducted in 2016 of 50 studies revealed an effect size of 0.66 (Kulik & Fletcher, 2016). According to the literature, ITS are widely used in schools and universities (especially for STEM and for the medical sector) but empirical research on ITS effectiveness in VET were not found.

8.2 Smart classrooms

A smart classroom is a physical learning room equipped with sensor technology. The data collected via sensors, e.g. with microphones or cameras, are used by humans or AI systems to provide learning assistants, tools or strategies for the learners (Southgate et al. 2019). A smart classroom should support the teacher in teaching in order to make learning more effective for the students.

The special thing about a smart classroom is that the learning environment is context-specific. This means that the learner's environment is recorded (for example, using sensors). Thus, for example, the room temperature can be adjusted to achieve optimal learning conditions (Southgate et al., 2019, p.31). Furthermore, it is special that individual support can be offered to the learners based on the data collected. It is also possible to adapt the way information is presented to personal learning preferences. Smart classrooms are therefore ideally context-specific, adaptable and personalisable (Hwang, 2014, p.6).

In Germany, the Technical University of Kaiserslautern and the German Research Center for Artificial Intelligence are working together on a smart textbook for tablets[16]. With the help of the smart textbook "HyperMind", individual learning should be made possible. For example, an eye-tracker is installed under the display. This enables the eye movements of the students to be

[16] https://www.uni-kl.de/uedu/arbeitsfelder/unterrichtskonzepte-af1/hypermind/

recorded and identifies where reading is slower or something is repeated. This activity detection can be used as an indication that a student could use help or additional information at this point. The student can then be provided with individual content[17]. The smart textbook is also intended to help teachers to shape the learning process. For example, the data collected from the students can be used to train an AI. In this way, learning behaviour can be analysed (Learning Analytics). These techniques have not yet been widely used.

In China, smart classrooms are already more widespread. In 2018, a Chinese school made the headlines by filming students in class and using AI to evaluate whether they followed the lessons. If facial recognition detected that a student was mentally absent, the teacher received a push notification on his or her mobile phone. Whether the focus here was on the learning success of the students and not on monitoring was much discussed in the media[18]. So, in the case of smart classrooms, as with all applications, dual-use must be discussed and it must be determined whether the positive effects of use outweigh the negative and how these can be promoted in contrast to negative consequences. Nevertheless, digital infrastructure in the classroom is becoming increasingly important. In Lithuania, preparation and adjustment of the digital infrastructure for vocational education and training is included in the occupational standard for VET teachers approved in 2019. The VET centres providing vocational education and training programmes in the fields of engineering, machinery production and metalworking have been significantly upgraded in terms of technological and digital infrastructure in recent years. VET providers are being equipped with robotic equipment (e.g. industrial welding robots), simulations of the smart/digital factories and other technological solutions of digital infrastructure. This significantly contributes to the attracting of students and development of their digital skills. However, one of the problems is related to application of these digital skills in the work at the enterprises, which in many cases are lagging behind such VET providers in terms of digitalisation of their technologies and infrastructure.

8.3 Learning Analytics

Learning Analytics (LA) has been defined as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs." (SOLAR, 2011). It can assist in informing decisions education and training systems promote personalized learning and enable adaptive pedagogies and practices (Johnson et al, 2014).

However, whilst there has been considerable research and development in LA in the formal school and higher education sectors, much less attention has been paid to the potential of LA for understanding and improving vocational education and training. There are a number of possible reasons for this.

Universities and schools have tended to harvest existing data drawn from Virtual Learning Environments (VLEs) and to analyse that data to both predict individual performance and undertake interventions which can for instance reduce drop-out rates. The use of VLEs in VET is more limited and "collecting traces that learners leave behind" (Duval, 2012) may fail to take cognizance of the multiple modes of formal, informal and workplace learning and the importance of key indicators such as collaboration.

While Learning Analytics in educational settings very often follow a particular pedagogical design, vocational learning is much more driven by demands of work tasks or intrinsic interests of the learner, and often linked to work processes and workplaces, for example through apprenticeships (Ley et al, 2015). Learning interactions at the workplace are to a large extent

[17] https://www.youtube.com/watch?v=8QocWsWd7fc

[18] https://www.telegraph.co.uk/news/2018/05/17/chinese-school-uses-facial-recognition-monitor-student-attention/

informal and practice based and not embedded into a specific and measurable pedagogical scenario.

Despite these difficulties, vocational learners can potentially benefit from being exposed to their own and other's learning processes and outcomes as this potentially allows for better awareness and tracing of learning, sharing experiences, and scaling informal learning practices (ibid). LA can, for instance, allow trainers and Learning & Development professionals to assess the usefulness of learning materials, increase their understanding of the workplace learning environment in order to improve the learning environment and to intervene to advise and assist learners. Perhaps more importantly, it can assist learners in monitoring and understanding their own activities and interactions and participation in individual and collaborative learning processes and help them in reflecting on their learning.

There are a number of research and development projects around recommender systems and adaptive learning environments. LA is seen as having strong relations to recommender systems (Adomavicius & Tuzhilin, 2005), adaptive learning environments and intelligent tutoring systems (Brusilovsky & Peylo, 2003), which are increasingly being adapted for vocational education and training. Apart from the idea of using LA for automated customisation and adaptation, feeding back LA results to learners and teachers to foster reflection on learning can support self-regulated learning (Zimmerman, 2002). In the workplace sphere LA can be used to support the reflective practice of both trainers and learners "taking into account aspects like sentiment, affect, or motivation in LA, for example by exploiting novel multimodal approaches may provide a deeper understanding of learning experiences and the possibility to provide educational interventions in emotionally supportive ways." (Bahreini , Nadolski, & Westera, 2014) .

One potential barrier to the use of LA in the workplace is limited data. However, although obviously smaller datasets place limitations on statistical processes, MacNeill (2015) stresses the importance of fast data, actionable data, relevant data and smart data, rather than big data. LA, she says, should start from research questions that arise from teaching practice, as opposed to the traditional approach of starting analytics based on already collected and available data. Gasevic, Dawson and Siemens (2015) also draw attention to the importance of information seeking being framed within "robust theoretical models of human behavior" (Wilson, 1999). In the context of workplace learning this implies a focus on individual and collective social practices and to informal learning and facilitation processes rather than just formal education.

The Experience API has been designed to capture different modes of learning and linked to a Learning record Store can provide LA based feedback to learners. The increasing use of sensors promises to open up new forms of data for Learning Analytics. Simon Buckingham Shum (2019) has reported on systems developed for nursing education, using a variety of sensors to capture data from nursing interventions, providing feedback to teams as a basis for reflection.

8.4 Digital Assessment

The use of Artificial Intelligence (AI) within assessment tools supports assessment and evaluation through automated grading and feedback, including a range of student-facing tools, such as intelligent agents that provide students with prompts or guidance when they are confused or stalled in their work. Such tools are increasingly being embedded in popular online learning applications like DuoLingo.

The development of Natural Language Processing (NLP) allows the digital assessment of open questions and texts, as well as other forms of questions like sentence completion or filling in missing words which research suggests are more effective forms of assessing learning (Jacoby, 1978).

Digital Assessment is not only important for providing formative feedback to students, but allows teachers an evaluation of student understanding and engagement, helping them to focus teaching on supporting learners with things they may not easily understand.

Many early applications for digital assessment were based on multiple choice questions. These are still popular. But Donald Clark (2018) a leading e-learning developer says that "these have been shown to be effective, as almost any type of test item is effective to a degree, but they have been shown to be less effective than open-response, as they test recognition from a list, not whether it is actually known." It can be difficult to write meaningful multiple choice questions without including a 'dud' answer and so other options should be used if you want a more meaningful assessment. The use of AI and Natural Language Processing allows more sophisticated approaches to e-Assessment than could previously be undertaken.

Much of assessment has traditionally been summative - to test what students know and can do in the middle or at the end of a course. Summative assessment is usually required for awarding grades or certificates. Yet research suggests that more formative assessment designed to provide feedback to students is important to support their learning. The use of technology can both reduce the workload for teachers and trainers and increasingly provide automated feedback to learners.

The UK JISC (2020) have published a report on "The future of assessment: five principle, five targets for 2025.": In it they call for assessment to be:

- Authentic (peer and self, immersive)
- Accessible (technology)
- Appropriately automated (feedback and adaptive)
- Continuous (learning analytics, digital qualifications, AI)
- Secure (data forensics and invigilation).

Paul McKean (Attwell, 2020b), Jisc's head of further education and skills says "Our vision for Education 4.0 includes personalised and adaptive systems which allow students to learn at their own pace. Some aspects of assessment could be automated, and AI could help teachers understand how learners are progressing. Machines release learning content at a time that's appropriate to each individual student – whether that's video or a simulation or written documents - tailoring the pace and type of learning so that everyone is challenged."

In an interview Paul McKean pointed to the need to reimagine summative assessment, raising policy issues for government and employers. He said we could introduce ongoing and cumulative summative assessment. Through a learning journey the system can recognise competencies and skills deficiencies on the way and can recognise the skills people already have. This would lead to a big increase in the productivity of education and training with only the need to teach what people need to learn, rather than having to follow the entire curriculum.

8.5 Pedagogy: Blended learning, MOOCs, Online courses

The integration of technology in education requires a re-examination of pedagogy and pedagogical approaches. The use of AI is no different in both posing new pedagogic challenges and at the same time new pedagogical possibilities.

One possibility is the scaling up of individual learning opportunities. DuoLingo, a free language learning platform launched in 2011, claims 300 million active learners and 100 million downloads of its smartphone application. As of November 2019, the language-learning website and app offered 94 different language courses in 23 languages. Pedagogy is based on the repetition of words and expressions with the grammatical rules being eventually internalized. This, it is claimed, is the way people learned their native languages. The extensively gamified application makes extensive use of AI both in the development of online learning exercises and in the provision of personalised learning activities. The pedagogy is based on short learning lessons, grouped around different themes and at progressively higher levels.

General overview of MOOCs

MOOCs can be defined as: “A MOOC is a course of study made available over the Internet without charge to a very large number of people: anyone who decides to take a MOOC simply logs on to the website and signs up”.

The acronym MOOC stands for Massive Open Online Courses, representing the key elements describing this new type of course:

- Massive: the term “massive” refers to the number of participants taking part in MOOCs, which is supposed to be significantly large.
- Open: the term “open” refers to a course which is offered without any fees or any specific requirements or barriers to entry.
- Online: MOOCs were created as an e-learning pattern to be accessed on the web, based on the idea of distributed content freely accessible on the web rather than from textbooks. Later, this trend slightly changed, as there are now many blended MOOCs combining both face-to-face and online modules.

MOOCs can be considered as an evolution of Open Educational resources (OERs), which are free web-based learning resources. MOOCs combine different features from social networking and free online resources. The main distinctive element of MOOCs is represented by its participants, and their need to autonomously organise their learning approach according to learning goals, interest and skills. Some MOOCs features are similar to those of ordinary face-to face or web-based courses, such as a fixed timeline, homework and tests to take, specific subject matters to be addressed each week, materials and activities. However, MOOCs also bring some new characteristics, such as the lack of definite prerequisites to access the course and of a formal accreditation system, as well as the unrestricted and potentially unlimited participation of people sharing the same interest towards a specific subject.

The first MOOCs were highly successful in attracting a great number of people, evidencing the potential of this new web-based phenomenon. Following the first positive experiences, promoted by different Universities mostly based in the USA (such as the Massachusetts Institute of Technology, Stanford and Harvard), a number of new platforms were established, providing different types of MOOCs. Some examples include Coursera, edX and Udacity in the United States. Most of the providers, which were either profit or non-profit institutions, worked in synergy with academic institutions.

The first massive open online course called "Connectivism and Connective Knowledge" was run in 2008 by Canadian scholars George Siemens and Stephen Downesiv. Then, another Canadian educator, Dave Cormier from the University of Prince Edward Island, coined the term MOOC in order to describe this new type of course, which was at first delivered by means of RSS feeds and collaborative tools, such as blogs, or Moodle. MOOCs soon became a valuable tool to democratize higher education, and many academic institutions decided to offer new courses creating new business models. This is evidenced by the rise of many web-based providers, such as Coursera, working in partnerships with universities. European MOOCs appear in Europe at a later stage. The first European MOOC was launched in January 2012 by the University of Helsinki, Finland, followed by MOOC experiences in Germany (University of Potsdam) and Scotland (University of Edinburgh).

Types of MOOCs

MOOCs can be classified in different types. The two main types of MOOCs are known as cMOOCs and xMOOCs. cMOOCs stands for connectivist MOOCs, and is based on the learning theory of connectivism, which was developed by George Siemens. cMOOCs allow learners to create and share their knowledge, establishing their own network, and to interact using several tools which do not necessarily belong to the same platform, such as social networks, Wikis and Google groups. Within cMOOCs, learners' participation is strongly encouraged. Usually, this type of MOOCs is not linked to any academic institution but depends on the contribution of individuals. Its focus on interaction is one of its defining features. xMOOCs stands for extensive MOOCs, designed to be used as a complement to other learning resources (e.g. university courses). xMOOCs are more structured, and less focused on distributed content: most contents are posted on the course page, without any need to access contents outside the platform.

To recap, as it is described on Figure 1 and Figure 2:

- cMOOCs: this type of MOOCs focus on the establishment of networks among learners. cMOOCs are less structured and rely more on learners' self-organization and participation, in terms of content provision and peer evaluation, with a view to create new knowledge.
- xMOOCs: the learning approach in xMOOCs is traditional and teacher-centered. Tools used within this MOOC type include videotaped classes, learning activities, and tests, with a view to ease knowledge transfer. In xMOOCs, learning objectives are fixed by teachers, and communication is limited among participants.

Apart from the above-mentioned types of MOOCs, new forms of MOOCs have emerged from xMOOCs, such as vMOOCs (vocational MOOC),"smOOCs" (small open online courses with a lower number of participants) and "bMOOCs"(blended MOOCs), hybrid MOOCs which combine in-class and online activities allowing learners to interact in real-time, feeding their motivation and commitment to the courses.

The vision behind MOOCs

Originally, MOOCs were created to be attended by a large audience from different parts of the world, namely from the developing countries, as a way to open academic education to low income students. In spite of this, new patterns were developed, going beyond the idea of offering affordable academic-level education. More and more MOOC providers, therefore, have started to offer free courses, sometimes charging students for exams or certifications. Ultimately, the idea of MOOCs is based on the idea of promoting learners' empowerment, while encouraging an interaction and active engagement among learners, and enhancing their critical thinking.

MOOCs are a Great Way to Learn AI

MOOCs focused on AI will be important in creating a more open, accessible, flexible, affordable, transparent and accountable future. They will play a key role in stimulating the adoption of new technologies and new forms of learning, including learning peer-to-peer, increasing digital skills, amplifying networks and recycling knowledge.

MOOCs provide the opportunity to connect with people who share the same interests or professional profiles. As a result, students are able to reach out to new groups and generate new ideas, to initiate novel projects or other interpersonal engagements, for a wide variety of purposes. Regardless of where you live or what resources are available to you locally, MOOCs can allow you to step on an open and global stage.

Artificial Intelligence Powered MOOCs

Artificial intelligence (AI) has played an important role in making MOOCs what they are today. By exploiting the vast amount of data generated by learners engaging in MOOCs, AI techniques have been proposed to improve our understanding of MOOC participants and enable MOOC practitioners to deliver better courses. These approaches have also greatly improved student experience and learning outcomes through constructing intelligent and personalized learning trajectories

One research area that has gained significant popularity in the last few years is how artificial intelligence (AI) and data mining (DM) can contribute to better understanding the MOOC ecosystem, and how they can contribute to improving it. In a nutshell, AI studies how to design intelligent machines and systems that analyse their environment and take actions that maximise their chances of success. AI borrows from various fields such as computer science, mathematics, and robotics. An AI-augmented MOOC platform can enable a better understanding of how learning happens in MOOCs as well as a more engaging learning experience for learners, thus improving their learning outcomes. The goal of data mining is to extract useful knowledge, information and patterns from seemingly unstructured data. To do so, it borrows tools, techniques and algorithms mainly from AI and statistics. MOOCs offer a very rich environment for DM given the large amount of data generated by learners using the platform but making sense of such data is not a trivial task. In some ways, all AI research in MOOC can be considered under DM since it relies on data to operate – the goal isn't to come up with new theoretical developments in AI but rather to use AI tools to solve a problem that generally involves big data.

9. THE PREPARATION OF TEACHERS FOR AI-BASED VOCATIONAL EDUCATION

The report has made it clear that there are basically two ways in which AI finds its way into vocational training. One is in the form of AI-based tools that teachers and students use. Secondly, AI is changing the world of work, which requires new skills from students. These two dimensions are to be taken into account when extending the DigiCompEdu Framework (Redecker, 2017). The DigCompEdu Framework aims to capture and describe educator-specific digital competences by proposing 22 elementary competences organised in 6 areas. Area 1 is directed at the broader professional environment, i.e. educators' use of digital technologies in professional interactions with colleagues, learners, parents and other interested parties, for their own individual professional development and for the collective good of the organisation. Area 2 looks at the competences needed to effectively and responsibly use, create and share digital resources for learning. Area 3 is dedicated to managing and orchestrating the use of digital technologies in teaching and learning. Area 4 addresses the use of digital strategies to enhance assessment. Area 5 focuses on the potential of digital technologies for learner-centred teaching and learning strategies. Areas 6 details the specific pedagogic competences required to facilitate students' digital competence. For each competence, a title and a short description are provided, which serve as the main point of reference.

On the basis of the information collected, the project partners have supplemented the core competencies in the six areas or explained what influence AI has on them. It is important to mention in advance that digital competences will remain relevant, but that some of them will gain more importance within the framework of AI than others.

The dimension "AI-based tools in school" is basically transferable to general education. Smart Classrooms, Intelligent Tutoring Systems can be applied in general and higher education as well as in vocational training. But, the special feature of vocational education and training is that people are specially qualified for certain professions. However, these professions are changed through the use of AI. Young people for example who are currently being qualified for administrative professions may come into contact with and use AI-based administration systems in their later working lives. They probably do not have to deal with deep learning, neural networks etc. themselves, but they should understand the basic principles. In industrial and technical professions, content-related knowledge about AI will gain more in importance. Regardless of the profession, knowledge about AI will gain in relevance. This results in the dimension "Preparation for an AI-based world of work".

What does this mean for teachers in vocational training? On the one hand, they have to acquire skills in order to use AI applications in class. Some of these can be well described by the existing digital competences. On the other hand, vocational school teachers must acquire professional skills in order to be able to impart professional knowledge about AI to students. This professional competence then implies that teachers know which AI technologies are relevant in the profession for which they are training. In addition, professional AI competencies help to better analyse the potential of AI applications, since knowledge about the underlying technologies is available. This means that it also makes sense for vocational school teachers who train for professions that are not yet strongly influenced by AI technologies to deal with AI in terms of content. This professional dimension is not reflected in the current DigiCompEdu framework to the necessary extent and is being supplemented within the framework of the Taccle AI project. However, this is not a seventh area, but rather a cross-sectional area, which is to be interpreted as the basis for all six areas.

In the following, the existing six areas of competence within the framework of AI and VET will be interpreted and in part expanded. Reference is also made to the "new" cross-sectional area of teachers professional knowledge about AI and the future world of work.

Area 1 covers the "professional engagement" of teachers. This field comprises the core competencies Organisational communication, professional collaboration, reflective practice and Digital Continuous Professional Development (CPD). The core competencies are influenced by the use of AI by providing new ways of executing these processes. Chat bots could be used to shape communication with learners, parents or other stakeholders. These AI-based communication systems could also be used for communication between teachers and trainers. AI-supported MOOCS can be used by teachers to train themselves.

Reference to the new area: Up to now there are few existing teaching materials to deal with AI in vocational school, as it is not firmly anchored in the curriculum. If teachers nevertheless want to do so, they have to develop some of these themselves. This means that they need professional knowledge and the workload increases. However, this can be reduced if teachers within a school and with teachers from other schools work together to develop innovative pedagogical concepts. Then professional competence is still necessary, but the work can be distributed.

Area 2 "Digital Resources" looks at the competences needed to effectively and responsibly use, create and share digital resources for learning. AI-based search systems can help to find suitable digital resources. AI can also be used for natural language processing for the development of digital learning resources. AI can organise (and recommend) digital content for individual learners - especially in areas where learners need additional support, e.g. mathematics and language teaching. The competence "to effectively protect sensitive digital content" is becoming increasingly important, as the use of AI also involves the use of large amounts of personal data. Teachers should be able: To design and plan the installation of the AI-enhanced media technologies in the vocational school.

Reference to the new area: AI can be used to support the use, creation and distribution of digital resources. On the other hand, AI plays a role as a topic that is addressed by the resources. Teachers must therefore think about which AI content and competences will be relevant on the labour market in the future and should therefore be covered in class.

Area 3 is dedicated to managing and orchestrating the use of digital technologies in teaching and learning. This area is especially strongly influenced by "AI-based tools". AI and digital devices can link learning in the workplace to learning in the classroom. AI can be used to develop personalised learning pathways and materials, focusing on areas where students either need more support or on areas where they can advance to higher levels of learning. AI can also develop personalise learning programmes outside the workplace or the classroom though technology enhanced learning and distance learning programmes, available on multiple devices. Furthermore, AI can be used for collaboration between learners, for instance the use of AI teacher assistants in moderating discussions and providing relevant and timely learning materials. Use of AI to provide feedback to learners based on Learning Analytics including practice-based learning as well of cognitive learning.

AI can support learner-centred teaching through individual learning opportunities. Therefore, teachers should be able: To install AI-enhanced learning management systems in the school-based and work-based learning environment. To collect, aggregate, analyze and evaluate data from learning processes by using Learning Analytics.

Area 4 addresses the use of digital strategies to enhance assessment. AI can be used to assess learning performance. With the help of data and simulation, practical knowledge could also be queried and evaluated. The retrieval of practical knowledge would increase the authenticity of assessments. The competence "To generate, select, critically analyse and interpret digital evidence on learner activity, performance and progress, in order to inform teaching and learning" can be supported by AI-based learning analytics. The framework also states that "(...) the use of digital technologies in education, whether for assessment, learning, administrative or other purpose, results in a wide range of data being available on each individual learner's learning behaviour." AI can help analyze and interpret this data. This allows more accurate decisions to be made, both in the classroom and at the organisational level of the school. For this to be possible, teachers must be able: To select and install the AI enhanced online tools for diagnostics and assessment of performance at learning and work.

Area 5 focuses on the potential of digital technologies for learner-centred teaching and learning strategies. In this area AI can be particularly helpful, because one of its strengths is the personalisation of learning materials and tasks.

Reference to the new area: Another competence of teachers is "to use digital technologies to foster learners' active and creative engagement with a subject matter. This is critical for AI and VET. AI is already used in many professions, so that the use of AI technologies is relevant for students. The motivation to deal with the topic of AI can therefore increase.

Area 6 details the specific pedagogic competences required to facilitate students' digital competence. This area plays an important role in the DigiCompEdu framework and gains in importance through our extension by an AI dimension. As important as it is that teachers can use AI tools to personalise learning tasks or exams, the real goal is to prepare young people for an AI-based working environment. So teachers must be able: To design the concept of digital AI managed process chain in the teaching and learning process. To select digitalized learning and teaching scenarios that facilitate problem oriented and self-organized learning in the work processes.

New learning arrangements can help to support problem and action-oriented learning. An example for new learning arrangements is given in the Appendix ("Smart factories in vocational schools in Lower Saxony and Bremen").

The DigiCompEdu Framework is designed to be used in all sectors of education. Nevertheless, VET is special, so the DigiCompEdu Framework needs to be adapted. This is mainly due to the fact that technologies play a particularly important and dual role for VET teachers. On the one hand technology forms the subject of much vocational education and training in its use in different occupational areas. On the other hand, technology is a means of delivering VET. The acquisition of digital competences is certainly an important first step towards being able to deal with new technologies and to use them in a targeted and pedagogically valuable way. A first result of the Taccle AI project is the fact that the digital competences in the framework are becoming more meaningful in the context of AI in VET but must be extended by one dimension "professional expertise". On this basis there can be suggested the following competence framework of AI teaching and application of AI-based tools and measures in the vocational education and training (Table 2):

Extensions to the DigiCompEdu Framework: AI and Vocational Education and Training
A. Awareness of the implications of AI for work and society

1. To identify the main changes in work processes due to the use of AI. 2. To identify and discuss the implications of AI for skills and knowledge needs in the work processes. 3. To explain the implications of AI for the vocational education and training systems and their reform and development. 4. To explain the implications of AI for the design, provision and award of qualifications within all occupational profiles within important domains such as technical production, construction, health, trade, social and agriculture.
B. VET curriculum design and development
1. To facilitate open content in the VET curricula and the inter-disciplinary integration of vocational knowledge fields related to the implementation of AI technologies. 2. To design VET modules and curricula for the attainment of competencies needed to work and learn with AI-based technologies. 3. To adjust school-based and work-based training for the skills required for using AI technologies and solutions in work processes. 4. To apply AI solutions (e.g., learning analytics) for the design and implementation of VET curricula or modules.
C. School-based and work-based vocational training

1. To prepare AI enhanced workplaces for the work-based learning; to install and /or adjust the AI augmented workplaces for learning purposes; to install and maintain smart classrooms for VET.
2. To use AI-based tutoring systems in the training process; to apply "just-in-time" learning solutions enhanced by the AI in the work-based learning; to use Learning Analytics in the contexts of work-based learning and informal training.
3. To use the AI applications for the engagement, recruitment and support of VET students and apprentices: e.g. to design and evaluate chatbot applications, smart tutoring systems.
4. To support independent learning and competence development of students/apprentices in the field of AI applications in the work process by design and initiation of smart factory projects
5. To use AI enhanced technological solutions for the effective communication between VET teachers and company trainers in new work-based learning activities.
6. To use AI for development of multimedia learning materials and Open Educational Resources for VET; to apply AI powered MOOC's for vocational learning.
7. To apply AI-enhanced solutions for the formative and summative assessment of work-based learning.

B. Competence development of VET teachers and trainers

1. To identify the competencies needed for the teaching and training of trainers and teachers on how they can enhance their capacity to apply AI in the work processes.
2. To design and apply different kind of initial and formative training courses for teachers and trainers in order to deal with human centered AI solutions in their professional role.
3. To apply AI solutions for the development of professional and pedagogical competencies including course designs in different formats and arrangements: internal, MOOC, online etc.

Table 2: Extensions to the DigiCompEdu Framework: AI and Vocational Education and Training

This framework is aimed to serve as a basis for further discussions between the experts and researchers on the implications of the digitalization and AI for the work, careers and competence development of VET teachers and trainers. It also provides initial guidance for the wider discussions about the new competence requirements of VET teachers and trainers, as well as new approaches to their competence development.

10. ETHICAL ISSUES IN THE FIELD OF AI IN VET

Much concern has been expressed over the dangers and ethics of Artificial Intelligence both in general and specifically in education.
The European Commission (2020) has raised the following general issues (Naughton, 2020):

- human agency and oversight
- privacy and governance,
- diversity,
- non-discrimination and fairness,
- societal wellbeing,
- accountability,
- transparency,
- trustworthiness

However, John Naughton (2020), a technology journalist from the UK Open University, says "the discourse is invariably three parts generalities, two parts virtue-signalling." He points to the work of David Spiegelhalter, an eminent Cambridge statistician and former president of the Royal Statistical Society who in January 2020 published an article in the Harvard Data Science Review on the question "Should we trust algorithms?" saying that it is trustworthiness rather than trust we should be focusing on. He suggests a set of seven questions one should ask about any algorithm.

1. Is it any good when tried in new parts of the real world?
2. Would something simpler, and more transparent and robust, be just as good?
3. Could I explain how it works (in general) to anyone who is interested?
4. Could I explain to an individual how it reached its conclusion in their particular case?
5. Does it know when it is on shaky ground, and can it acknowledge uncertainty?
6. Do people use it appropriately, with the right level of scepticism?
7. Does it actually help in practice?

Many of the concerns around the use of AI in education have already been aired in research around Learning Analytics. These include issues of bias, transparency and data ownership. They also include problematic questions around whether or not it is ethical that students should be told whether they are falling behind or indeed ahead in their work and surveillance of students.

The EU working group on AI in Education has identified the following issues:

- AI can easily scale up and automate bad pedagogical practices
- AI may generate stereotyped models of students profiles and behaviours and automatic grading
- Need for big data on student learning (privacy, security and ownership of data are crucial)
- Skills for AI and implications of AI for systems requirements
- Need for policy makers to understand the basics of ethical AI.

Furthermore, it has been noted that AI for education is a spillover from other areas and not purpose built for education. Experts tend to be concentrated in the private sector and may not be sufficiently aware of the requirements in the education sector.

A further and even more troubling concern is the increasing influence and lobbying of large, often multinational, technology companies who are attempting to 'disrupt' public education systems. Audrey Waters (2019), who is publishing a book on the history of "teaching machines", says her concern "is not that "artificial intelligence" will in fact surpass what humans can think or do; not that it will enhance what humans can know; but rather that humans -- intellectually, emotionally, occupationally -- will be reduced to machines." "Perhaps nothing," she says, "has become quite as naturalized in education technology circles as stories about the inevitability of technology, about technology as salvation. She quotes the historian Robert Gordon who asserts that wnew technologies are incremental changes rather than whole-scale alterations to society we saw a century ago. Many new digital technologies, Gordon argues, are consumer technologies, and these will not -- despite all the stories we hear -- necessarily restructure our world.

There has been considerable debate and unease around the AI based "Smart Classroom Behaviour Management System" in use in schools in China since 2017. The system uses technology to monitor students' facial expressions, scanning learners every 30 seconds and determining if they are happy, confused, angry, surprised, fearful or disgusted. It provides real time feedback to teachers about what emotions learners are experiencing. Facial monitoring systems are also being used in the USA. Some commentators have likened these systems to digital surveillance.

A publication entitled "Systematic review of research on artificial intelligence applications in higher education- where are the educators?" (Olaf Zawacki-Richter, Victoria I. Marín, Melissa Bond & Franziska Gouverneur (2019) which reviewed 146 out of 2656 identified publications concluded that there was a lack of critical reflection on risks and challenges. Furthermore, there was a weak connection to pedagogical theories and a need for an exploration of ethical and educational approaches. Martin Weller (2020) says educational technologists are increasingly questioning the impacts of technology on learner and scholarly practice, as well as the long-term implications for education in general. Neil Selwyn (2014) says "the notion of a contemporary educational landscape infused with digital data raises the need for detailed inquiry and critique."

Martin Weller (2020) is concerned at "the invasive uses of technologies, many of which are co-opted into education, which highlights the importance of developing an understanding of how data is used."
Audrey Watters (2018) has compiled a list of the nefarious social and political uses or connections of educational technology, either technology designed for education specifically or co-opted into educational purposes. She draws particular attention to the use of AI to de-professionalise teachers. And Mike Caulfield (2016) in acknowledging the positive impact of the web and related technologies argues that "to do justice to the possibilities means we must take the downsides of these environments seriously and address them."

11. CONCLUSIONS

Artificial Intelligence significantly changes the world of work, skills needs and educational practices. These changes are occurring now and in the most cases they are irreversible. Scenarios of change suggested by scholars and experts indicate controversial effects of the AI on the work, skills and vocational education and training: from task encroachment, elimination

and hollowing out of skilled work and vocational and high skills to the liberation from the routine and low skilled work and empowerment of the worker to deal with the complex work tasks and processes.
Economic factors play highly important role in fostering or limiting these changes, because the replacement of work by AI driven technology depends on the comparative costs, competitive advantages and provided marginal productivity. In general, with technological change processes fostered by the AI and automation, such as a "digital taylorism", task encroachment tends to increase the weight of capital and to decrease the importance of labour in the production process. Nevertheless, education, and in particular, vocational education and training remain significant factors of skill provision and development in responding to these changes and new skill needs.
The response of the VET to these changes produced by the AI and automation concerns the transformation of the VET curriculum and the development of training methods and practices, as well as the assessment of learning outcomes, the role and responsibility of VET teachers and trainers and other aspects of the VET provision.
With regard to the change of VET curricula, AI comes to the curricula mainly as an integral part of training in the use of technology, as one of the key technological solutions that foster and enhance the implementation of the technology in the production processes. It means that AI related know-how and skills become an integral part of the knowledge and practical skills applied in the work processes. It requires the application of holistic and work-process oriented approaches to curriculum design, which enable the provision of a systematic and holistic understanding of the work processes and applications of AI in these work processes. With regards to the implications for qualifications, there are increasing demands for knowledge and higher level skills which foster the development and implementation of the new units or parts of qualifications aimed to deal with the AI enhanced or modified technological and work processes (for example, of additional qualifications (Zusatzqualifikation) in Germany and the Galaxy model of CNC operator qualifications in the project Industry4Change).
Two main trends can be highlighted in the practices and processes of VET provision. The first is the strengthening of the integration of the use of AI and related technological solutions in practical and work-based learning and training, thus fostering the practices of dual vocational training by using different simulated and technologically enhanced training environments (e.g. Smart factory approach in the VET centres in Germany and the use of simulated 4IR production lines in some sector practical training centres in Lithuania).

These changes require important institutional and organisational adaptations, adjustments and improvements, such as better integration into the school organisation by well established bigger teams of VET Teachers, development of learning projects by teacher teams at the school, avoiding becoming too dependent on Industry support, and stronger involvement of company AI projects between training centers and local industry, or close cooperation between the VET providers and local SMEs or large industrial companies.
The second is a focus on the application of AI technological solutions for the improvement of didactic pedagogical processes and the capabilities of VET teachers and trainers, mainly related to the provision of knowledge, development of key skills and assessment of learning outcomes. This approach is more typical in the UK. It requires supporting the institutions with new AI enhanced technologies and ensuring proper training and professional development for VET teachers, trainers and administration staff and students to exploit these solutions.

In the project partner countries, it seems that this progress is closely linked with the trends of development of Industry 4.0 and the institutional development of the VET systems. The biggest progress is seen in Germany, explained by the rapid development of Industry 4.0 technologies

and work processes together with comparatively smooth acceptance and integration of these changes in VET ,especially in the VET Dual System. Other partner countries are behind and focus on the different trends of adjustment of the VET provision to the new challenges.
In the UK the main focus is on the improvement of the didactic processes and teachers capabilities, as well as on the enhancing learning capacities of students by applying AI solutions. In the school-based VET systems in Lithuania, Italy and Greece the integration of AI in VET practices remains very much dependent on the initiative of VET teachers, trainers and students, although there are some institutional initiatives and solutions, such as enhancement of the VET centres and sectoral practical training centers and their investment in AI enhanced technologies in Lithuania. In general the introduction and implementation of AI in the curricula and processes of the VET is at the initial stage in the all partner countries.

REFERENCES

Arnold, R., Lipsmeier, A & Ott, B. (1998). Berufspädagogik kompakt; Prüfungsvorbereitung auf den Punkt gebracht. Berlin: Cornelsen.

Adomavicius, G., Tuzhilin, A. (2005). Toward the Next Generation of Recommender Systems: A Survey of the State-of-the-Art and Possible Extensions. IEEE Transactions on Knowledge and Data Engineering, 17, 734-749. http://dx.doi.org/10.1109/TKDE.2005.99

Attwell G. (2020c) Interview with Donald Clark

Attwell G. (2020a) Interview with Chris Percy

Attwell G. (2020b) Interview with Paul McKean

Aunkofer, Benjamin (2017): Automatisierungspyramide. Retrieved from https://www.der-wirtschaftsingenieur.de/index.php/automatisierungspyramide/ , 05.10.2019

Bahreini,K., Nadolski, R., Westera, W. (2016). Towards multimodal emotion recognition in e-learning environments, Interactive Learning Environments, 24(3), 590-605.

Becker, M. & Spöttl, G. (2015). Berufswissenschaftliche Forschung. Ein Arbeitsbuch für Studium und Praxis. Frankfurt am Main: Peter Lang GmbH.

Bender, G. (2020). The myth of job polarisation may fuel populism. Social Europe. Retrieved from https://www.socialeurope.eu/the-myth-of-job-polarisation-may-fuel-populism, 27. 02. 2020.

Bundesinstitut für Berufsbildung (BIBB). (2018). Ausbildung gestalten. Industrielle Elektroberufe. Mechatroniker/Mechatronikerin. Bonn: Bundesinstitut für Berufsbildung.

Bundesinstitut für Berufsbildung (BIBB) (2019). Digitalisierung und Künstliche Intelligenz. Berufsbildung in Wissenschaft und Praxis, 48(3).

Bundesministerium für Bildung und Forschung (BMBF) (2018): Strategie Künstliche Intelligenz der Bundesregierung. Retrieved from https://www.bmbf.de/files/Nationale_KI-Strategie.pdf, 15.4.2020

Bundesministerium für Bildung und Forschung (BMBF) (2019). Industrie 4.0. Retrieved from https://www.bmbf.de/de/zukunftsprojekt-industrie-4-0-848.html, 24.06.2019

Bundesministerium für Wirtschaft und Energie (BMWi) (2019): Landkarte Industrie 4.0. Anwendungsbeispiele. Testzentren. Informations- und Unterstützungsangebote. Retrieved from https://www.plattform-i40.de/PI40/Navigation/Karte/SiteGlobals/Forms/Formulare/karte-anwendungsbeispiele-formular.html , 24.06.2019

Bosede, I. E., Cheok, A.D. (2018). Why Not Robot Teachers: Artificial Intelligence for Addressing Teacher Shortage, Applied Artificial Intelligence, 32(4), 345-360.

Brusilovsky, P. & Peylo, C. (2003). Adaptive and intelligent Web-based educational systems, International Journal of Artificial Intelligence in Education, 13 (2-4), 159-172.

Brynjolfsson, E. & McAfee, A. (2014). Second Machine Age, Work, Progress, and Prosperity in a Time of Brilliant Technologies. New York: Norton & Company.

Buckingham, Shun S. (2019). Learning Analytics and AI for Future focused learning, presentation at Edu Tech Australia Conference, June, 2019

Bundesagentur für Arbeit (2019). Mechatroniker/in. BERUFENET Steckbrief. Retrieved from http://planet-beruf.de/fileadmin/assets/PDF/BKB/2868.pdf, 05.10.2019.

Caulfield, M. (2016). Announcing the digital polarization initiative, an open pedagogy project [Blog post]. Hapgood. Retrieved from https://hapgood.us/2016/12/07/announcing-the-digital-polarization-initiative-an-open-pedagogy-joint/

Cedefop (2019). Artificial or Human Intelligence. Thessaloniki, European Center of the development of Vocational Training. Briefing Note 9140. Retrieved from https://www.cedefop.europa.eu/files/9140_en.pdf , 21.01.2020

Checucci, P. (2019). Lavoratori maturi e nuova occupabilità l'innovazione tecnologica 4.0 in due studi territoriali. Inapp Report, agosto 2019, Retrieved from https://d2snyq93qb0udd.cloudfront.net/FondazionePirelli/newFondazione/wp-content/uploads/2019/10/15094524/INAPP_Checcucci_Lavoratori_maturi_e_nuova_occupabilit%C3%A0_2019.pdf , 22.02.2020

Clark, D., (2018). Breakthrough that literally opens up online learning? Using AI for free text input. Retrieved from https://donaldclarkplanb.blogspot.com/search?q=+as+almost+any+type+of+test+item+is+effective+to+a+degree%2C+but+they+have+been+shown+to+be+less+effective+than+open-response%2C+as+they+test+recognition+from+a+list%2C+not+whether+it+is+actually+known , 27.02. 2020

Confindustria (2019). Dove va l'industria italiana. Rapporto 2019. Milano: Centro Studi Confindustria

Deitmer, L. (2007). Die Einführung des Lernfeldkonzeptes in der beruflichen Erstausbildung, Definition/Ziel des Konzeptes, Erwartungen, Auswirkungen auf Curricula, Schulorganisation, Unterrichtsgestaltung und Lernortkooperation, Handlungsschritte zur Einführung, Ausblick. In S.Kreklau (Ed.). Handbuch der Aus- und Weiterbildung (pp. 81 - 95). Unterschleißheim/München: Wolters Kluwer.

Deitmer, L. (2019). Innovation Skills in Apprentice Training. In S. McGrath, M. Mulder, J. Papier, R. Suart (Eds.). International Handbook of Vocational Education and Training, Changing world of work. Dordrecht: Springer International. Retrieved from https://link.springer.com/referenceworkentry/10.1007%2F978-3-319-49789-1_79-1

Deitmer, L. & Heinemann, L. (2019). Promoting Quality in Apprenticeships: Self Evaluation as an Instrument for Trainers to access Apprenticeship Quality. In: F. Marhuenda, J.M. Chisvert-

Tarazona (Eds.). Pedagogical concerns and market demands in VET; Proceedings of the 3rd Crossing Boundaries in VET conference (pp 201-205). University of Valencia. Retrieved from https://zenodo.org/record/2644069#.XcrTmL9CeRs

Deitmer, L. & Gerds, P. (2004). Ist die Berufsschule im Rahmen des dualen Systems reformierbar? Eine Bilanz des Modellversuchsprogramms „Neue Lernkonzepte in der dualen Berufsausbildung“ der Bund-Länder-Kommission. Zeitschrift für Personalführung.

Deutsche Industrie- und Handelskammer (DIHK) (2018). IHK-Leitfaden zu den Änderungen in der Prüfungsorganisation der Industriellen Metallberufe, Industriellen Elektroberufe und des Mechatronikers. Änderungsverordnung zum 1. August 2018. Hinweise für Ausbildungsbetriebe und Auszubildende sowie Prüferinnen und Prüfer. Berlin: Deutscher Industrie- und Handelskammertag (DIHK).

Duval E. (2012). Learning Analytics and Educational Data Mining, Erik Duval’s Webblog. Retrieved from https://erikduval.wordpress.com/2012/01/30/learning-analytics-and-educational-data-mining/,

European Commission (2016). New skills agenda, human capital, employability and competitiveness 2016. Luxembourg: Publications Office of the European Union.

European Commission (2018a). Advisory Committee on Vocational Training. Opinion on the Future of Vocational Education and Training Post 2020. Luxembourg: Publications Office of the European Union.

European Commission (2018b). Artificial Intelligence for Europe. Luxembourg: Publications Office of the European Union.

European Commission (2018c). Artificial Intelligence for Europe. Luxembourg: Publications Office of the European Union.

European Commission (2018d). Digital Education Action Plan. Luxembourg: Publications Office of the European Union.

European Commission (2019). Ethics Guidelines for trustworthy AI. Luxembourg: Publications Office of the European Union.

European Commission (2020). White Paper on Artificial Intelligence - A European approach to excellence and trust. Luxembourg: Publications Office of the European Union.

European Commission (2020). Artificial Intelligence | Shaping Europe's digital future. Luxembourg: Publications Office of the European Union. Retrieved from https://ec.europa.eu/digital-single-market/en/artificial-intelligence.

Gašević, D., Dawson, S. & Siemens, G. (2015). Let’s not forget: Learning Analytics are about learning. TechTrends.

Gerds, P. (2001). Der Lernfeldansatz – ein Weg aus der Krise der Berufsschule? (The Learning arena approach - a way out of the crisis at vocational schools?) In P. Gerds, A. Zöller (Eds.). Der Lernfeldansatz der Kultusministerkonferenz. (pp. 20-50). Bielefeld: W. Bertelsmann.

Gordon, R. J. (2016). The Rise and Fall of American Growth - The U.S. Standard of Living Since the Civil War. Princeton University Press.

Gorldt C., Wiesner S., Westphal I., Thoben K.D. (2017). Product-Service Systems im Zeitalter von Industrie 4.0 in Produktion und Logistik – Auf dem Weg zu Cyber-Physischen Product-Service Systemen. In: M. Bruhn, K. Hadwich (Eds.) Dienstleistungen 4.0. (pp. 363-378).Wiesbaden: Springer Gabler.

Heinemann, L. & Deitmer, L. (2019). New Forms of Learning and Teaching and Organisational Change – a Case Study at the Building Industry. In B. Stalder, C. Nägele (Eds). Trends in Vocational Education and Training Research, Vol. II. Proceedings of the European Conference on Educational Research (ECER), Vocational Education and Training Network (VETNET) (pp. 162-170). Retrieved from https://zenodo.org/record/3358906#.Xcqd479CeRu.

Hirsch-Kreinsen, H., Itterman, P. (2017). Drei Thesen zu Arbeit und Qualifikation in Industrie 4.0. In G. Spöttl, L. Windelband (Eds.). Industrie 4.0 – Risiken und Chancen für die Berufsbildung. (pp. 131-152). Bielefeld: W. Bertelsmann Verlag.

Holmes, C. & Ken, M. (2012). The changing shape of the UK job market and its implications for the bottom half of earners. Resolution Foundation.

Hwang, G.-J. (2014). Definition, framework and research issues of smart learning environments - a context-aware ubiquitous learning perspective, Smart Learning Environments, 1 (1),1–14.

JISC (2020). The future of assessment: five principles, five targets for 2025. Retrieved from

https://www.jisc.ac.uk/reports/the-future-of-assessment , 27.02.2020

Johnson, L. Adams Becker, S., Estrada, V., Freeman, A. (2014). NMC Horizon Report: 2014 Higher Education Edition. Austin, Texas: The New Media Consortium

Ley T., Lindstaedt S., Klamma R. and Wild S. (2015). Learning Analytics for Workplace and Professional Learning. Retrieved from http://learning-layers.eu/laforwork/

Lee, H. & Pfeiffer, S. (2017). Industrie 4.0 – Szenarios zur Facharbeiterqualifizierung und ihrer betrieblicher Gestaltung. In G. Spöttl, L. Windelband (Eds.). Industrie 4.0 – Risiken und Chancen für die Berufsbildung (pp. 153-170).Bielefeld: W. Bertelsmann Verlag.

Luber, S. (2017). Was ist eine Smart Factory? Retrieved from https://www.bigdata-insider.de/was-ist-eine-smart-factory-a-643838/ , 05.10.2019

Manzei, C., Schleupner, L. & Heinze, R. (2017). Industrie 4.0 im internationalen Kontext. Kernkonzepte, Ergebnisse, Trends. Berlin: VDE Verlag GmbH.

Marcus, G., Davis, E.. (2019). Rebooting AI-Building artificial intelligence we can trust. Pantheon

Mason, P. (2019). Time for postcapitalism. Social Europe, https://www.socialeurope.eu/time-for-postcapitalism

MacNeill, S. (2015). The sound of learning analytics. Retrieved from http://www.slideshare.net/sheilamac/the-sound-of-learning-analytics

McIntosh, Steve (2013). Hollowing out and the future of the labour market. Research paper number 134. UK Government, Department of Business, Innovation, and Skills.

McKinsey (2018). AI, Automation, and The Future of Work: Ten Things to solve For. Briefing note for the Techn4Good Summit, organised by the French Presidency. June 2018.

mmb Institut. (2020). KI@Ed noch nicht in der fläche angekommen. Ergebnisse der 14. Trendstudie „mmb Learning Delphi". Retrieved from https://www.mmb-institut.de/wp-content/uploads/mmb-Trendmonitor_2019-2020.pdf, 10.04.2020

Naughton, J. (2020). The real test of an AI machine is when it can admit to not knowing something. Guardian. Retrieved from https://www.theguardian.com/commentisfree/2020/feb/22/test-of-ai-is-when-machine-can-admit-to-not-knowing-something.

Niedersächsischer Bildungsserver (2019). BBS fit für 4.0. Retrieved from https://www.nibis.de/bbs---fit-fuer-40-smart-factory_9989 , 05.10.2019.

Oesch, D., Piccitto, G. (2019). The Polarization Myth: Occupational Upgrading in Germany, Spain, Sweden, and the UK, 1992–2015. Work and Occupations, 46 (4).

Pedró, F., Subosa, M. , Rivas, A & Valverde, P. (2019). Artificial intelligence in Education: Challenges and Opportunities for Sustainable Development. Paris: UNESCO, Education Sector.

Pfeiffer, S. (2017). Work 4.0 – New challenges for participation and qualification. In F. Kaiser, S. Krugmann (Eds.). Social Dimension and Participation in Vocational Education and Training. Proceedings of the 2nd conference "Crossing Boundaries in VET". (30-34). Rostock: University of Rostock.

Rauner, F., Haasler. (2009). Lernen im Betrieb. Eine Handreichung für Ausbilder und Personalentwickler. Konstanz: Christiani Verlag.

Redecker, C., Punie, Y. (2017). European Framework for the Digital Competences of Educators: DigiCompEdu.. Luxembourg: Publications Office of the European Union.

Schumacher, S. (2016). BBS fit für 4.0 – Kultusministerium und Wirtschaftsministerium geben Startschuss für vier „smart factories" an berufsbildenden Schulen in Niedersachen. Retrieved from https://www.mk.niedersachsen.de/startseite/aktuelles/presseinformationen/bbs-fit-fuer-40--kultusministerium-und-wirtschaftsministerium-geben-startschuss-fuer-vier-smart-factories-an-berufsbildenden-schulen-in-niedersachsen-148362.html, 24.06.2019.

Selwyn, N. (2014). Data entry: Towards the critical study of digital data and education. Learning, Media and Technology, 40(1), 64–82.

SoLAR (2011). Open Learning Analytics: An Integrated & Modularized Platform. White Paper. Society for Learning Analytics Research. Retrieved from http://solaresearch.org/OpenLearningAnalytics.pdf.

Southgate, E., Blackmore, K., Pieschl, S., Grimes, S., Mcguire, J., Smithers, K. (2019). Artificial Intelligence and Emerging Technologies in Schools. Newcastle: University of Newcastle, Australia.

Spiegelhalter, D. (2020). Should We Trust Algorithms? Harvard Data Science Review. Retrieved from https://hdsr.mitpress.mit.edu/pub/56lnenzj, 27.02.2020.

Spöttl, G., Gorldt, C., Windelband, L., Grantz, T., Richter, T. (2016). Industrie 4.0 – Auswirkungen auf Aus- und Weiterbildung in der M+E Industrie. Study of the Bavarian Metal and Electrical Industry. München: baymee. Retrieved from www.baymevbm.de/industrie4.0, 27.01.2020.

Stanev, S. (2020). Uber, employment and the gig economy. Social Europe. Retrieved from, https://www.socialeurope.eu/uber-employment-and-the-gig-economy, 27.02.2020.

Stiglitz, J.E. (2019). People, Power and Profits. Progressive Capitalism for an Age of Discontent. London: Penguin.

Susskind, D. (2020). A World Without Work: Technology, Automation, and How We Should Respond. London: Penguin Allen Lane.

Susskind R., Susskind, D. (2015). The Future of Professions. How Technology will Transform the Work of Human Experts. Oxford: Oxford University Press.

Tåhlin, M. (2029). Polarisering Myten – Försvinner verkligen de medelkvalificerade jobben? Retrieved from https://arenaide.se/wp-content/uploads/sites/2/2019/05/rap-polariseringsmyt-final-webb2.pdf , 27.02.2020.

Tuomi, I. (2018). The Impact of Artificial Intelligence on Learning, Teaching, and Education. Luxembourg: Publications Office of the European Union.

UNESCO (2019). How can artificial intelligence enhance education? Paris. Retrieved from https://en.unesco.org/news/how-can-artificial-intelligence-enhance-education, 27.02.2020.

Watters, A. (2019). Ed-Tech Agitprop. Retrieved from http://hackeducation.com/2019/11/28/ed-tech-agitprop, 27.02.2020

Watters, A. (2018). The stories we were told about education technology. Retrieved from http://hackeducation.com/2018/12/18/top-ed-tech-trends- stories, 27.02.2020.

Weller, M (2020). 25 years of Ed Tech. Athabasca University: AU Press.

Wilson, T. D. (1999). Models in information behaviour research. Journal of Documentation, 55(3), 249-70.

World Economic Forum (2020). Jobs of tomorrow, Mapping Opportunity in the New Economy. Geneva. Retrievew from http://www3.weforum.org/docs/WEF_Jobs_of_Tomorrow_2020.pdf, 27.02.2020

Zimmerman, B. J, (2002). Becoming a self-regulated learner: An overview. Theory into Practice, 41(2), 64-70.

Zuboff, S. (2019). The Age of Surveillance Capitalism. London: Profile Books

APPENDIXES

Appendix 1: Methodology

A first goal of the Taccle AI project is to explore the impact that AI has or will have on VET and how VET already responds to it. These findings should be the first step to determine what competences VET teachers will need to have in the future to prepare young people for a (probably) AI-based working environment. In the initial phase of the project, therefore, the existing literature was first screened and interviews with VET teachers and other stakeholders were conducted in order to better understand the subject area.

1. **Literature overview**

The main focus of the literature search was to identify the role artificial intelligence can play in vocational education and training. Since there was hardly any literature directly on AI and VET, we approached the topic exploratively. Based on the expertise of the project partners and intensive discussions, a thematic mapping was developed along which the literature research took place. Artificial intelligence can, therefore, enter vocational education and training in two fundamental ways. Firstly, AI-based assessment tools, intelligent learning systems or robots can be used in the classroom. AI would then influence learning and teaching in the form of **AI-based tools**. On the other hand, AI can be addressed as a consequence of the increased use of technology in business and industry in the classroom. AI technologies are discussed in VET schools in a practical or theoretical way to **prepare young people for an AI-based working environment**. These two possibilities of how AI can influence vocational training were investigated more deeply in the literature research, taking keywords into account.

On this basis, the literature review was guided by the following questions: what is the impact of AI on VET? More specifically, which AI-based tools could be useful to support teaching and learning processes? Which are their characteristics? How could VET schools/centres training offers and activities be updated in view of a world of work based on artificial intelligence?

The string "*Artificial Intelligence OR AI*" were combined using the Boolean AND with the following keywords which are related to the aim of the study: "*Vocational Education and Training*", "*New World of Work*", "*Smart Factory*", "*Skills*", "*Competences*", "*Teaching and Learning*", "*Learning Analytics*", "*Digital Assessment*", "*Intelligent Tutoring Systems*", "*Adaptive Learning*", "*Pedagogical Agents*, *School Management Systems*", "*Smart Learning Environments*"; "*Adaptive Learning*", "*Employment and Labour Market*", "*Ethics*", "*Learning Management Systems*".

The project partners have basically limited themselves to literature published in the last ten years. However, if there was relevant literature outside this time window, it was included.

Due to the explorative nature of the review, the research was not restricted to the most significant databases for searching relevant papers regarding educational research (i.e., Scopus, ERIC, Web of Science, Emerald, Springer, Taylor & Francis Online, Oxford University Press). The research was also expanded to institutional and European projects reports (e.g.

Erasmus + projects), and grey literature. In order to ensure quality, peer-reviewed papers and journal papers were preferred, where the results insist on empirical studies. As mentioned before, since there are relatively fast changes and technological innovations in the field of AI, non-peer reviewed reports, internet articles or other sources were used to include current perspectives. In conclusion, while this overview is not exhaustive, a concerted effort has been made to identify and include peer-reviewed and grey literature, policy reports, and expert research reports that would be of interest to teachers or trainers on the subject.

Contributions about topics which did not address the research questions (e.g. history of AI, technological details of AI, etc.) were excluded from the review.

2. **Comparative case-study**

Parallel to the literature research, the project partners conducted a comparative case-study through semi-structured expert interviews to identify perspectives and experiences of the respondents on the topic of AI and VET. According to Meuser and Nagel, experts are those persons who are themselves part of a field of action. The status "expert" is always relational to the research topic and is awarded by the researchers (Meuser/Nagel 2009: 18). Basically, two groups were clustered, each of which was awarded the status of expert. One group comprises vocational school teachers, trainers or other persons who deal with the vocational training system in practice. The other group consists of persons primarily from the field of artificial intelligence and development. On the basis of the same research questions of the literature review, the following interview track were identified:

- What influence do you think AI and automation is going to have on occupations that you or your institution provide training for?
- Do you think AI is going to effect approaches to teaching and learning. If so could you tell us how?
- Have you or your institution any projects based around AI. If so could you tell us about them?
- How can curricula be updated quickly enough to respond to the introduction of AI?
- Do you think AI and automation will result in less jobs in the future or will it generate new jobs. If so what do you think the content of those jobs will be?
- Some people have predicted AI will have a significant impact on vocational education and training and that teachers and trainers in VET should be able to access Continuing Professional Development. If so, how do you think CPD should be organised and delivered?

The semi-structured interview method made it possible to discuss topics within the framework of AI and VET which were not included in the track. The gathered data were analysed in order to highlight the best practices implemented by interviewees in facing the coming of AI in VET.

Appendix 2: Findings - Good-practices and Interview summaries related to AI, Industry 4.0 and VET

Germany

1. **Deep Reinforcement Learning-Project in german VET School**

The topic of the project was *Deep Reinforcement Learning - preparation of the topic "artificial intelligence" and implementation of an agent in the game "Sonic the Hedgehog".* Sonic is a computer game series of the Japanese publisher Sega. The classic main parts of the series are characterized by fast 2D jump 'n' run passages. There you control the blue game character Sonic The Hedgehog through so-called "zones", which are divided into individual "acts". In all Sonic games rings are collected, which the main character loses when touching an opponent. If he is hit without rings, you lose an extra life. In the classic main games, after using up all extra lives and continues, you have to start all over again after a game over.

The task of the student group was to implement an agent into the game and finally to give a project presentation about the project. To achieve this overall goal, some intermediate goals had to be achieved:

1) Acquire an understanding of artificial intelligence and neural networks
2) Gain advanced knowledge of the Python programming language
3) The AI should master different levels independently

How is the project structured?

Trainees of the vocational school "information technology assistants" (German: "Informationstechnische*r Assistent*in") took part in the AI project. The AI project took place in the second year of training within the framework of the learning field "Planning, implementing and evaluating projects" (practice). The total time required was 160 hours per school year. The project meetings usually took place on a full day of lessons. The students had the opportunity to work in the computer room or in the corresponding workshops of the school. During this time, a teacher was present to provide support, but did not actively participate in the project.

As part of the AI project, the students were given a presentation on project management by the responsible teacher. With this knowledge team rules were established, field analyses were made, a target matrix was created, a schedule and work packages were created. The individual work packages were assigned performance specifications and outputs that had to be delivered. Responsibilities for the work packages were also defined. Furthermore, the students were assigned roles within the project group: e.g.

Role	Task
Team speaker	Moderates the group work and makes sure that everyone can get involved, that the topic is worked on consistently and that the team rules are observed.
Timekeeper	Make sure that the timetable is respected.

Quality Assurance Officer	Make sure that work is done properly and accurately.
Foreign Minister	Communicates with people outside the team, maintains contact and involves people. Often the team spokesperson is also the foreign minister.

What do the trainees learn in the project?

The trainees were able to acquire both technical and social skills in the course of this project. On the one hand, they learned project-oriented work in a group, they set themselves goals and divided and organised their work independently. On the other hand, they independently dealt with a programming language (Python) that was new to them and learned its basics to the extent that they were able to understand, modify and create programs. In addition, the trainees have dealt with the basics of neural networks and the different terms of machine learning, so that they were able to present the basics to their fellow students and explain the terms. They acquired this knowledge mainly by watching videos. They used textbooks less, because they mostly dealt with the AI topic in a very mathematical way and the mathematical knowledge of the students was not sufficient for this.

They have dealt with the topic "Deep Reinforcement Learning" and were able to program an agent to such an extent or to change existing programs in such a way that this "agent" learns to improve "his" game. In the end, they got so far into the programming of the "agent" that they were able to explain to their classmates which parameters they had to adjust/change so that their "agent" could improve his game.

Reflection and Recommendations for other teachers

The supervising teacher reports in the interview that basic knowledge in the field of AI is becoming increasingly important for information technology assistants, since in the context of the digitalised working world, processes are increasingly influenced by algorithms and the use of computers. In addition, many of the students attend the technical secondary school (In Germany: Fachoberschule für Technik) after their vocational schooling in order to subsequently complete a corresponding course of study. Since the students have to deal with the topic of artificial intelligence at the latest then, it makes sense to deal with it already in the vocational school. In the project documentation the students report that it was surprisingly easy to acquire basic knowledge about AI. However, they emphasize that the deeper immersion in the subject matter was an obstacle, as more complex mathematical knowledge would have been necessary. The students report that reading about this AI content sometimes led to lower motivation and productivity. Overall, however, the students report that the choice of project was a good decision and that they have gained an advanced understanding of AI and its practical implementation.

When asked about what needs to happen on the part of the school and the teachers so that such projects can be practiced regularly, the teacher interviewed reported that, on the one hand, appropriate further training for the teachers is necessary. Besides the transfer of knowledge about AI, the joint development of teaching concepts should be more

important. In addition, existing teaching materials should be jointly reviewed and classified. Useful material could then be made available to interested colleagues as Open Educational Resources. The exchange with product developers is considered desirable in the area of teacher training. In such a framework, the social, political and sociological aspects of AI should be discussed more critically.
The teacher recommends that the students have a say in choosing the appropriate topic. Students need motivation and perseverance to work in project groups, so it is an advantage if the project tasks are linked to the students' interests. In addition, clear evaluation criteria should be established and communicated transparently.

2. Smart Factories in vocational schools in Lower Saxony and Bremen

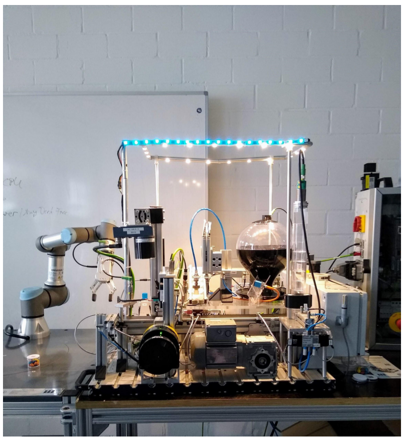
The Taccle AI project sought examples of whether and how AI is used in vocational schools. In Germany, there is a tendency to orientate oneself towards Industry 4.0. AI is usually not taught directly, but dealing with the latest Industry 4.0 is encouraged. This creates a basis on which to build in order to address AI technologies in the future. So-called Smart Factory systems have been set up at numerous vocational schools in Lower Saxony and Bremen. Interviews have already been conducted with some vocational school teachers to learn more about the implementation. We would like to present two of them here in summary.

a) Vocational school in Wolfsburg

At the Vocational School (BBS) 2 in Wolfsburg, so-called smart factory systems were virtually integrated into the classroom in the summer of 2019. These new classrooms are now called laboratories at the school. The smart factory systems were built by trainees for automation technology, mechatronics and IT. The industrial facilities at the neighbouring Volkswagen plant serve as a model. The students can use the Smart Factory models to gain practical experience in dealing with the latest Industry 4.0 technologies.

Smart Factory Plant

The Smart Factory plant in Wolfsburg is a model of a smart filling plant. Production is started via a self-programmed smartphone app. First a can is placed on a conveyor belt. This is then filled with chocolate coins and fitted with a lid. A QR code is then printed on the can. This code can then be scanned in again at the end to display the production data (filling date; number of chocolate counters, etc.) on a tablet. For example, the energy data acquisition can be viewed for each can. In addition, a digital twin is created for each can via the CAD construction. The machine can generate a self-diagnosis and provide automatic and dedicated support requests. In order to enable the trainees to record what they have learned or to acquire further knowledge on the topics, there is a direct link to the school's online learning platform via a QR code. The online learning platform serves as a basis for digital learning and teaching at school. The learning platform is also open to other vocational schools.



Reflexion

The supervising teacher, reports in an interview that one factor for success is the cooperation between Volkswagen, the vocational school and other industrial partners. In this way, technical knowledge and knowledge of the industrial plants could be combined with the didactic know-how of the school. In addition, the agile project management and the outstanding commitment of the trainees played a significant role in the success.

Web links to the project:

A video about the project (german): https://www.foraus.de/de/foraus_108586.php

b) **Vocational Training Centre Bremen (TBZ)**

A Smart Factory model was also built at the TBZ Bremen. The project was implemented in cooperation with the Future Workshop of the Mercedes-Benz plant in Bremen. Mechatronics trainees took part.

The Smart Factory plant

The trainees developed a project structure plan for a smart manufacturing plant. This was then implemented in cooperation with the Future Workshop of the Mercedes-Benz plant in Bremen as part of a learning location cooperation. The project resulted in a model of a networked and highly flexible production process consisting of a driverless transport system (AGV) as equipment carrier, a collaborative robot for removal and placement and two conveyor belts made of industry-related components. A Siemens S7-1500 (PLC) took over the control of the Smarten Factory. For the control of the AGV, the current Arduino technology from the modular system was used. "Although this construction kit is not an industry standard, it is very popular with the trainees because of the Arduino technology! ", says the supervising vocational school teacher. The basis of this learning field instruction was a learning and work task that summarized the competencies from the areas of control engineering, robotics and project management as well as their interfaces. Via the learning platform "Itslearning", the project teams were supported in communicating and connecting the learning locations company, school and home (blended learning).

Reflexion

The pupils were able to acquire both technical and social skills in the project. On the one hand, they dealt with networked production processes and additive manufacturing methods (3D printing). On the other hand, they learned to find their way around in an interdisciplinary way of working in teams. The teacher interviewed reports that such projects should be carried out with all mechatronics classes.

Web links to the project:

Homepage of the BBS on SMF: https://www.tbz-mitte.de/aktivitaten/projekte/#Projekt Smart Factory

Greece

1. **Design and Development of a Learning Management System for Vocational Education (University of Piraeus)**

University of Piraeus designed and implemented a Learning Management System (L.M.S.) targeting to support Vocational School students with their laboratory courses. They addressed the support of laboratory courses for vocational School students by proposing an approach through the use of this L.M.S. that was appropriately designed and organized. The L.M.S. platform has been designed to embed and run certain artificial intelligence (A.I.) algorithms, in order to be really flexible for the different levels and capabilities of students. There is a tripartite division into a data structure (the global data base), a set of operators on that data structure, with conditions for when they apply and actions for what they do (hence, productions), and a scheme for deciding which operators to apply (the control system). The way this is accomplished is by creating activity indexes for each student. These indexes function taking into account a full set of criteria like the student revisions, the exercise difficulty, the speed of completions etc. These algorithms in combination with a proper curriculum organization from the teachers can lead to a "clever" platform that proposes activities to a student according to his level. The whole functionality is based on Drupal's Computing Module which is a framework that facilitates distributed computing between Drupal and external programs written in non-PHP languages such as Java and Python. This model is then used to predict items (or ratings for items) that the user may have an interest in. Content-based filtering approaches utilize a series of discrete characteristics of an item in order to recommend additional items with similar properties. These approaches are often combined into Hybrid Recommender Systems. The final solution evaluates a set of criteria which are:

a) The amount of false answers.
b) The amount of questions answered.
c) The time the students stays in each question.
d) The optimum solution, if there are more than one correct answers.
e) The use of references.

With these criteria, the system may lead the student to higher or lower level activities.

2. Industry 4.0 now crowdhackathon

The Business and Industry Association (SEV), in collaboration with technology and digital innovation company Crowdpolicy, launched the first industry innovation marathon, industry 4.0 Now! crowdhackathon at November 2019.
Action "4.0 Now!" aim was to contribute directly or indirectly on:

- Developing business partnerships between startups and established businesses.
- Developing partnerships with universities and research teams to implement R&D projects.
- The orientation of research programs in scientific and technological areas related to the Greek economy, industry and its needs.
- To develop an innovation ecosystem around established businesses
- Finding and developing the human resources that companies need to design, implement, and support business applications related to "Industry 4.0".

The thematic areas the participating teams developed applications were:

- Factory automation - Intelligent robotics - Human Machine Interaction.
- '0 defects' - Reduction of production errors and defective products, early detection of product failures without human intervention.
- Customized product design.
- Managing the flow of goods & traceability along the value chain. Improving supply chain efficiency.
- Digital twins - factory simulation for optimization of operation
- Virtual Control Centers - Remote monitoring and confirmation of factory normal operation and proper execution of tasks.
- Real time decision making.
- Damage prediction - preventive maintenance.
- Energy efficiency optimization
- "0 waste" - smart waste management & recovery
- 3d printing

3. Teaching factory at the University of Patras

The “factory-to-classroom” teaching factory (TF) operation model aims at transferring the real production environment to the classroom and allow students to be trained by addressing appropriate real-life engineering problems. The actual production site is used to enhance the teaching activity with the knowledge and experience existing in the processes of every day industrial practice. The “lab-to-factory” TF operation mode aims to transfer knowledge from academia to industry. Industrial-grade or didactic equipment in the academic facilities is used as test-beds and demonstrators for new technological concepts that are to be validated and introduced to industrial practice.
The TF paradigm has been assessed based on real-life applications together with industrial organisations. Applications indicatively included the line balancing of a new production area and the planning of a material kitting area in a construction equipment factory, the validation of a new integration and control architecture for industrial robots in an automation company, designing a Multi-Technology Platform that combines a milling working centre with a robotic arm equipped with a laser-head for a machine shop etc. The applications have demonstrated and verified the TF potential to bring together the manufacturing learning and working environments

Italy

Some teachers and directors of the Italian VET-centers and VET-schools were interviewed with a semi-structured track in order to probe what actions the Italian VET system is implementing to face the fourth industrial revolution. The pilot investigation involved 7 VET-teachers and two directors belonging to different VET-federations and VET-schools. Analyzing their responses revealed interesting data.

Firstly, most of the interviewed teachers are aware of the fact that the mass diffusion of AI is modifying and will modify the work processes, e.g.:

There will be a significant impact of the AI, especially for students that are going to work in big companies and corporations in which the automation is continuously increasing as well as the call for high-qualified workers. In contrast, the tertiary sector will not be influenced by industry 4.0. [INT9/1]

It will be disruptive. Nowadays, there are already some changes. The new technologies are changing and transforming the world of work, radically, e.g., workers profiles, planning, organizing etc. Flexibility and openness to the current changes as well as life-long learning will be required to the workers of the future [INT6/1].

Secondly, they seem to be mindful of the need to intervene on various levels to cope with this change, primarily through updating the students' curriculum and promoting training for teachers.

At this time, no provision has been made in the field of initial-VET, except for updating employment profiles. In fact, in 2019, the national list of occupational profiles on which the curricula for professional qualification and professional diploma are based was updated. Among the various changes to the list, the new "IT operator" profile (EQF 3) has been added, and the "technician for the programming and management of production plants" (EQF 4) profile has been updated.

Furthermore, some VET-centers updated training modules, mainly in electrical and mechanical sectors, especially in the fourth years' programmes, taking into account the continuous innovation process that the production world is undergoing, (e.g., robotics modules). Still, none of the interviewees highlighted didactical practices related to the new elements introduced by these changes.

Teachers have different opinions regarding the skills to be strengthened in the curriculum re-profiling. Still, generally, we could affirm that both STEM and transversal skills (soft-skills) are perceived as crucial. For example, a teacher involved in the technology sector makes the following proposals [INT6/4]:

- *Education and training linked to the development of technical and specific competencies and skills based on the new technologies, mainly related to their working profile.*

- *Training for soft skills linked to the job sector, work environment and interpersonal processes.*

- *English training in order to allow students to invest in their development finding new resources in different languages* .

Some more substantial interventions have been made in the post-secondary level VET courses. For example, several VET-centers are providing courses on robotic arms in order to face technological innovation challenge. However, these courses are still at an early stage, and it is still early to receive useful feedback from students and teachers.

The interviewed VET-centers directors seem to be fully aware of the importance of the changes which are taking place:

> *The introduction of AI and automation will lead to an adaptation of the types of workplaces, with the presence of new figures, new operating methods and new settings which, on the one hand, will require the ability to adapt and innovate and on the other they will lead to new potential professional opportunities [INT2/3].*

> *The advent of AI will certainly also have repercussions on training methods, in particular for the following aspects: change of the training contents to be treated, with the introduction of new topics, remodelling of topics normally treated and a consequent adaptation of training times and methods; change of didactic methodologies to be used to deal with new topics; adaptation of laboratory equipment; need to better understand and evaluate the prerequisites, in terms of skills, knowledge and abilities, that students will need to be able to understand new technologies; need to strengthen collaboration with companies to better structure the technical content to be treated [INT2/2].*

> *The process of renewal and retraining of job duties is a topic addressed in the labour market in recent decades. The introduction of new technologies for production processes will once again involve, as in the past, a renewal of the tasks entrusted to people. In my opinion, it will be necessary to face a higher speed of change in these tasks. Therefore the process of continuous training of workers will be a strategic topic also in the world of school [INT3/5].*

Finally, the opinion shared by most of the interviewees is the need to involve the teachers in training courses that involve highly qualified specialists in AI and automatization.

> *Trainers and teachers need to be trained in Artificial Intelligence. In my opinion, they should be compulsory courses funded by the State and provided by the same with regard to public schools, perhaps during the summer period. As for private institutions, however, the funding should refer to the institution itself, but the grant should come from the Region or Ministry of Instruction, in any case [INT4/6].*

> *I believe it is essential that the first responsible for the training of the students or the trainers fall within the training and requalification plans not only in relation to the new skills required but also to the new teaching methods supporting the training processes. This training intervention for trainers will require resources and times not only for the implementation phase but above all for the planning phase or to define the best methods and strategies to be used and to better understand the goal that you want to achieve. So I imagine organic training courses (skills, methodologies, tools), and*

mandatory in order to guarantee uniformity in the level of skills of the trainers' group within the center [INT3/6].

Based on the results and excerpts of interviews showed above, we could make the following remarks:

· Most interviewees teachers are aware of the fact that the mass diffusion of AI is modifying and will modify the work processes, which is why it is necessary to intervene with different measures;

· The initial VET training system of Italy is not implementing significant changes to cope with AI diffusion. The only interventions made so far concern the modification of some curricula and didactic modules, especially in the fourth years;

· Some more substantial interventions have been made in the post-diploma VET courses;

· Most teachers declare that they need to be involved in training courses on the AI topic.

Didactic and curriculum innovation in Italy seems to need a boost. In particular, there is little attention paid to the three-year programs (EQF3), which involve subjects who are destined to be weaker in the face of the changes taking place.

Lithuania

Interviews with the representatives of the public VET providers and enterprises in Lithuania disclosed, that so far the AI makes the first steps into the work and training practices and processes. What regards the VET curricula and processes, some knowledge and skills related to the AI are integrated in the training modules, but there are no specific modules dedicated to the AI application. Introduction of the AI related knowledge and skills very much depends on the attitude and enthusiasm of teachers, because it has not yet become the general trend in VET. The usage of AI applications in the training process has not yet come to the training practice. There are very few teachers who have sufficient know-how and expertise to use such applications. Usually AI is not provided as separate competence or discipline in the curriculum, but it can make integral part of the VET curriculum (for example, in the modular curricula of mechatronics, especially in the modules related to programming of controllers, running and controlling of the fully automated production systems).

In some VET centres having the status of sectoral practical training centres the training programme involves training in the classrooms and workshops of the sectoral practical training centre, independent learning by using the online platform, working with the simulated Industry 4.0 production lines. Different skills related to the application of the AI are being included in the new modules related to robotics and production automation. The knowledge and skills related to AI are integrated in the modular curricula of CNC metalworking operator, welder, car mechatronic. These skills and competencies are developed in the laboratories of mechatronics, electronics and electronic control systems located at the sectoral practical training centres. The knowledge on AI is also included in the modules of electronics and welding. There are also provided some skills related to programming, setting and using different applications with AI, for example in setting of the parameters of controllers, AI applications for setting of the welding parameters in the welding robots, AI usage in the Smart House applications.

There are also used different AI driven applications provided by the producers of automated equipment and robots in the field of welding. Competencies needed for the remote control and programming of the parameters of welding processes are also being included in the training curricula. VET teachers need additional training in dealing with AI solutions in practical training. For example, there are needed skills for programming of the smart equipment of the engineering industry (automated technological processes). The technological level of equipment in the sectoral practical training centres permit to implement such modules. The main problem is that the provided skills will be difficult to apply in the enterprises, because majority of them do not possess such advanced equipment.

What regards the companies, AI solutions also make the first steps in their work processes. For example, there was interviewed a very innovative company working in the field of production of mechanically processed parts and elements. They have their own training centre used for the continuing training of their own employees, company based apprenticeship training of the new employees by using dual apprenticeship approach. AI solutions are currently being designed and implemented for the control of the technological processes, handling of orders, monitoring of the production output, quality assurance and other fields. So far, the knowledge and skills related to AI are provided in the context of competencies needed for the handling of the CNC operated metalworking machines. The company is actively involved in the different national and EU projects related to training and competence development for the digitalised work processes and Industry 4.0.

They coordinated the Erasmus+ project "4Change" which elaborated a new model of qualification of the CNC operator with the consideration of skills and competencies required by Industry 4.0 and digitalisation (Galaxy Model). Interviewed representatives expressed the belief, that so far the main focus of vocational training towards the introduction of the AI in the curricula should be directed to the building of the trust of workers and operators in the "supplementary" function of the AI. This means for example, employees tend to distrust the AI measures used for the improvement of the work processes and treat them just as additional measures of their control, rather than measures to enable and enhance more transparent, effective and timely management, which could contribute to better visibility of the contribution of employee to the development of the company and could also enable employees to participate in the improvement of work processes. Therefore, it is important to enable constructive attitudes of the VET students and employees to the usage of AI in the work processes.

Another interviewed company works in the field of machinery production for food, beverage and chemical industries. They see the prospects of the AI application in the development of the innovative networked control and operation of the technological processes of the food, beverage and chemical industries. It could enhance the competitiveness of the providers of machinery and equipment in the local, EU and global markets, when they could offer AI enhanced technological processes and production lines to their customers. To attain this goal it is necessary to create strong partnerships and clusters with the research and development units of the universities, universities and applied sciences and VET providers focused on the development and implementation of innovations from the one side and on the capacity building of the human capital (including operators and middle level technicians) from the other side. They are interested in the development of skills and competencies of the operators and especially supervisors of the workplaces on how to work with the AI applications in the monitoring and quality assurance of technological work processes (e.g. smart applications of the monitoring of welding processes and setting of the welding parameters).

United Kingdom

1. Adaptive tutoring systems: Basingstoke College of Technology

In the UK it is required to pass Maths and English exams at Level 4 or above as part of vocational Education and Training courses. Students must continue to retake the exams until they have passed. At Basingstoke College of Technology, like other Further Education Colleges, many students arrive still needing to pass their English and maths GCSEs. While initially they may feel demotivated by their previous grades from school, the college tries to offer the support and encouragement they need to improve their results, and to help with further studies and employment.

In September 2018 BCOT launched the CENTURY AI based learning platform for GCSE English and maths classes as well as Functional Skills lessons. The system undertakes an initial diagnostic survey of each student's strengths and weaknesses, and tailors learning materials to support them individually. Students can also access the maths and English websites developed by the College. Additionally they have an individual learning plan which tracks their progress and displays it on a dashboard, also developed in house by the College. According to Charlie James, a Educational Technologist at BCOT, students find the dashboard helpful in showing them what they need to do as well as the specific subject they need to work on.

Students use CENTURY for independent learning in classes, during their one hour scheduled blended learning sessions, in their vocational maths hours and at home. The platform allows them do revision in their own time and helps them to understand where they need to improve rather than blanket revise all topics. Students find the dashboard very helpful in showing them what they need to do as well as the specific subject they need to work on. They have also found themselves competing on who can get the highest score, complete the most nuggets and spend the most time on the platform completing work set – all contributing to their revision for their Functional Skills and GCSE exams. In 2019, there were 839 Maths students and 816 English students (both GCSE and Functional Skills) using CENTURY. In comparison to the previous year, the statistics for the 2018 November resit exams showed the student pass rate percentage had increased by 9% for English GCSE and by 21% in Maths GCSE. However Charlie James cautions that there have been many changes in the deployment of technology and in pedagogic approaches so it is not possible to attribute all the improvements to one learning platform. Despite this, the data generated by the platform showed increased study time suggesting that students were engaged, using it at home and over half term.

2. Bolton College Chatbot: a personal digital assistant for every student

About Bolton College

Bolton College is one of the leading vocational education and training providers in the North West of England, specialising in delivering training – locally, regionally and nationally

– to school leavers, adults and employers. The college employs over 550 staff members who teach over 14,500 full and part time students across a range of centres around Bolton. The college's Learning Technology Team has a proven reputation for the use of learning analytics, machine learning and adaptive learning to support students as they progress with their studies.

The Ada Chatbot
The Learning Technology Team has developed a digital assistant called Ada which went live in April 2017. Ada, which uses the IBM Watson AI engine, can respond to a wide range of student inquiries across multiple domains. The college's Learning Technology Lead, Aftab Hussain, says "It transforms the way students get information and insights that support them with their studies." He explains: "It can be hard to find information on the campus. We have an information overload. We have lots of data but it is hard to manage. We don't have the tools to manage it – this includes teachers, managers and students." Ada was first developed to overcome the complexity of accessing information and data.

Student questions
Ada is able to respond to student questions including:

1. General inquiries from students about the college (for example: semester dates, library opening hours, exam office locations, campus activities, deadline for applying for university and more);
2. Specific questions from students about their studies (for example: What lessons do I have today/this afternoon/tomorrow? Who are my teachers? What's my attendance like? When is my next exam? When and where is my work placement? What qualifications do I have? What courses am I enrolled in? etc.)
3. Subject specific inquiries from students. Bolton College is teaching Ada to respond to questions relating to GCSE Maths, GCSE English and the employability curriculum.

Personalised and contextualised learning
Aftab Hussein explains: "We are connecting all campus data sets. Ada can reply to questions contextually. She recognises who you are and is personalised according to who you are and where you are in the student life cycle. The home page uses Natural Language Processing and the Watson AI engine. It can reply to 25000 questions around issues such as mental health or library opening times etc. It also includes subject specific enquiries including around English, Mathematics and business and employability. All teachers have been invited to submit the top 20 queries they receive. Machine learning can recognise the questions. The technical process is easy." However, he acknowledges that inputting data into the system can be time consuming and they are looking at ways of automatically reading course documentation and presentations.

All the technical development has been undertaken in house. As well as being accessible through the web, Ada, has both IOS and Android apps and can also be queried though smart speakers.

The system also links to the college Moodle installation and can provide access to assignments, college information services and curriculum materials. The system is increasingly being used in online tutorials providing both questions for participants and access to learning materials for instance videos including for health and social care.

It is personalised for individuals and contextualised according to what they are doing or want to find out. Aftab says: "We are looking at the transactional distance – the system provides immediate feedback reducing the transactional distance. "

Digital assessment

Work is also being undertaken in developing the use of the bot for assessment. This is initially being used for the evaluation of work experience, where students need to provide short examples of how they are meeting objectives – for example in collaboration or problem solving. Answers can uploaded, evaluated by the AI and feedback returned instantly.

Nudging

Since March 2019, the Ada service has provided nudges to students with timely and contextualised information, advice and guidance (IAG) to support their studies. The service nudges students about forthcoming exams, their work placement feedback and more. In the following example, a student receives feedback regarding his work placement from his career coach and employer.

The College is currently implementing ProMonitor, a service which will offer teachers and tutors with a scalable solution for managing and supporting the progress made by their students. Once ProMonitor is in place, Ada will be in a position to nudge students about forthcoming assignments and the grades awarded for those assignments. She will also offer students advice and guidance about staying on track with their studies. Likewise, Ada will nudge teachers and student support teams to inform them about student progress; allowing for timely support to be put in place for students across the College.

A personal lifelong learning companion

For Aftab Hussein the persona of the digital agent is important. He thinks that in the future that chatbot will morph into a personal cognitive assistant that supports students throughout their entire educational life, from nursery school to university and beyond.

"The personal assistant will learn from each student throughout their life and adapt according to what they like, while guiding them through studies. It could remind when homework is due, book appointments with tutors, and point towards services and events that might support studies, for example."

Web links to the project:

https://www.youtube.com/watch?v=xXQ2bxQrKuQ&feature=emb_logo