Royal HaskoningDHV Digital

REPORT

Identifying and Meeting Digital Skills Needs in the European Chemical, Pharmaceutical, Rubber, and Plastics Industry

Darwin: “It is not the strongest of the species that survives, nor the most intelligent. It is the one that is the most adaptable to change.

With the financial support of the European Union

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1 Introduction

This document provides a framework of digital skills, supporting transversal and social skills to make sure that professionals are prepared for the digital transformation of the chemical, pharmaceutical, rubber, and plastics sector. This framework can be used at vocational education and training (VET) and university curricula to make sure that the new generation of young people who are preparing for a career in these sectors possess the required advanced digital skills and qualifications. This will enable future employees to adapt to the digital innovations the industry goes through. This document is meant to provide a pragmatic solution how to upskill the current workforce on both workers and manager's level.

This document distinguishes between worker levels and management levels for the following industrial job profiles:

- Maintenance
- Logistics
- Operations
- R&D

This framework has been devised by the project partners FECCIA, ECEG and Ledarna, and formed the basis of extensive desktop research and the resulting workshops with employers, workers and managers during spring 2022. With a representation from the various sectors. This document first provides an insight in the background of professional skillsets whereby the framework forms the structure of optimal skill collaboration in industry. This is supplemented with quotes from the workshops, where people with relevant experience put themselves into industrial roles and discussed particular skillsets.

To structure the framework we followed the competence areas from The Digital Competence Framework (DigComp 2.0). (Digital skills & Jobs Platform, 2022)

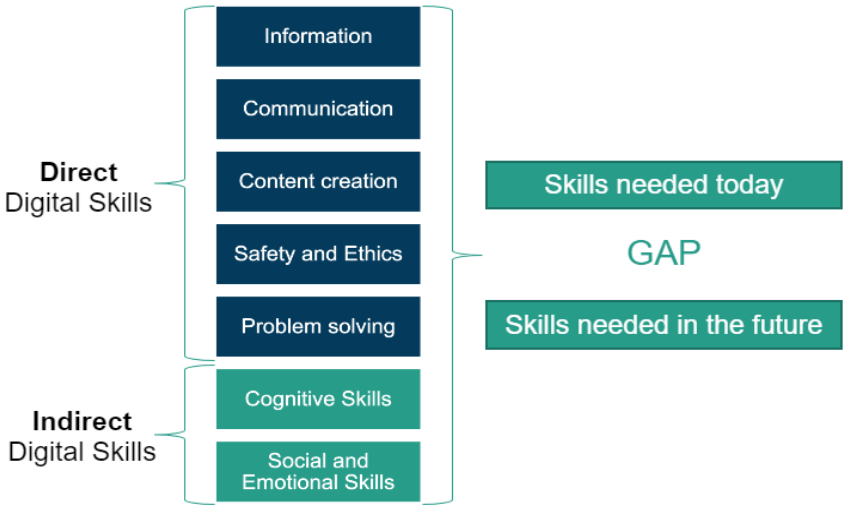


Figure 1 – Content of digital skills needed today and in the future.

The project partners Ledarna, ECEG and FECCIA, together with industriAll European Trade Union, who have been invited and accepted to be an active project observer, altogether representing the chemical, pharmaceutical, rubber, and plastics industry within the EU 27, have implemented the project to identify and anticipate the digital skills needed in the sector. The main objectives were:

- to find pragmatic solutions as to how to upskill the current workforce on all levels (workers and managers) within a very short time frame on the digital and transversal skills needed now,
- to also look at vocational education and training (VET) and university curricula with regard to digital, transversal and social skills to make sure that young people who are going to train or study to work in the future in the chemical, pharmaceutical, rubber, and plastics sector in the future possess the required advanced digital skills and qualifications,
- and to develop on the basis of these findings an integrated Life Long Learning (LLL) concept for digital skills.

The workshop results and the framework are a result of this project.

2 Current trends

2.1 T-profile

We use the widely used T-shaped profile to indicate generic skills for managers and workers independent of the sector or job profile and dedicated skills that are required for the sector or job profile.
When we are dealing with reskilling, an individual may have a Π (pi) profile, with two different legs in two different specialisms, resulting in specialist skills in two different areas, or even a M profile with expertise in multiple areas.

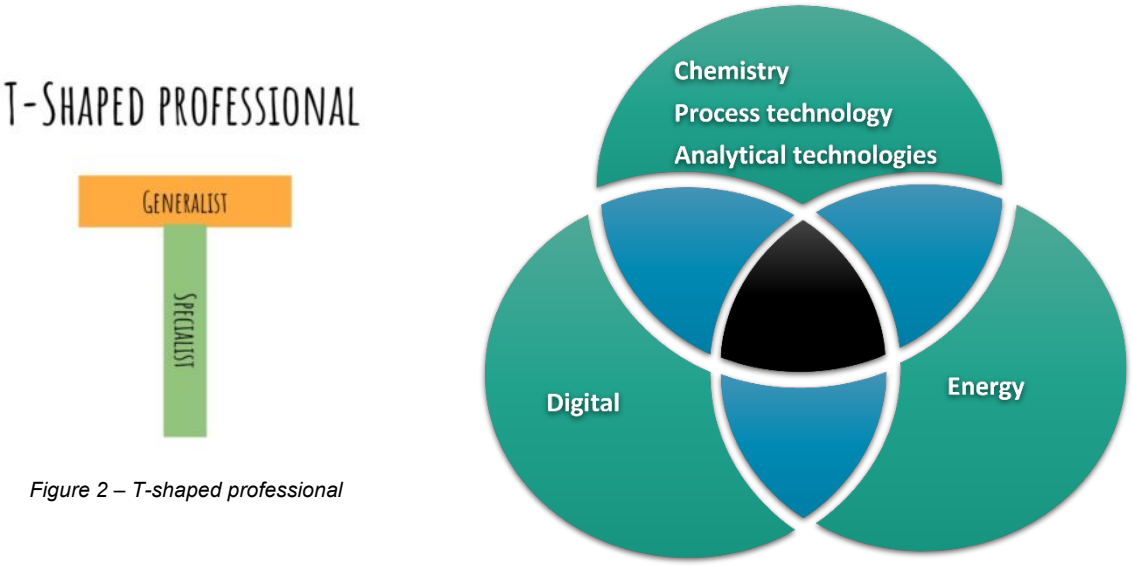


Figure 2 – T-shaped professional

The skills domain of the professional in chemistry can be considered to deal with the traditional skill domain areas for chemistry, process technology and analytical technologies, extended with knowledge on Digital technologies and Energy or Sustainability skills. IT professionals will cover the green lower left part, energy specialist the green lower right part. This framework deals with the blue left upper part and the black part that describes which skills a professional in industry much has about the digital technologies.

A special role exists for the data translator. A data translator is someone who can bridge the gap in expertise between technical teams, made up of data scientists, data engineers and software developers, and business stakeholders. An analytics translator enables the execution of your company's AI strategy. Data engineers are good at developing robust applications. Data scientists are good at distilling intelligence from data. Business teams know their specific processes, habits, and workarounds like no other. Still, there is a gap between data experts and business. (Xebia Acedamy, 2022)

2.2 Need for new skills as a result of new technologies

Digitalisation for industry is a means to obtain predictive quality, predictive cost, predictive supply and predictive maintenance, and enable information sharing across the supply and value chain and across plants. Digitalisation is not a goal but it can have a large impact like constant product quality, operator-independency, reduced waste, site invariance, control waste composition, reduced energy usage, decision support, scenario comparisons, simulations, improved yield, etc. We are faced with a long list of digital technologies that is entering industry like:

- Artificial Intelligence
- Cybersecurity
- Handheld sensors
- Industrial data lakes
- Blockchain
- Robotics and CoBots
- Augmented Reality
- Virtual Reality
- High Performance Computing
- Machine Learning
- Cloud Computing
- 5G
- 3d printing
- Predictive maintenance
- Soft sensors
- Quantum Computing
- Edge Computing
- In Silico research
- Digital twinning
- Federated learning
- Microelectronics

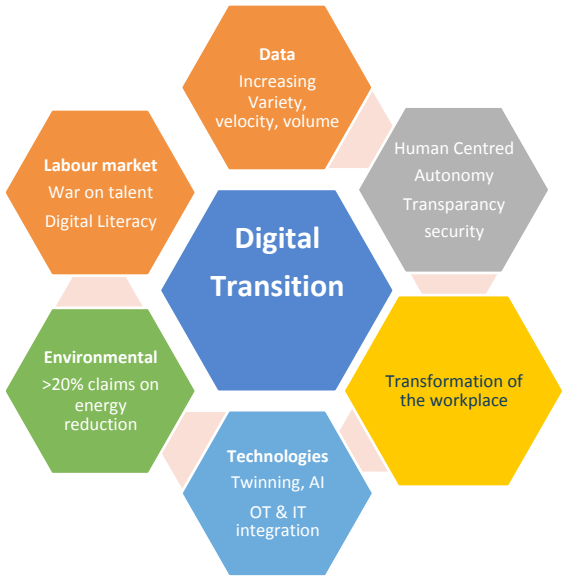


Figure 3 – Opportunities in the digital transition

The half-life of knowledge across any profession is shortening rapidly. artificial intelligence augmented and virtual reality, digital twins, or industrial data lakes simply were not part of the regular education 10 years ago. During our professional life we must master skills and acquire new ones to stay up to date Darwin: “It is not the strongest of the species that survives, nor the most intelligent. It is the one that is the most adaptable to change.”

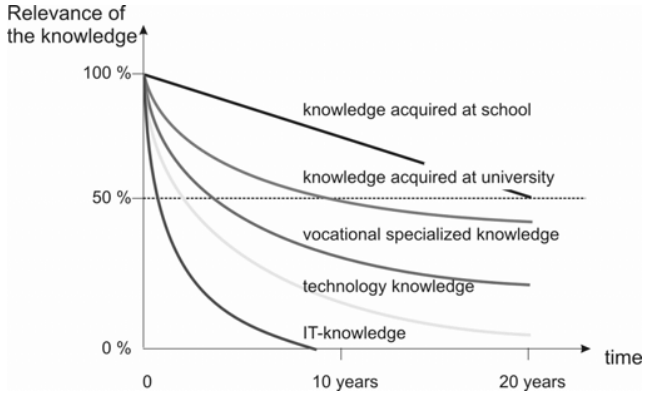


Figure 4 – Knowledge relevance of IT techniques due to rapid changing techniques (Vemuri, 1993).

The connectivity to people and information is increasingly being supported and mediated by digital technology. A technology-rich industry requires individuals to acquire a new set of skills related to the use of ICT or digital technologies. With the increasing digitization, the labour market has quickly evolved, requiring a workforce that possesses extensive digital skills. Another result of the ongoing digital transformation is the fact that teams become virtual teams asking for another type of leadership and approach.

The growing amount of available data introduces new data analysis skills and technologies like edge computing to be able to cope with growing amount and growing variety of data. The disruptive nature of the digital revolution has caused redundancy of skills, creating the need to constantly evolve and learn new skills. We need to upskill and reskill ourselves continuously.

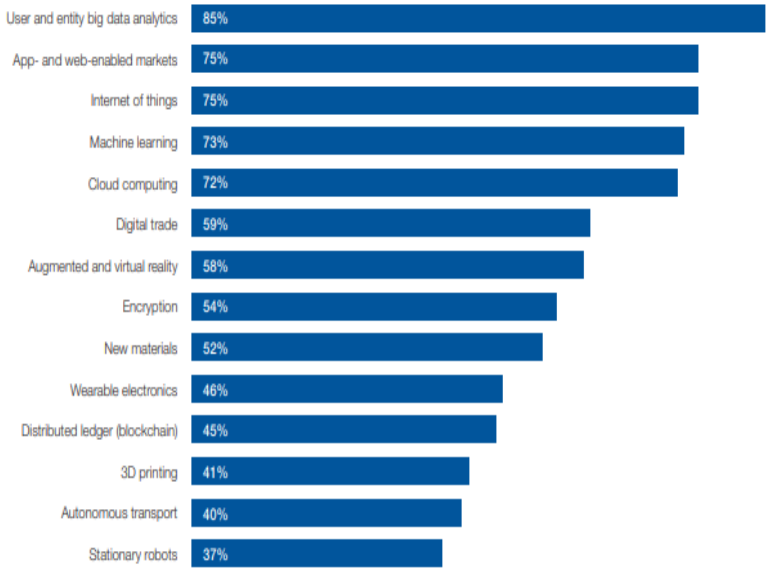


Figure 5 - Technologies by proportion of companies likely to adopt them by 2022 (World Economic Forum, 2018).

2.3 Life-Long-learning: Need for fast and targeted up and reskilling

Many studies and surveys indicate the need to accelerate the up and reskilling process with respect to digital skills. The digital transition is an important cornerstone in the recovery plan (EC: Recovery and Resilience Facility, sd) for Europe to mitigate the economic and social impact of the coronavirus pandemic and make European economies and societies more sustainable, resilient and better prepared for the challenges and opportunities of the green and digital transitions. And the current infrastructural projects to deal with the energy transition and autonomous supply chains enlarges this need.

After automating what can be automated the next step is to provide learning at the time and place where professionals need them and in the format that professionals like most.

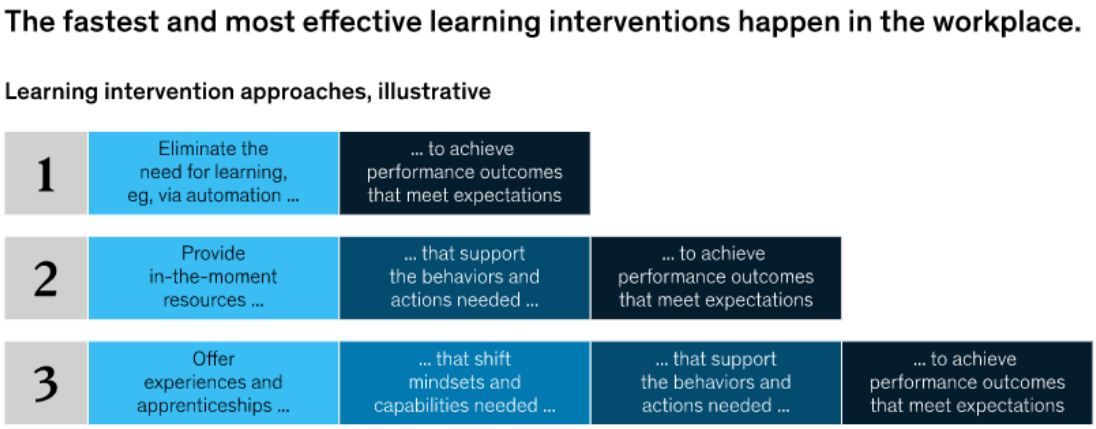


Figure 6 - The fastest and most effective learning interventions happen in the workplace (McKinsey blog, 2022)

2.4 New techniques lead to new roles

Examples of new technology impact of Artificial intelligence (AI). AI commonly refers to a combination of;

- Machine learning techniques used for searching and analysing large volumes of data.
- Robotics dealing with the conception, design, manufacture and operation of programmable machines and algorithms.
- Automated decision-making systems able to predict human and machine behaviour and to make autonomous decisions.

Any trustworthy AI has three components;

1. It should be lawful, complying with all applicable laws and regulations.
2. It should be ethical, ensuring adherence to ethical principles and values.
3. It should be robust, both from a technical and social perspective, since, even with good intentions, AI systems can cause unintentional harm.

Accountability in AI systems can be referred to as follows; The ability to inspect, review or otherwise interrogate an AI system with the goal of:

1) making processes associated with each of its life cycle stages transparent;
2) demonstrating compliance with laws and regulations, and standards and guidelines;
3) aiding investigations into the cause(s) of failure or erroneous decisions and supporting the identification of responsible parties.

Overly trusting automation in complex system operation is a well-recognized decision support problem. Known as **automation bias,** humans have a tendency to disregard or not search for contradictory information in light of a computer-generated solution that is accepted as correct. (Cummings, 2014)

If we take all the data generated in the world between the beginning of time and 2008, the same amount of data will soon be generated every minute. In the past we only focused on structured data that neatly fitted into tables or excel files. In fact, 80% of the world's data is unstructured (text, images, video, voice, etc.). However, we can now analyse and bring together data of different types such as messages, social media conversations, photos, sensor data, wearables, ERP, business applications, CRM, weather data, webdata, smart phones, mobile sensors, warehouse data, location data. We are now collecting data from every sensor on each machine at subsecond level. Current technology allows us to analyse data while and where it is being generated (edge computing and smart sensors). Moreover, veracity refers to the messiness or trustworthiness of the data. Which includes how we fix incomplete time series due to machine failures, and the conversion to other units and data protocols etc.

Figure 7 - Data governance lifecycle (Sacolick, 2018)

All of this leads to the following new data roles:

Figure 8 - Newly identified data governance roles (Experience league Adobe, 2022)

3 Existing Skills frameworks

3.1 DigComp 2.0

DigComp provides a common framework to assist European citizens and workforce in self-evaluating their skills, setting learning goals, identifying training opportunities, and reaching more and better career opportunities. The different competence areas from The Digital Competence Framework (Digital skills & Jobs Platform, 2022) are described in the table below. Moreover, the highlighted skills during the workshop employers are added.

Table 1 - Digital competence areas, aspects and skills

Competence areas	Aspects	Highlighted skills during the employer workshop
Information	• Digital literacy • Browsing, searching and filtering information • Analysing digital information · • Evaluating digital information • Storing and retrieving digital information • Computational thinking	• Analysing digital information • Evaluating different sources of digital information • AI skills for managers • Data quality and data stewardship
Communication	• Communicating through digital channels • Interacting with machines • Sharing information and content • Networking and collaborating through digital channel • Interacting with and participating in communities and networks • Netiquette • New media literacy • Virtual collaboration	• Virtual team management and related tools • Virtual team leadership
Content Creation	• Creating and editing content (different formats, e.g., word processing, photos, videos) • Integrating and re-elaborating existing resources of knowledge and content • Developing creative formats, including multimedia, and programming • Understanding and applying regulations with regard to copyright and licences.	• Linkedin possibilities
Problem solving	• Analysing technical problems • Identifying needs and technological responses • Innovating and creatively using technology • Prioritising problems and responses • Identifying competence gaps • Implementation of digital solutions	• Data Analysis skills

Ethical and safety	• Protecting self from online fraud, threats, cyber bullying, etc. • Protecting personal data • Protecting digital identities • Protecting health • Protecting the environment • Sustainability • Ethical awareness	• Stay accountable using autonomous decision-making systems. • Knowledge of ethical AI guidelines • Knowledge of trustworthy AI and approaches
Indirect skills	• Cognitive skills • Social and Emotional skills	• Adaptivity, learning agility, readiness for change • Self-leadership • Dealing with digital self-organising teams • Intercultural competences

3.2 European Chemistry Thematic Network

The Bologna process requires universities in Europe to develop easily readable, comparable and compatible degrees. As part of the work in the EU project "*Tuning Educational Structures in Europe*" (Uniduesto, 2004), the European Chemistry Thematic Network (ECTN, 2016) developed a framework for the three cycles qualification in chemistry, the **Chemistry Eurobachelor®**, the **Chemistry Euromaster®** and the **Chemistry Doctorate Eurolabel®**.

The second cycle was extended with the **Chemical Technology Euromaster®**. The qualifications can be obtained in accreditation processes as regular or renewal ones, and recently there is new possibility to apply for Eurolabel® as add-on.
The framework was endorsed by the European Chemical Society EuChemS (formerly *European Association for Chemical and Molecular Sciences EuCheMS)* (EuChemS, sd). Several accreditation agencies included the **Chemistry Eurobachelor®**, the **Chemistry Euromaster®**and the **Chemistry Doctorate Eurolabel®** into their portfolio (ECTN, sd).

In the overview[1] of the ECTN framework digital skills are **not or hardly mentioned** at the moment. Therefore, we strongly advise to integrate the outcome of this research project into the ECTN framework.

Please note that in the proposed learning activities of the ECTN framework there's limited focus on digital learning approaches. With the current possibilities of online learnings, virtual reality, simulations, etc, we see room for innovation of the learning approach as well.

During their degree programme students should develop a realisation of the importance of chemistry in the world around us and of its possibilities for helping to solve problems for which mankind needs to develop solutions if it is to survive. It is thus vital that teachers do not stress only the academic side of the subject, but also present material relevant to topics such as:

- Chemistry and industry
- Chemistry and the environment
- The economic importance of chemistry
- Chemistry and energy, climate change and food production
- Chemistry and biology
- Chemistry and medicine
- Social aspects of chemistry

.

[1] *Eurolabels Chemistry Eurobachelor, Euromaster, Technology Euromaster,. Doctorate (ECTN Label Committee, 2022)*

4 Workshop agendas and quotes

4.1 Employer workshop

During the workshop we focussed on the digital skillsets for employers using the following agenda of the meeting:

- Overview Industry 4.0
- Introduction round
- Explanation of the competence skillsets of the European digital competence framework
- Discussion on the Impact on accountability for employers
- Discussion on new Roles with respect to data driven organisations
- The digital transformation barriers
- Brainstorm on digital application and related skills
- Identification of Needed Digital skills for an employer
- Different type of Learning activities
- Discussion on education

The workshop was aimed to discuss the digital transformation and the role of talent, to discuss associated digital skills for employers and to discuss how we may obtain theses skills sets. An interactive environment was used as the basis of the workshop.

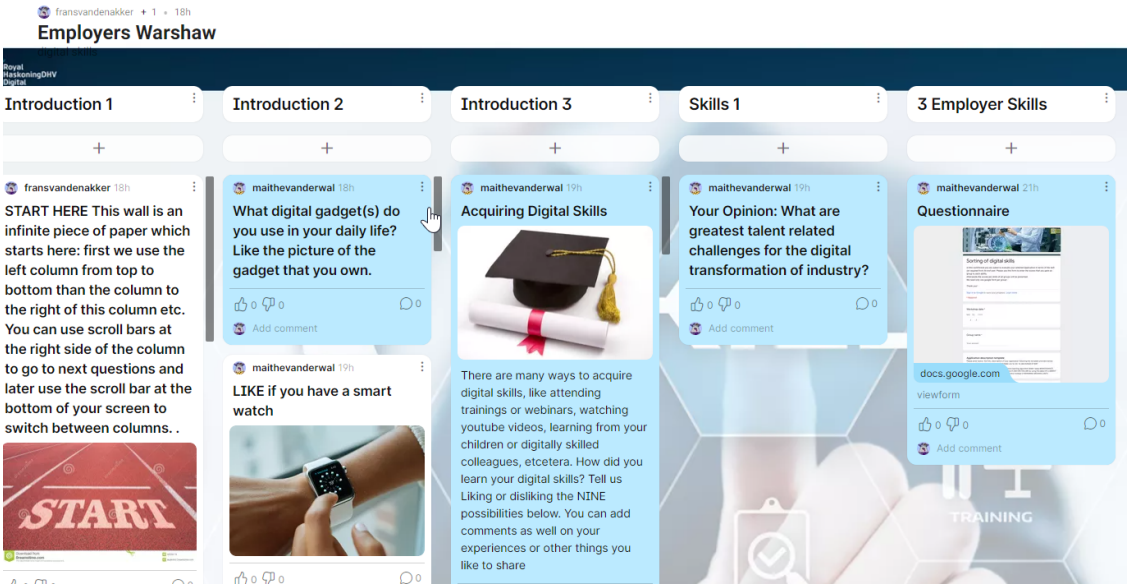


Figure 9 – Example of uses interactive environment.

This section includes quotes from the workshops where interactively the guests put themselves into the position of the various job profiles.

- *"Technology in industry has always been changing and people always adapted accordingly. And 85% of the people are very eager able to adapt: we must give extra attention to the other 15%."*
- *"We must ensure that we offer an inclusive training that reaches everyone independent of digital literacy or age."*
- *"As senior managers and employers we must have enough data translator skills to translate our business needs into digitalisation roadmaps."*
- *"Given the war on talent upskilling and reskilling are needed in the onboarding process of new staff."*
- *"We must provide training programs that are effective for large and small companies."*
- *"The human must stay in control in the digital industry."*

4.2 Worker workshop (blue collar)

During the workshop we focussed on the digital skillsets for workers using the following agenda of the meeting:

- Explanation of Workers job clusters for Maintenance / Service in, Production and Logistics
- Examples of digital technologies that are introduced and influences the workplace of workers: smart maintenance and the usages of drones for inspections, advanced process control with sensor data and possibilities to determine setpoints using machine learning and an example of chemical inventory tracking software that influences the logistical engineers.
- A group discussion on the transformation of the workplace and whether we expect less or more hazardous tasks, stress, changing tasks and repetitive tasks.
- We discussed the different competence profiles from the DigComp 2.0 framework (Digital skills & Jobs Platform, 2022).
- There is a focus on cybersecurity to create awareness on impact and the high connectivity of things and components.
- We discussed the autonomy of blue workers that work together with computers and robots.
- We discussed the new role of blue workers with respect to data: are the focussed at data generation, data quality, data interpretation, data security, data analysis or on using the data?
- We discuss the 5V's of data: variety, volume, velocity, veracity and validity.

The core exercise is planned to prioritize skills per job profile and indicate required skill level (basic, intermediate, advanced, expert).

Figure 10 - Picture from the worker workshop

This section includes quotes from the workshops where interactively the guests put themselves into the position of the various job profiles.

- *"Receiving emails without clear information is a waste of my time."*
- *"Log reports that are written like novels are a waste of my time."*
- *"Log reports without enough information prevent fast and acute responses."*
- *"Who is there to train the digital applications when we will have forgotten how our basic processes work?"*
- *"We must standardize our terminology even for the most basic things like the type of units and unit operations to be able to communicate."*
- *"How we can we learn to work alongside of cobots?"*
- *"My co-workers are coming from multiple countries: to communicate effectively we need English language skills."*
- *"We remotely monitor sites abroad but the terminology and language is different there, as long as there is no automatic translation, we need English as basic language and more standardization."*
- *"The amount of sensors and data is growing and growing but our brain cannot parallel process all the information: computer have to filter this for me."*
- *"We are the trainers of the digital tools of today: who will train the digital tools of tomorrow when our expertise is gone?"*
- *"We must be skilled in reading different types of data visualisations."*
- *"An understanding of underlying processes and systems is needed to correctly interpret data."*

Figure 11 - Picture of the worker's workshop

4.3 Managers workshop (white collar)

During the workshop we focussed on the digital skillsets for managers using the following agenda of the meeting:

- Discussion of management roles within own sector.
- The tasks for a manager. (Lead, develop people, coach, celebrate, check, support, develop, listen, control, reduce cost, standardize, steer, facilitate, understand, analyse, learn)
- Examples of industry 4.0 technologies in maintenance, logistics and operations.
- The transformation of the management context.
- The different type of Digital Skillsets.
- Roles with respect to data.
- Discuss and prioritize digital management skills: technical and non-technical.
- Adding subskills.
- Different type of Learning activities.

This section includes quotes from the workshops where interactively the guests put themselves into the position of the various job profiles.

- *"Learning how to filter fake news from kindergarten will give everybody better digital information skills."*
- *"Successful communication asks for standards and protocols and for awareness of existing standards and standardizing bodies."*
- *"A use case library of failed attempts with data exchange across vendors/value chains can accelerate the learning curve."*
- *"USBs are not allowed anymore but all contractors have access to the cloud data?"*
- *"Who unplugs the cloud in case of a cyberattack?"*
- *"Awareness about digital safety aspects must grow on all job levels and job profiles."*
- *"Adaptivity skills: learning how to unlearn.*
- *Digitalisation needs a new mind set of the manager, more trust and a different kind of control*
- *Digitalisation forms a new working culture and easier connection of teams*
- *Different communication styles are needed and communication hygiene"*

4.4 Knowledge Institutes

During this workshop we used format-free guided discussion between two highly experienced front-runners of education in academic digital skills in the pharmaceutical and chemical industries.

“With young people entering university already having a strong familiarity of digital technologies, and industries expecting graduates to be knowledgeable about digitalisation and Industry 4.0, it is crucial to step up the rate at which digitalisation is integrated into education.” (New School, april 2022)

The following questions were the basis of the workshop discussions.

- How to deal with different digital literacies from individuals due to different backgrounds or educations?
- Is there a need for an international test/competence level framework for digital skills like there is for English literacy?
- The position of data science topics within the curriculum of the chemical engineer.
- The usage of digital learning in the curriculum (AR/VR/ Online learning/ Digital Twinning/ simulation)
- Collaboration between universities and industry (innovation projects and hybrid researchers)
- What is needed in the data lab? (FAIR data, open science data)
- What non-technical aspects have to be included in the curriculum. (ethics, engineering aspects, change of human-machine interaction)

This section includes quotes from the workshop:

- *“The university focus on digital literacy for all students and is looking for a balance between the basic chemistry and the digital skills.”*
- *“Adaptivity is a key skills and chemical scientists shave to be able to talk with all kinds of disciplines including data scientists.”*
- *“Digital natives de not immediately have the digital skills that it takes to work in the chemical industry.”*
- *“In addition to skills infrastructure is needed to get trained in digital way of working: asking for data exchange and data labs together with industry.”*
- *“Corona has accelerated working in virtual teams and working remotely.”*

5 Digital skills framework

This chapter describes the digital skills framework based on the input of all workshops. Per job profile there is a description of the impact of digitalization and supplemented with a detailed description of the digital skills needed.

Within the appendix there is an overall skills framework in integrated formats per job profile, which can be seen in Appendix A1, 0 and 0.

5.1 Digital skills for workers of all sectors

- Experience in interaction with digital systems using various types of interfaces.
- Experts in risks and regulations as result of unsafe interaction with digital tools and data.
- Experts in communicating insights in required (digital) format and system to co-workers and managers.
- Ability to work with service and industrial robots using various interfaces like voice based or gestured based.
- Experience with wearable sensors (upcoming trend).

5.2 Digital Skills for managers of all sectors

Even as of today (Asad, 2021), Digitalization has taken over the managerial process, but yet the managers are here to stay, i.e., this role will not be digitalized in near future. As few of the researchers (like: (Frank M. Fossen, July 2019)) they identify both destructive and transformative effects of digitalisation on managers. However, their research concludes that managers perform nonroutine that cannot easily be replaced by machines. Since machines do not possess few potentials which are highly essential for this occupation. The statement comes with a proof that the manager's role requires capabilities that machines are not able to have. Capabilities such as originality, persuasion, social perceptiveness, assisting the mentee and empathy for others.

The impact of digitalization on managerial occupations is not as destructive and though it is a fact that the human role in human-machine interaction can never be neglected. Especially for the kind of efforts done by humans using the technological development to achieve desired results via machines. But for managers in managerial positions required to have qualifications and advancement in technology to stay competitive in this digital transformation.

- Leadings virtual team: digitalization enables working together in an online environment, however, brings additional complexities. Geographically dispersed meetings are becoming more relevant, which is leading to different monitoring behaviour. Providing platforms for collaborations. This includes a larger cultural diversity in the teams
- Able to stay accountable when using decision support system and is able to use explainable AI technology to understand how decisions are being taken.
- Ability to identify digital skill demand for the related teams.
- Data roles: ability to team formation based on data roles.
- Ability to divide tasks in a team of humans and robots.
- Ability to act as responsible for CyberThreat Detection and Mitigation.
- Ability to act as product owner in Agile engineering process.

- Familiar with concepts of Artificial intelligence and especially of Machine learning, Responsible AI, and Explainable AI.
- Familiar with concepts of Human Robotics interfacing that allows the human operator to control, monitor, and collect data, and can also be used to program the system.
- Knowledge about data engineering processes.
- Knowledge about data legislation like the Ethical AI guidelines and European legislation on data storage.
- Familiar with Concepts of Industrial data spaces.
- Familiar with the Concepts of ontologies, semantics and data standardization.
- Familiar with the 5V model for data.
- Familiar with pros and cons (safety!) of cloud-based solutions.

5.3 Digital Skills for Employers

Major findings:

- The disruptive nature of digital technology asks for upskilling every 10-15 years and maybe every 5-6 years. The speed of the transformation introduces the need to acquire new skills quickly and the educational system cannot keep up with the needs of the agile and adaptive nature of industry reacting to changing environment.
- Employers have to build competences how to stay accountable using autonomous decision-making systems and need knowledge on ethical AI guidelines and knowledge of trustworthy AI and approaches.
- Employers have a data role to assure availability of data and generate insights from the growing amount and growing variety of data. Their data analysis skills are becoming more and more important.
- For the social and cognitive skills, the workshop emphasized the need for Adaptivity, learning agility and readiness for change mainly as result of the fast-changing technology context.
- Another supporting skill identified is self-leadership and the skill to deal with digital self-organising teams.
- The labour market situation and the growing diversity in teams ask for improved skills on intercultural competences.
- Employers like other professionals have a preference to learn from others or in contact with others.
- The participants scored that they have on average 48% of the **digital** knowledge they need for their tasks. This is in line with research that shows that in 1960's it used to be 90%. But today people believe that they have less than 50% information with them.
- Another result of the ongoing digital transformation is the fact that teams become virtual teams asking for another type of leadership and approaches.
- The growing amount of available data introduces new data analysis skills and technologies like edge computing to be able to cope with the growing amount and growing variety of data.

5.4 Maintenance job clusters

“The digitization of manufacturing is gradually transforming the maintenance function from analogue and paper based towards digital and sensor based. This offers on the one hand many opportunities for e.g. predictive maintenance, but on the other hand, it requires many new skills. Partly, this digitization helps to improve registrations of failures, asset condition and usage by making the registration less dependent on human input. However, expert knowledge and knowledge management remain key: more specialists are required for collecting and analysing specific data.” (Tiddens, 2018)

Smart Maintenance relies on the comprehensive collection of data, and the capacity for remote monitoring to enable a constantly updated information stream, available at any time and in any place. This leads to guided predictive maintenance and optimized repair strategies. Machines with deep learning capacity not only analyze past and present performance but can also offer valuable insights and diagnostics for machines and their components.

5.4.1 Maintenance workers

- (Online) Statistical process control and related asset performance metrics.
- Load monitoring technologies to collect loading data on the component itself, e.g., temperature, vibration, humidity, strain or electric current.
- Process sensor technologies to provide data relating to output characteristics, e.g., pressure, flow, and temperature.
- Statistical process control, physics-based models and data-driven models, that can be used to create a tailored monitoring application for an asset (Tiddens, 2018).
- VR assisted maintenance.
- Work order management systems.
- CMMS computerized maintenance management systems (IBM IT Infrastructure, sd).
- Predictive /preventative maintenance: machine learning, operational data analytics and predictive asset health monitoring.
- Spare part and service tool supply chain management systems.
- Reporting, analysis and auditing: Generate reports across maintenance categories such as asset availability, materials usage, labour and material costs, supplier assessments and more.
- Remotely assessing asset health
- Analyse information to understand asset availability, performance trends, maintenance inventory optimization and other information to support business decisions and gather and organize information for audits (Northern Digital).

5.4.2 Maintenance managers:

- CBM maturity systems for asset owners.
- Selection criteria for maintenance decision support systems.
- Knowledge on statistical process control, physics-based models and data-driven models.
- Maintenance data gathering and monitoring strategies.
- MRO Materials and inventory management systems and underlying philosophy.
- Digital twin components and architecture; insights how a virtual model of the physical world enables data analysis, system monitoring to alert problems, downtime prevention, and future planning via simulations. (Sharma, 2021)

5.4.3 Maintenance supporting skills (Fechter, 2020)

- **Diverse skill set**: A maintenance engineer who knows how to maintain relationships with vendors, as well as use enterprise asset management and work order software will be even more useful to their host company.
- **Collaboration and communication expertise**: Most field engineers are required to be in constant communication with other technical staff. Today's maintenance engineer though needs to collaborate effectively with other departments to streamline the production cycle and eliminate repair downtime.
- **High-level problem solving skills**: Any engineer employed will be given certain types of tools to work with. They then must utilize those tools to tackle all sorts of problems, no matter how strange or technically challenging.

5.5 Logistics job clusters

Figure 12 – Example of an industrial logistics environment.

Digital platform in logistics creates visibility of inventory positions, movement of goods, delivery performance and compliancy with respect to safety processes. (Gmür, 2018)

In pharmaceutical logistics, digitalization initiatives are currently mainly focused on tracking & tracing practices. New shipment regulations (GDP) are forcing companies to place greater emphasis not only on how they track and trace their shipments, but also on temperature control during shipment. Smart technologies and centralized cloud platforms provide better and more comprehensive means to comply with these requirements. In addition to track & trace, pharmaceutical logistics is also showing a strong interest in serialization.

Many pharmaceutical companies are also looking into opportunities to implement central supply chain control towers and the underlying IT solutions as a means not only to gain more visibility into their supply chain, but above all to give them better proactive control over their shipments and supply chain execution.

5.5.1 Logistic workers

Expert level:

- Able to work with Supply chain management systems.
- Able to work with Chemical Inventory systems.
- Able to work with Warehouse systems.

- Able to work with Tracking and tracing solutions.
- Able to work with Yard management systems that manage inbound and outbound vehicles and trucks, personnel, shipments, pallets and everything moving in the yard to docks.
- Able to use the data provided by supply chain control towers and the underlying IT systems to analyse supply chain status and identify problems.

Advanced level:

- Understands the tagging and tracing possibilities of various systems and tagging technologies like QR codes, RFID technologies, barcodes, embedded chips).
- MSDS documentation and repository systems, with for example IT assistance (European Comission DG Enterprise and Industry, 2008).

5.5.2 Logistic managers

- Is an expert in the criteria to select inventory tracking systems, supply chain management systems and is able to use the best option for the given situation?
- Is an expert on the principles of warehouse design to be able to be able to successfully steer the usage of warehousedesign tools to maximize utilization.
- Is an expert in the criteria for the selection of communication software that provides real-time updates on goods movement and can use them to select the best option for the given situation.
- Has advanced knowledge about Safety Data Sheets (SDS) regulation databases and support tools and is able to assure compliance to relevant legislation.
- Has advanced knowledge Chemical storage regulations like selling and packaging of substances and mixtures (CLP Regulation).
- Has advanced knowledge about databases and tools in relation to the Registration, Evaluation, Authorisation and restriction of Chemicals (REACH) regulation and knows how to use them to comply with regulations.
- Has intermediate knowledge on IT-tools to generate Exposure Scenarios (ES), Chemical Safety Assessments (CSA), and Chemical Safety Reports (CSR).
- Has Intermediate knowledge about user models and personas for inventory and supply chain management systems.
- Has intermediate knowledge about statistical based improvement processes (six sigma, kaizen) to reducing manual interference and eliminating human error and can act as sponsor of an improvement project.
- Has basic knowledge on pros and cons of Blockchain and ledger technologies for tracing of transactions and movements of goods and can be an active participant in a discussion on technology selection.
- Has dedicated experience with clinical-trial supply chain & logistics (in case of pharma dedicated logistics)

5.6 Operations job clusters

Figure 13 – Example picture of an industrial operations environment.

IoT leads to new system architectures where open standards play a significant role. Through better connectivity, information will be much more easily available, which could result in integration of previously isolated functions will become more closely integrated. Here modelling at the right level of fidelity will be key. It can be expected that the importance of optimization will increase. Another trend is the fact that hand held sensors and wearable devices will enter the shopfloor.

5.6.1 Operations workers

Expert level:

- Able to work with distributed control systems.
- Ability to track and report performance using digital communication and associated devices.
- Ability to work alongside cobots in an efficient and safe way.
- Ability to work with chemometrics results to inspect and record product quality.
- Ability to work with energy monitoring systems and analyse data to optimize usage.
- Familiar with definitions to ensure correct communication across value chain.

Advanced level

- Familiar with the components and layers of a MES system.
- Familiar with production planning systems.
- Familiar with production process design, factory design principles and functions of different units.
- Familiar with (standardized) terminology for units, controls, planning etc and is able to use the definitions across disciplines and across organizations.

5.6.2 Operations managers

- Able to select and use Industry 4.0/Smart industry Maturity models for the own organization.
- Familiar with the concept of Cyber-Physical Systems.
- Familiar with concepts of distributed robust system-wide optimization methods.
- Familiar with concepts of system operation methods combining data-driven and model-driven approaches.
- Familiar with concepts of scheduling, planning and demand-side management for industrial production systems.
- Is familiar with concepts of networks within the enterprises and networks among enterprises and value chains.

- Understands the working of Energy monitoring systems at unit, production and site management.
- Familiar with concepts of multivariable supervisory process control.
- Has knowledge about available machine interfaces and data standards: ability to decide which standards are applicable for given application.
- Change management:
  - Acts as sponsor of digital transformation processes.
  - Is familiar with automatic digitization of Piping and Instrumentation Diagrams.
  - Familiar with scanning devices to create the digital copy of current factory, units and production lines.

5.7 Research and Development

Digital technologies are changing the way research and innovation is being performed: examples are in silico research for items like drug candidate screening, cell simulations, as well as the use of digital twinning to predict impact of new technologies and the usage of technology scouting using artificial intelligence.

New ways of data driven chemistry and research are emerging. Part of a data driven research and innovation strategy is to collect, aggregate and analyse all available research data and provide data to all relevant workers (internal knowledge management system).

To accelerate this: data sharing and even model sharing across companies is required which introduces the need for skills on data sharing, industrial lakes and federated learning to share knowledge with respect of the intellectual property rights.

Advantages of in silico studies as listed by research square (Avissar-Whiting, 2021).

- Analyses can be performed simply and cheaply using only a computer and the necessary software. During the global lockdowns of the 2020 COVID-19 pandemic, many researchers were able to contribute to research efforts via in silico methods.
- Studies do not employ the use of human subjects, animal models, or cell culture, so they typically do not require ethics oversight or specialized equipment.
- Results are obtained extremely quickly relative to other types of research.
- Molecular docking studies can be used to quickly assess the feasibility of repurposing a known drug for the treatment of a new disease and to explore potential side effects resulting from off-target interactions.

Technology scouting using artificial Intelligence uses the power of natural language processing to scan patents, company websites and research documents for technological solutions and accelerate technology scouting and extends possibilities beyond the network of involved researchers and consultants.

The digital twin as a representation of existing and future physical assets can be used to support construction planning and align with simulations, 3D models and schematics, this impacts all aspects of research and design from workflow planning towards designing the maintenance strategies.

5.7.1 R&D workers

- Familiar with best practices of data driven research for the own related research topics.
- Able to work with concepts of federated learning and possibilities to share data with compromising IP position.
- Familiar with FAIR principles of data to allow building industrial data lakes.
- Able to identify and collect data as input for digital twinning and simulation models in general.
- Able to work with in silico research tools especially for pharma.
- Able to use VR and other advanced visualisation methods to communicate design ideas with other business groups.

5.7.2 R&D Managers

- Familiar with the concept of Digital and AI based technology scouting.
- Familiar with concepts of data driven research.
- Familiar with concepts of industrial data lakes.
- Familiar with concepts of federated learning and possibilities to share data with compromising IP position.
- Familiar with concepts of networks within the enterprises and networks among enterprises and value chains.
- Familiar with open science and open research data concepts.
- Familiar with digital twinning impact for research.
- Familiar with pros and cons of Virtual Reality in research during design phase.
- Familiar with in silico research especially for Pharma.
- Acts as sponsor of digital transformation process of R&D department.

6 Lifelong Learning: individual learning paths and learning preferences

Current theories (Training Industry, 2018) on Learning & Development of professionals stress that the learning preference of an individual is even more important than their personal learning style (visual, auditory, reading, and kinesthetics). Participants in this research indicated their learning preferences as follows:

Table 2 - Results of learning preference survey

Preferred Learning activity yes/no?	Positive answer percentage
Learning from colleagues	100
Using applications at home	90
Webinars	90
Working together	70
In company training	50
MOOC's	10
Formal education	10

The workshop confirmed the preference to learn together in joined activities a preference that is indicated by other studies as well and sometimes is summarized in the preference for blended learning. The study also indicate that this preference is independent of the experience of age of the professionals.

Learning is a very individual and a complex social activity. In the traditional 70-20-10 model 70 percent of learning happens in the workplace through practice and on-the-job-experience, 20 percent comes through other people via coaching & feedback and 10 percent follows from formal learning activities like courses.

However, this now changes towards a model learning by education consists of courses, open online courses and microlearning, that are followed at an individual place and pace. This is combined with Learning by Experience: on the workplace, using tools like stretch assignments, job rotations, and special (pilot)projects. The largest shift is towards Learning In interaction and relationships. In collaboration and partner projects, employees develop by building connections with other professionals and they get a network that enables them to use collective intelligence.

Please be aware that the impact of any learning activity is highest when there is the need and possibility to immediately apply new knowledge to real-life situations and problems. A specific training possibility emerges from the usage of digital twins as training environment and from virtual reality (VR). VR offers an alternative to traditional methods of training by offering workers interactive and immersive 3D simulation environments to train critical skills. For example: using VR for training maintenance procedures in Naval Training Systems (Shannon K. T. Bailey, 2017). VR systems may simulate complex tasks that are not feasible or practical to teach in real life due to safety or cost concerns. VR gives a vivid illusion of the reality and is able to immerse the trainee in the situation. The physical interactions with the training system are believed to give better imprinting.

Studies towards the learning preferences of industrial professionals show that **professionals use various ways** to stay up to date in their profession. They attend courses, webinars and follow (at their own time and place) e-learning content. They are a member of in-company innovation projects and interact with professionals of other companies at workshops or community sessions or work together for open

innovation projects. **Every format has its own advantages**, and every employee has his **own preferences**. To be able to use this collective intelligence, it is important to actively build an external network as a company as well as each individual employee. It helps employees develop **by building connections with other professionals** and thought leaders for their current job and for future positions. The complete set must ensure that anybody can reach out to the required source of information at any time and use a preferred way of learning.

Tool	Elaboration
Incompany Training Activities	Building one culture, one language and translate concepts to the needs of the company Can be used to inspire and connect
Online Courses	Gives general introduction, scalable, low cost Can provide official certificate , so suited for personal development
Webinars, Congresses	Provides external network and information on trends
Community / Peer Group Sessions	Enables learning from peers: a preferred way of learning for professionals to share expertise and learn together.
Open Innovation	Strengthens strategic partnerships and may bring innovation ideas
Gamification	Use data savviness games to enhance learning in a fun 'out of the box' setting
Sandboxes	Experiment with data in a controlled environment
Coaching	Process that aims to improve performance and focuses on the 'here and now' rather than on the distant past or future. Helping individuals & groups to learn rather than teaching them

Figure 14 - Overview of the current available digital skilling tools

Studies towards the learning preferences of industrial professionals show that professionals use various ways to stay up to date in their profession. They attend courses and webinars, follow (at their own time and place) e-learning content. They are a member of in-company innovation projects and interact with professionals of other companies at workshops or community sessions or work together for open innovation projects. Every format has its own advantages, and every employee has his own preferences. To be able to use this collective intelligence, it is important to actively build an external network as a company as well as each individual employee. It helps employees develop by building connections with other professionals and thought leaders for their current job and for future positions. The complete set must ensure that anybody can reach out to the required source of information at any time and use a preferred way of learning.

Table 3 – Overview of attention needed for learning activities

Tool	Attention needed
Incompany training activities	Development costs and time effort of participants
Online courses	Not specific and must be in line with individual needs
Webinars, congresses	Follow up is difficult
Community sessions	Asks for moderation and mutual topics
Open innovation	Innovation goals to be selected in line with strategy of the organisation

6.1 Master curriculum best practices

More and more research projects create a data management plans to define a policy how to handle research data, define collection, storage and data formats to comply with a FAIR data policy and to describe how to participate with the open research Europe policy. This leads to guidelines for all students, lab journals, security guidelines etc.

Successful usage of open education Resources requires a standardized taxonomy on skills sets and courses content to enable identification of educational resources, it also asks for modular resources and evaluation processes to assess quality and content of the educational resources. English is the defector standard of educational resources that must be used in diverse student populations, or which is intended to be published as open educational resource. The curriculum typically is updated every 3 years by leading universities, this allows to include new digital technologies.
Educational resources may be offered to professionals as well as citizens by national programs.

- **Cooperation with industry**
  - The cooperation with industry is vital to stay up to date with the needs of industry. Learning Communities including the link with SME's (internships e.g.)

- **Learning approach for digital skills**
  - To create a common basis on digital skills it is common practice to offer students entrance tests and courses on basic digital skills. This can be done across disciplines and with project assignments or online courses. One set of entrance courses regular mentioned by knowledge institutes is the Khan academy[2]
  - A best practice is the usage of cross disciplinary digital project weeks in which students work on industrial challenges to be solved with digital technologies: this enlarges both communication as well as digital skills
  - Most digital technologies focused at the related industrial sectors are offered

- **Digital learning technologies**

  - **LMS systems and flipped classroom concept**
    Leading universities all use online learning environments (LMS systems) and tend to apply a flipped classroom concept that allow to focus on how information can be used. The usage of online or e-exams is increasing, and new technologies are used for candidate authentication (voice, image recognition) and to monitor the candidate via webcam for suspicious behavior.

  - **Virtual reality and 3d Simulations**
    A good example of the impact of Virtual reality in education is the usage of Virtual Reality to experience the structure of proteins with multiple students at the same time. With a VR headset (Google Cardboard compatible) and a smartphone, everyone can experience the

[2] *https://www.khanacademy.org/*

3D chemical structure from the Protein Data Bank.
Another example is the usage of gamification and 3d-modelling to learn about protein folding

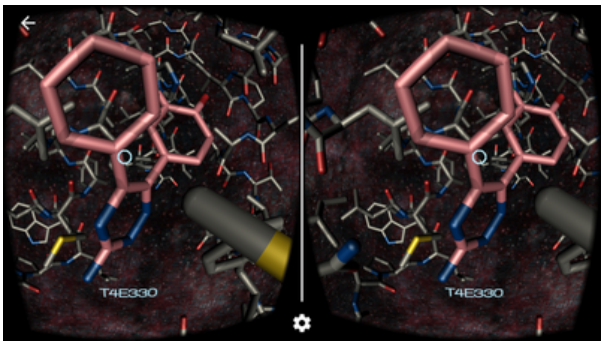


Figure 15 - Image of PROteinVR

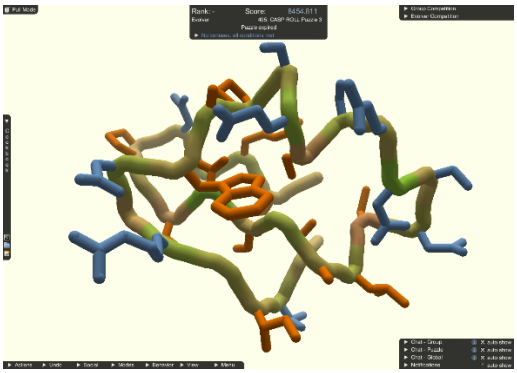
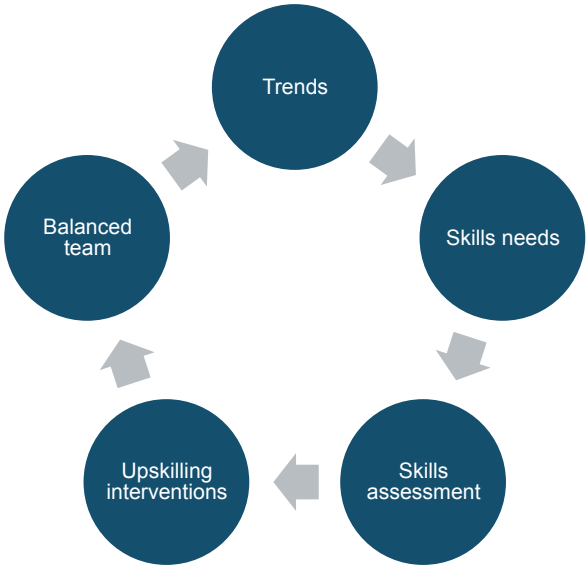


Figure 16 - Image of the FOLDIT game

- **Digital twinning for training:**
  Digital twinning is starting to be used for training as a method to deal with normal operation or maintenance but also how to react to anomalies and incidents in a realistic and safe manner. Related to this trend is the usage of e-labs to provide e-learning and real scientific experiments and data analysis tools, reducing lab costs and creating a 24/7 accessible test environment for training.

7 Summary

- We advise to use the outcome of this project to extend the ECTN frameworks with more digital skills.
- We advise to pay more attention to digital learning approaches using online learnings, virtual reality, simulations, etc.
- The project has provided a Digital Skills framework for the sector specific jobs and tasks, the differences across the sectors are not large, however in pharma the usage of digital technologies seems already more advanced of which the in-silico research is an illustrative example.
- Digital skilled lecturers/professors are a prerequisite to transfer knowledge and a train-the-trainer approach is a best practice to enlarge the learning capabilities of a sector.
- Digital awareness of senior management is a prerequisite for the digital transformation process of any organisation. Short introduction videos and use cases libraries can provide efficient learning activities.
- Micro learnings can facilitate the life-long-learning process of professionals offering learning activities to individual need at the time and place when new skills are required.
- To be able to educate and acquire new skills facilities are needed like data labs to acquire skills.
- Building an eco-system with industry (cases, expressed needs, hybrid teachers) is a best practice to align industrial needs with curriculum, upskill both trainers and professionals. The learning community model integrates learning, innovation and work at one centre is a concept that shows it value at the moment.



- In the future we can expect an acceleration of up and reskilling by applying a Skills Intelligence process to support individuals with their individual learning needs. Skills intelligence uses AI based methods to support and advice individuals on their skllling needs and training path, it starts to be used in industry and first experiences are promising.
- Joined strategies (skills roadmap) from industry and knowledge institutes.
- A process must be implemented to keep aligning courses to the needs of the industry, since the current digital skills framework due to the continuous emerging of new technologies must be updated soon.
- Adaptivity has been indicated as the main supporting skill to acquire and preparing to be able to learn how to unlearn.
- Cyber security and awareness of digital vulnerability needs more attention to be able to make informed decisions on adopting new digital technologies.
- Managers in general must get familiar with technologies to make decisions on their digital transformation roadmaps.
- Managers must also be able to create a team with the required digital skills.

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Appendix

A1 Digital skills workers

Generic skills
• Experience in interaction with digital systems using various types of interfaces. • Experts in risks and regulations as result of unsafe interaction with digital tools and data. • Experts in communicating insights in required (digital) format and system to co-workers and managers. • Ability to work with service and industrial robots using various interfaces like voice based or gestured based. • Experience with the upcoming trend of wearable sensoring. • Adaptivity, learning agility and readiness for change mainly as result of the fast-changing technology context. • Self-leadership and the skill to deal with digital self-organising teams. • Skills on intercultural competences as result of the growing diversity in teams.

	Maintenance	Operations	Logistics
Specific skills	• Knowledge about statistical process control and related asset performance metrics • Knowledge about Load monitoring technologies to collect data on components condition • Knowledge about process sensor technologies that provide data relating to output characteristics • Basic AI understanding • Ability to work with computerized maintenance management systems • Ability to work with supply chain management systems • Ability to work with order systems	• Able to work with distributed control systems • Able to work alongside co-bots • Able to work with energy monitoring systems and analyse data to optimize usage • Familiar with production process design, factory design principles and functions of different units.	• Able to work with Supply chain management systems. • Able to work with Inventory systems. • Able to work with Warehouse systems • Able to work with Tracking and tracing solutions. • Able to use the data provided by supply chain control towers. • Understands the tagging and tracing possibilities like QR codes, RFID technologies, barcodes.

A2 Digital skills managers

Generic skills	
• Able to Lead virtual team. • Able to stay accountable when using decision support system. • Able to use explainable AI technology to understand how decisions are being taken. • Advanced Translator skills. • Able to identify digital skill demand for the related teams.	• Able to form a team-based on data roles. • Familiar with concepts of Human Robotics interfacing. Knowledge about legislation on data storage and data usage. • Familiar with Concepts of Industrial data spaces. • Able to act as responsible for Cyberthreat Detection and Mitigation. • Familiar with concepts of Artificial intelligence (Machine learning, Responsible AI, and Explainable AI).

	Maintenance	Operations	Logistics
Specific skills	• Familiar with CBM maturity systems for asset owners • Knows Selection criteria for maintenance decision support systems • Has knowledge on statistical process control, physics-based models and data-driven models. • Has knowledge on Maintenance data gathering and monitoring strategies. • Has knowledge on Materials and inventory management systems and underlying philosophy • Is familiar with Digital twin components and basic architecture. • Has insights how a virtual model of the physical world enables data analysis, system monitoring to alert problems, downtime prevention, and future planning via simulations.	• Able to select and use Industry 4.0/Smart industry Maturity models for the own organization • Familiar with the concept of Cyber-Physical Systems. • Familiar with concepts of distributed robust system-wide optimization methods. • Familiar with concepts of system operation methods combining data-driven and model-driven approaches • Understands the working of Energy monitoring systems at unit, production and site management. • Has knowledge about available machine interfaces and data standards: ability to decide which standards are applicable for given application. • May Act as sponsor of digital transformation process.	• Is an expert in the criteria to select inventory tracking systems, supply chain management systems. • Is an expert in the criteria for the selection of communication software that provides real-time updates on goods movement • Has Intermediate knowledge about user models and personas for inventory and supply chain management systems. • Has basic knowledge on pros and cons of Blockchain and ledger technologies for tracing of transactions and movements of goods

A3 Digital skills employers

There is a large overlap with the skill needs for managers, but the employer has slightly different focus points

Generic skills	
• Able to Lead virtual team. • Able to stay accountable when using decision support system. • Able to use explainable AI technology to understand how decisions are being taken. • Basic Translator skills. • Able to identify digital skill demand for the related management teams • Familiar with open innovation aspects and cooperation with industry	• Aware of digital roadmaps for the sector • Familiar with concepts of Human Robotics interfacing. Knowledge about legislation on data storage and data usage. • Familiar with Concepts of Industrial data spaces. • Able to act as responsible for Cyberthreat Detection and Mitigation. • Familiar with concepts of Artificial intelligence (Machine learning, Responsible AI, and Explainable AI).

Specific skills	Pharma	Chemistry	Rubbers& Plastics
	• Familiar with digital roadmap for the pharma industry • Familiar with in silico research possibilities	• Familiar with digital chemistry roadmaps on European level (CEFIF etc)	• Familiarity with simulations about material properties like tensile strength

A4 Skill levels: Basic, Intermediate, Advanced, Expert

Skill levels are defined as follows:

Basic

Knowledge: The person has a basic or general familiarity, awareness, or understanding of the subject, technique, or concept

Skill: Basic tasks or activities can be performed

Experience: No or very little practical experience with the subject, technique or concept

Intermediate

Knowledge: The person is familiar with, aware of, or understands the topic, technique, or concept and is able to explain it to others - but not in detail

Skill: The person is able to successfully complete tasks as required, usually at an operational level. From time to time the help of an expert may be required

Experience: Some practical experience on the topic, technique or concept

Advanced

Knowledge: The person is well acquainted with the topic, technique or concept, has a good understanding of it and is able to explain it in detail to others

Skill: The person is able to successfully perform tasks associated with this skill without assistance and can support others in doing so. The help of an expert is rarely required

Experience: usually more than one year (depending on skill, it can be several years) of hands-on experience with the subject, technique, or concept

Expert

Knowledge: A person is known as an expert in that field. He or she can provide guidance and answer questions related to this area of expertise and the area in which the skill is used

Skill: The individual is able to successfully perform the tasks associated with this skill at a strategic level. Able to provide guidance and answer questions related to this skill and the area in which the skill is applied

Experience: Usually many years of practical experience on the subject, technology or concept