Bridging the Digital Talent Gap: Towards Successful Industry-University Partnerships

European Commission

INFORMATICS EUROPE

Bridging the Digital Talent Gap: Towards Successful Industry-University Partnerships

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Report prepared by Informatics Europe (Enrico Nardelli and Cristina Pereira) and the Rapporteurs of the parallel sessions in Artificial Intelligence, Cyber Security, and Software Engineering with the support of the European Commission, Directorate-General for Communications Networks, Content and Technology.

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Foreword

The rapid pace of digital transformation is changing every aspect of our lives – and is also generating needs for new skills and knowledge in the workplace. As job profiles evolve, shortages and mismatches can result, but universities may be able to help.

Looking at current data, we are concerned that the gap between the demand for advanced digital skills and the supply of suitable employees is becoming entrenched. There are currently around nine million people employed as ICT specialists in the EU – two million more than five years ago – and, based on market trends, we expect this figure to continue growing. But already today posts for ICT specialists in the EU are going unfilled. This growing structural shortage must be addressed, in order to preserve the innovation potential and future competitiveness of European businesses and jobs.

Universities have a strong role to play, but it is not always easy for them to adapt their curricula to rapidly changing needs, while at the same time providing a solid foundation for their students. To consider how we can best address the situation, we decided to co-organise the Digital Talent Gap Workshop on October 2019 in Rome, where we brainstormed ways of boosting collaboration between academic institutions and Industry. The workshop brought together representatives of universities, businesses of all sizes, and students, and focus on Artificial Intelligence, Cyber Security and Software Engineering.

Participants were encouraged to share their insights and experiences, work together to explore the issues at stake, and co-design concrete solutions for the way forward. The results of this fertile discussion can be found in this report, which will feed into the current debate on future policies, including programmes at European level like the Digital Europe programme.

Fabrizia Benini, European Commission and *Enrico Nardelli*, Informatics Europe

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Executive Summary

This report presents the results of the discussions held during the workshop *Bridging the Digital Talent Gap: Towards Successful Industry-University Partnerships* organized by Informatics Europe and the European Commission's Directorate-General for Communications Networks, Content and Technology (DG CONNECT) in Rome on October 2019.

The main goal of the workshop was to bring together Academia, Industry and Policy for an open dialogue in the search of solutions for the widespread problem of the digital talent gap in Europe. Currently, the EU is facing a systemic gap in terms of digital competences, including the most advanced. Almost all Member States face shortages for digital experts in all areas or ICT. If not urgently addressed this digital talent gap will consist in a serious threat for the future economic development of Europe.

Taking advantage of their broad networks in higher education and Industry, Informatics Europe and DG CONNECT joined forces and brought together a distinct group of people to brainstorm and propose solutions to this challenging problem in particular for the areas of Artificial Intelligence, Cyber Security and Software Engineering. Each area was the central theme of five-hour parallel sessions, where participants joined together to debate the main challenges and stakeholders, and propose solutions and recommendations.

Recommendations for **Artificial Intelligence**:

- Universities need to develop more specific master courses in the area.
- Universities need to develop curricula that are accessible to students without a specialized Informatics background (to support the creation of basic expertise in Artificial Intelligence also for experts in other disciplines).
- Universities need to include in the Artificial Intelligence curricula contents that specifically address ethical and societal issues.
- The education system needs to be more productive, insisting more on the increase of the number of skilled graduates in Artificial Intelligence, also including PhDs, which seems a rather viable solution to give EU small companies better chances to recruit talented Artificial Intelligence experts.
- More effective collaboration between Academia and Industry should exist at the stage of design and shaping of new curricula, also as part of "National strategies for Artificial Intelligence", which must give priority to actions that support this collaboration.
- The creation of an EU institute for AI, as a permanent structure, that can support the development of EU tools and platforms for research and development in AI. This institute would favour aggregation of researchers, support the dissemination of EU tools in third-level education and provide companies with a technically competitive basis to develop AI-based solutions.

Recommendations for **Cyber Security**:

- Create a common understanding about the set of knowledge and skills needed to qualify Cyber Security experts.
- Explore new ways to strengthen collaboration and create permeability between businesses and university, dialogue and constant exchange, allowing experts from Industry to contribute to teaching and vice versa. This collaboration is crucial to improving the match between supply and demand of Cyber Security skills, but also to ensuring mutual learning, pooling resources and overcoming constraints.

- Enhance and expand the offer of Universities and other higher education institutions, which should adopt more flexible approaches and, for example, design flexible learning pathways that allow students to combine academic assignments with hands-on experience in businesses.
- Extend the reach of Universities and other higher education institutions, which should provide more options, for example, for students from other disciplines who want to turn towards ICT related studies, drop-outs or professionals in search of a career change or upskilling opportunities.
- Build a pipeline of Cyber Security talents by combining actions at different levels. Already in primary and secondary schools, it is necessary to strengthen the understanding of security risks posed by digital technologies and raise awareness of the main mechanisms to protect one's own digital devices and data.

Recommendations for **Software Engineering**:

- Improve the image of Software Engineering and a broad public understanding of its benefits. This might be achieved by a much closer cooperation between Academia and Industry.
- Modern Software Engineering curricula should benefit from such a close collaboration. This might happen by dual study programs, where realistic industrial case studies are closely coupled with conceptual and fundamental aspects taught within the academic Software Engineering study program. As a base, convincing industrial examples showing the benefits of Software Engineering should be collected and should be made accessible in open-access repositories.
- Modern Software Engineering curricula should comprise multidisciplinary projects where students learn to cooperate with stakeholders from possible application domains.
- Certification programs for the Software Engineering profession as well as educational up-skilling programs in Industry should be developed. This will allow to clarify and improve the role and image of a Software Engineer in industrial projects for developing complex systems.
- All these recommendations should be further elaborated and disseminated by a working group at European level where stakeholders from universities and companies jointly develop guidelines and recommendations on how to close the gap between a research-oriented education and industrial needs. Informatics Europe could bring its broad network of academic institutions and industrial research labs in support to initiate and lead such a working group.

All parallel sessions have acknowledged that Europe needs a more open cooperation between Industry and University and that the European Commission and European associations in ICT have a key role in nurturing and fostering this cooperation. The challenges identified during the workshop equally affect all Member States, independently from their size and their industrial profile, and addressing them requires high levels of private and public investment. These challenges have to be tackled collectively, by pooling resources and expertise across Europe and encouraging Universities, research institutions and businesses to cooperate, increase the relevant training offer and contribute to create digital ecosystems able to attract, train and retain digital talent. The forthcoming Digital Europe Programme (DEP) will be a key instrument to trigger the digital transformation of the European economy and society. Among its actions, DEP will support the development and delivery of specialised Master's programmes in advanced digital technologies, short term training courses and job placements, by bringing together Academia, Research and Industry. Joint action by all stakeholders across the European Union is crucial to increasing our talent pool and making sure that Europe and its Member States develop and progress together.

1 Introduction

Technologies have always offered opportunities for competitiveness, innovation and societal improvements. Industrial machines, by empowering the physical strength of people have helped to increase productivity, delivering more products and better services with less effort and at lower costs. The quality of life has steadily improved in the past four centuries, due to this industrial revolution. Starting from the second half of the XX century a new breed of machines appeared, the "digital systems". Largely immaterial, being based on software, they contain knowledge like books. However, differently from books, theirs is "actionable knowledge", that can be put into action at our will[1]. They are therefore dramatically different from industrial machines, since they amplify the cognitive capabilities of humankind.

Digital systems offer great opportunities for Europe to stay competitive, increase its potential for innovation and remain an inclusive society. Today's most successful businesses are those that use digital technology not just to boost productivity and improve internal processes, but as a means of reinventing themselves: their operational models, their value chains and their customer relationships. Digital transformation is the term used: in order for it to materialise, people with proper scientific and engineering knowledge and skills to create, develop, roll-out, and use these digital systems are a necessary condition. This implies satisfying the growing demand for specialists in digital technologies, as well as up-skilling the EU's citizens and workforce in the context of rapid digitalisation.

Currently, the EU is facing a systemic gap in terms of digital competences, including the most advanced. While digital experts are among the most demanded professionals, almost all Member States face shortages in key areas, such as software development and analyses as well as database and networks. 53% percent of companies who tried to recruit digital specialists report finding it difficult[2]. The limited availability of proper knowledge and skills is the most frequently cited obstacle to investment across the EU (expressed by 77% of companies)[3]. The demand for advanced digital competences has been rising strongly over the past decade, with an average growth in the number of ICT specialists in employment of almost 4% a year, over the last 10 years[4]. However, supply is not keeping up with demand and the EU already lacks around 1 million ICT specialists.

An important element to consider in this scenario is the tension between the need of universities to provide solid foundations to their students, and the rapid change in competences demanded by business, deriving from the fast pace of technology. This situation is more acute in exponentially burgeoning fields such as Artificial Intelligence, Cyber Security and High-Performance Computing. In addition to that, the field has complex multifactorial ingrained problems that need to be addressed for Europe to reach a higher offer of highly skilled professionals. The most elementary being: (i) the low number of school pupils deciding for a higher education degree in Informatics[5] (resulting, among other factors, from the lack of proper teaching of the discipline in schools and the very low proportion of women among the incoming students) and (ii) the low graduation rates (a significant number of students enrol, but do not complete their studies) in Informatics Bachelor programs.

Informatics Europe and DG CONNECT joined forces to organize a workshop[6] in Rome, in October 2019, intended to debate and propose concrete solutions on possible ways of increasing the specialised educational offer in the areas of Artificial Intelligence, Cyber Security and Software Engineering. The main goals were to discuss how cooperation among universities and business partners developing and deploying digital technologies could contribute to alleviate the problem of the digital talent gap. Each area was the topic of a parallel session lead by a facilitator and a rapporteur. In the following sections, we present the report with main findings and recommendations drafted by each session's rapporteurs.

[1] E. Nardelli. Informatics: the third "power revolution" and its consequences, April 2017.
[2] European Commission, Digital Economy and Society Index (DESI) 2019, based on Eurostat data (isoc_ci_eu_en2).
[3] European Investment Bank, EIB Investment Survey 2018.
[4] Calculation based on Eurostat data (isoc_sks_itspt).
[5] We use the term Informatics, which depending on the country or source can also be referred as Computer Science, Computing, IT, ICT, Computer Engineering).
[6] https://www.informatics-europe.org/ecss/about/past-summits/ecss-2019/talent-gap-workshop.html

2 Artificial Intelligence

Rapporteur: Daniele Nardi, "Sapienza" University of Rome, Italy
Facilitator: Tanya Suarez, BluSpecs, Spain

2.1. Methodology and Process

The session on Artificial Intelligence (AI) was arranged around the following four main specific issues:

1. Competition for talent from large multinationals could be preventing deep skills from being developed and inhibiting the growth of AI research groups and SMEs/Startups.
2. To respond to the rapidly changing nature of AI and the respective markets, more innovative curricula are required at third-level education.
3. Current skills and learning are focused on existing non-European technology platforms and stacks.
4. While the technical skills for AI are being developed, developers must also understand the ethical and legal implications of AI adoption.

The methodology chosen to run the workshop, as suggested by the facilitators, was developed in two phases, that were preceded by a quick general introduction to the field (Daniele Nardi) and to the market needs (Tanya Suarez). After the introduction, five groups were formed spontaneously, with two groups focusing on the innovation of the curricula, given the number of interested attendees.

Phase 1 aimed at ***identifying a set of ideas***, through a prior analysis of *Causes, Stakeholders and Similar Solutions*. The first phase was held in the morning after the introduction and was concluded by a brief presentation of each of the five groups.

Phase 2 aimed at ***developing one or two ideas*** emerged in the first phase, through the definition of *Objectives, Impact, Key Phases, Resources*. The second phase was held after the lunch break and its outcomes have been synthesized and presented to the general audience in the final session of the workshop by the rapporteur (Daniele Nardi).

The program was undoubtedly extremely ambitious to provide well-articulated conclusions; however, the goal of reaching useful reflections and concrete suggestions for possible future actions has been to a large extent achieved.

The outcomes of this session are summarized below, which includes four sections, one for each of the four above highlighted specific issues. For brevity, we will refer to them as: (1) Talent Competition, (2) Curriculum, (3) Platform, (4) Legal and Ethics.

We close this chapter with some final remarks.

Issue 1. Talent Competition

Competition for talent from large multinationals could be preventing deep skills from being developed and inhibiting the growth of AI research groups and SMEs/Startups.

According to a study by PwC[7], the potential global gain in GDP attributable to AI could reach $15.7 trillion by 2030. Much of this gain is likely to come from companies that did not exist three years ago.

At present, Europe is home to 1,600 AI early stage Startups, with nine in ten focusing on the business-to-business (B2B) market, developing and selling solutions to other companies

According to MMC ventures, in 2018 one in twelve Startups is an AI company, but only one of the top 10 global AI unicorns is European. In fact, it is from the UK[8].

Phase 1:

Causes: the group in many ways pointed out the clear **lack (or unbalance) of resources to be committed by European research groups and Startups in hiring talents in AI**. Another relevant cause was identified in the **unsatisfactory relationship between academic curricula and Industry**, as **internships and stronger collaborations may indeed be regarded as a missed opportunity** at least for the SMEs/Startups. Finally, it was highlighted that **the attractiveness of big companies is also due to the large data resources that they already own**.

Stakeholders: the identification of the stakeholders highlighted not only the expected **triangle Academy-Industry-Students**, but also **government**, **agencies**, **facilitators** and **ecosystems**, proving that the issue is not confined to technical aspects, but it **involves society at large**.

Similar solutions: very few similar solutions were identified, and they range from **creating new specialists to specialized hiring formats**.

Ideas: the resulting ideas were largely focused on the **creation of more curricula**, with **more funding to the third-level education system** and the aim of **improving the attractiveness of the field** (not mentioned, but also relevant to gender issues). In addition, there were proposals for **creating specific forms of collaboration between Industry and Academy**, for example **co-funding academic positions and involving mentors in collaborations Academy-Industry**.

Phase 2:

In the second phase of the work, the group focused on the idea: "**Increase the number of skilled people**". The objectives that are suggested for the development for this idea are: increase of numbers (students, staff, …) and improve the relationship with companies. The pursuit of these objectives is expected to bring an impact by enabling master and PhD students to work on «industrial» problems. In this way, students are more interested by the work in EU companies and, at the same time, companies get access to state-of-the art knowledge and technical solutions. The means to develop the proposed ideas are identified in the "National Strategies for AI", which must give priority to the solution of the issues addressed here.

As final remark, the group pointed out that **bridging the gap in the talent competition is also a question of resources and the above proposed initiatives can reduce the gap**, **while really bridging it may require to mobilize a great amount of resources**.

[7] Sizing the prize. What's the real value of AI for your business and how can you capitalise? PWC, 2017
[8] The State of AI 2019: Divergence, MMC Ventures, 2019.

Issue 2. Curricula

To respond to the rapidly changing nature of AI and the respective markets, more innovative curricula are required at third-level education.

Two groups were identified to work on this topic, and the summary below reflects and combines the outcomes of both of them.

Phase 1:

Causes: the main causes that were identified from the standpoint of the current higher education offer were **the lack of involvement of companies in high level education**, **lack of dedicated curricula**, **slow reaction time of the academic environment (with significant differences across nations)**. In particular, **the difficulties of academic systems to keep the pace with the rapid development of the technology** and of the **short-term needs from the labour market** were emphasized.

Stakeholders: the identification of the stakeholders focused on **Academia**, **Students and Industry**, as expected. One group showed a broader vision including other stakeholders such as **observatories**, **unions** and **policymakers**.

Similar solutions: existing practices of curricular activities involving industries were reviewed, including **internships**, **joint PhDs** and the exchanges through the **EU student mobility programmes**.

Ideas: among the ideas that emerged from the two groups, a prominent role was given to the **creation of new specialized curricula with different aims**, including both **initiatives aiming at increasing the AI competences of ICT experts** as well as the **creation of new interdisciplinary curricula**. Another relevant idea that emerged from the discussion was the **need to improve the involvement of companies in the curricula**. The adoption of MOOCs was also suggested as a relatively inexpensive possible solution.

Phase 2:

One specific idea that was further developed in Phase 2 is the **identification of two categories of specialized Master Courses**, one for **STEM students** and one for **non-STEM students**.

The main objective is obviously **to increase the output of the education system** (i.e. number and qualification AI skilled graduates), **combined with the requirement to provide a solid background in Mathematics and Statistics**. However, a significant emphasis was given also to the need **to attract and educate profiles that received their education in subjects different from ICT, including also non-STEM disciplines**. The expected impact is a substantial increase (quantitatively and qualitatively) of the available workforce. The key step to achieve the above objectives was identified in **a strong partnership among Industry, Academia and Government**, as the basis to create **curricula that include internships and support hands-on experience, through the interaction with the non-academic partners**. The resources to support the proposed actions are expected not only from the government, but also from Industry and other stakeholders.

The idea that was developed by the second group aims at further creating competences and skills in AI, as **re-qualification of the existing workforce** as well as supporting programs of **lifelong education**. Such programs should be stimulated by specific investments and originated by a specific market analysis. The expected impact is the reduction of the talent gap, while preserving employability. It is interesting to observe that also in this case a key step is identified in the **establishment of a strong collaboration between Academia and Industry**. The specific suggestions to increase this collaboration were **the creation of joint boards, the possibility for academics to work part-time for companies and the development of joint projects, seminars and other forms of collaboration**. As for the resources, **public-private partnerships** were regarded as the basic building block, providing support for specific collaborations of the kinds highlighted above.

Issue 3. Platform

Current skills and learning are focused on existing non-European technology platforms and stacks.

This group was directly attended by the rapporteur, nonetheless the views presented below are those that emerged from the group discussion.

Phase 1:

Causes: it has been initially acknowledged that the **most deployed tools for education and training are currently provided by big non-EU companies**. They can invest large amounts of resources in internal development, typically followed by the release of open software for which maintenance is also provided. **The use of such software creates a legacy in the students, who view the companies behind such software as highly desirable targets for their careers**. The lack of resources to be invested in the creation of software tools was pointed out as the main cause for the limited use of EU tools, combined with the lack of recognition for the efforts required to make them available and maintained. In addition, entry barriers and lack of perceived quality make some existing tools less appealing.

Stakeholders: the identification of the stakeholders showed a large variety of players, including those **producing or using data**, **libraries**, **tools**, **platforms**, **cloud services**, **applications**. Also, **policymakers** were considered a key stakeholder to have an impact on this issue.

Similar solutions: some solutions in terms of EU tools, such as Rapidminer, KNIME, or the CERN-Lib were pointed out. However, they are not widely used in higher education systems: the causes are outlined above. The existing AI4EU platform is also regarded as a relevant effort in this direction, but it is still in progress and it is unclear how much it will address the algorithmic tools in addition to data repositories.

Ideas: several ideas emerged from the discussion, including **proposals to create resources**, **such as an EU cloud**, **partnerships with Industry**, **definition of open standards**, **additional regulations and dedicated funding programs to support tool development**. At a more general level, the **creation of an EU AI institute** was suggested, to support the above ideas in a coherent way.

Phase 2:

The idea that was selected for the second phase was the **creation of a European AI Institute**, that can support the creation and maintenance of state-of-the-art open tools (and open repositories). In short, creation of an EU institute like a CERN for AI (borrowed from the CLAIRE initiative). **The ambition is that such an investment would become a major instrument to foster EU leadership in AI**. The objectives to be pursued by such institute are the aggregation of researchers, the implementation of EU platforms and tools, that can have an easy access by EU companies, and become a means to bring EU research to market. The specific impacts, in addition to better positioning the EU with respect to AI technologies, could be lower time to market, lower entry barriers and exploitation of EU research from both scientific and commercial perspective.

Issue 4. Ethics and legal considerations

While the technical skills for AI are being developed, developers must also understand the ethical and legal implications of AI adoption.

Ethical and legal questions arise not only from the use of AI methods, but also from more general concerns, for example about data collection and management; however, the focus of the discussion was mainly on the specific questions brought about by AI technology.

Phase 1:

Causes: the causes that have been identified by this group were the **biases that can affect both data and algorithms**, and the **lack of transparency**. In addition, the impact on society that can be brought forward by the **risks of job losses generated by the introduction of automated solutions based on AI techniques** was highlighted. A limited technical competence of technology providers was another possible cause of problems (as opposed to the opportunity to leverage AI solutions).

Stakeholders: the identification of the stakeholders covered a large variety of roles, including **researchers**, **teachers**, **companies**, **students** and **society** at large.

Similar solutions: it was acknowledged that the **ethical and societal questions have already been embraced by the education system**, at least to some extent, by introducing dedicated initiatives. Some awareness and attention were also attributed to companies; however, it was pointed out that **large companies have the necessary resources to address ethical concerns, while for small enterprises it may be more challenging**.

Ideas: several ideas were put forward as a result of the discussion. As for the social issues arising from job losses, hope was expressed for the **development of new economic theories that suggest the appropriate actions to be taken by the governments to ensure a sharing of benefits and countermeasures to the potential drawbacks in terms of job losses**. On the ethical and legal aspect, several proposals were put forward, including the **introduction of these topics in high school**, **dissemination actions addressing the society at large**, the **production of guidelines for ethical and legal implications of the deployment of AI technology**. The general common denominator underlying all these proposals **is the creation of awareness at all levels.**

Phase 2:

The choice of the idea to be further developed follows quite naturally from the discussion in Phase 1 and Phase 2 of this group therefore focussed on the actions required to increase awareness of the ethical concerns that is now restricted to experts. It was acknowledged that such an action would require to **form specialists in ethical issues**. In addition, another key action was identified in the **introduction of Informatics and AI skills at all levels**, **from children to seniors**. It was suggested that this will generate not only awareness in society, but also provide an adequate input to the political actions that are needed to exploit the advantages and reduce the risks of AI technologies.

In practice, to increase awareness of ethical issues, it was suggested **the creation of an EU Interdisciplinary committee**. The role of the committee would be to **define undergraduate master curricula, possibly leading to a certification, and actions to recruit teachers**. The committee should also **exploit the use of mass media and social networks to disseminate the relevant messages to the society**.

The kind of resources that were suggested to implement the proposed actions, include **tools and platforms that support ethical and legal education**, possibly implemented through **well-defined guidelines and releasing certifications**. Finally, specific incentives for teachers were suggested as a way to make their continuing education more sustainable.

2.2. Conclusion

It is worth recalling that the time available made it daunting to reach well-defined conclusions and ground-breaking ideas. Nonetheless, some conclusions can be drawn, that can be taken into consideration for the subsequent developments of the EU policies towards the aim of the workshop, namely "Bridging the Talent Gap – Towards Industry-University Partnership".

Summarizing, both the groups working on curricula (Issue 2) and the group working on ethics (Issue 4) identified the **need to develop specific master courses**: in the case of the groups working on curricula the emphasis was on the inclusion of curricula that are **accessible to students without a specialized Informatics background**. The idea is to support the creation of basic expertise in AI also for experts in other disciplines. In the case of the group working on ethics, the emphasis was on the **inclusion of contents that specifically address ethical and societal issues**. In addition, **dissemination actions at all levels** were suggested to **create awareness**, **and understanding by the society at large**, of **the ethical and legal implications that the introduction of automated solutions based on AI technologies can bring about**.

The conclusions reached by the group addressing the **competition for talents** (Issue 1) also emphasized that the education system should be more productive, insisting more on the **increase of the number of skilled graduates in AI, also including PhDs**, which seems a rather viable solution to give EU small companies better chances to recruit talented AI experts. Another common element **in the design and shaping of new curricula was the need to have more collaboration between Academia and Industry**. However, there seems to be no clear consensus on the forms that such cooperation should take, while the means to develop the proposed ideas were identified in the **"National strategies for AI"**, which must give **priority to actions that support the collaboration between Academia and Industry**.

A final comment is deserved to the proposal arising from the group addressing the **need for EU tools and platforms for the AI training and education in EU third level education system** (Issue 3). The need to counterbalance the use of non-EU tools is motivated by the fact that, after study completion, graduates are attracted towards big foreign companies, thus limiting the development of AI Industry in Europe. The suggested action is the **creation of an EU institute for AI**, where **the creation of EU tools and platforms that support research and development in AI is appointed to a permanent structure**, that can favour **aggregation of researchers**, support the **dissemination of EU tools in third-level education** and also **provide companies with a technically competitive basis to develop solutions based on AI techniques that become successful in the market**.

3 Cyber Security

Rapporteur: Javier Lopez, University of Malaga, Spain
Facilitator: Alexander Riedl, European Commission, DG CONNECT, Belgium

3.1. Scene Setter

Our European society and economy are increasing their dependence on ICT as more and more simple objects can be connected to the Internet. Companies accelerate the adoption of digital technology to improve productivity and innovation capability. This comes at a cost, as it increases the risk of cyberthreats and cyberattacks. At the same time, we lack enough qualified Cyber Security experts. Therefore, growing investment in digital technology needs to be matched by a sufficient availability of Cyber Security experts and skills at all levels of the workforce.

It is highly critical for companies, education systems and public policymakers to address this issue. A number of elements need to be considered and examined. For instance, it is questionable whether there is enough training capacity and whether there are enough qualified educators. We also need to ask ourselves if Cyber Security programs should be highly specialized and technical, or, alternatively, should be more holistic and integrate human, economic and legal aspects.

3.2. Methodology and Process

The objective of the session on Cyber Security was to address the issues described above, by structuring the discussion around broad questions, such as:

- Are organisations realistically mapping the assets they have and the Cyber Security skills they miss? What kind of skills and experience are they looking for?
- What are universities offering and to which extent does the offer match the need of businesses and other organisations?
- How can businesses support higher education institutions to make their courses more relevant to their needs?
- How can more students be motivated to take up Cyber Security studies? How can we make sure that there is continuous training so that graduates' skills remain relevant throughout their professional careers?
- Are Cyber Security certifications after an Informatics degree a better solution than a dedicated degree in Cyber Security?
- To which degree should Cyber Security courses be integrated in other degrees?

With this objective in mind, the participants in the session were asked to discuss and identify main challenges to be addressed. On this basis, three discussion topics were identified and the attendees were split into three groups, each one discussing one topic: (1) Demand and supply of Cyber Security talent and skills; (2) Upskilling the labour force, and (3) Building the pipeline of talent.

Finally, the challenges and solutions analysed in each group were discussed among all the session participants for further improvement, enrichment and polishing of the results.

The outcomes are summarized in the following sections, which discuss the challenges identified and possible ideas for solutions.

Issue 1. Demand and Supply of Cyber Security Talents and Skills

When talking about Cyber Security skills, it is important to distinguish between different roles that require different (level of) skills. Three roles stand out:

- *Users' skills*: basic skills that include awareness of Cyber Security threats and risks for every employee and individual user;
- *Professionals' skills*: advanced theoretical and practical skills necessary to evaluate, forecast, handle and manage Cyber Security risks and attacks;
- *Leadership skills*: managerial, strategic and legal skills enabling good practices of Cyber Security to be part of the overall strategy of a company and of the governance of an organisation.

There are more than 600 centres (academic institutions, military academies and training centres) in the EU offering Cyber Security programmes[9].

However, the shortage of Cyber Security skills has been emphasised in various studies and working groups at the EU level (ECSO[10], JRC[11]). Looking at studies with a global perspective, for example, a report states that Europe may face a Cyber Security skills gap of 350,000 workers by 2022 (ISC[12]). At the same time, there is uncertainty about the knowledge and skills required.

These considerations suggest that it is unlikely that the gap will be filled in the short term, due to its size and the need to develop relevant curricula gradually. A holistic approach and a combination of actions are needed to respond to both short-term and long-term needs.

Challenge 1.1: in the short term, universities will not be able to produce a sufficient number of graduates.

Challenge: when trying to have a shared understanding of what Cyber Security talent means, in an ideal situation this would mean persons with an Informatics degree who, additionally, have a deep understanding of telecommunications and solid Cyber Security knowledge. However, reality shows that universities can enrol a small number of applicants annually in their Informatics and engineering programmes due to the finite number of resources (e.g. labs, professors, assistants, infrastructures). Waiting for people to obtain a specific Cyber Security degree and the related skills will not meet the numbers that businesses and the public sector will need in the short term.

Solution ideas: skills and talents with different levels of expertise must be considered. Currently, a number of people working in Cyber Security have a degree different than the one supposed necessary, or do not have a degree at all, but have obtained a certification (hence have developed the skills later on). In this setting, the **education capacity in universities and other institutions should be increased** (through actions taken by governments or through PPPs) to **train more Informatics and Engineering students** in their programmes. In addition, Universities and other Higher Education Institutions (HEIs) need to **expand and diversify the offer**, reaching out to more than only degree-seeking students and **providing specialised training, adapted to**

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[9] Survey JRC/CNECT (2018) http://publications.jrc.ec.europa.eu/repository/handle/JRC111441
[10] https://ec.europa.eu/esco/portal/skill
[11] JRC Technical Reports: European CS Centres of Expertise, 2018
[12] See: https://www.computerweekly.com/news/450420193/Europe-faces-shortage-of-350000-cyber-security-professionals-by-2022 . The study is based on a survey of 19.000 Cyber Security professionals around the world, including nearly 3.700 respondents in Europe.

different targets and people with different backgrounds. Skilled lateral entrants, aged engineers, or talented previous drop-outs need to be engaged and considered.

Challenge 1.2: a clear taxonomy of competences and mapping of the current offer is needed.

Challenge: strictly related to the previous challenge, there is the need to understand what Cyber Security skills mean, which distinctive areas of skills exist and what is the current education offer. While considering the framework offered by the US National Institute of Standards and Technology (NIST), the Association of Computing Machinery (ACM) Body of Knowledge, ECSO WG5 and efforts by four pilot projects funded by the European Commission (ECHO, CONCORDIA, CyberSec4Europe, SPARTA), a harmonized taxonomy for Cyber Security jobs and skills is clearly necessary.

Solution ideas: the European Union Agency for Cyber Security (ENISA) or the proposed Cyber Security Competence Centre and Network of National Coordination Centres (**CCCN**) may **lead the definition of a harmonized framework**, **next to the mapping of the current education offer and specialised centres for Cyber Security**. This endeavour could build on ongoing projects and initiatives at the EU level, such as:

- The taxonomy developed by the Joint Research Centre in 2017 as part of the impact assessment of the regulation for the cyber competence centres. By end of 2019, a second version of the Cyber Security taxonomy will be published.
- The Cyber Security education map prepared by ENISA (currently being updated), identifying the different universities and the type of Cyber Security programs and courses they offer.
- The Cyber Security Atlas developed by the European Commission, identifying around 660 Centres in Europe.

Challenge 1.3: lack of a comprehensive mapping of supply and demand of Cyber Security jobs, including at regional level.

*Challenge: s*kill needs and supply and demand for Cyber Security jobs differ from region to region, because of diverse economic specialisations. Therefore, a mapping of skill needs and demand-supply issues should be performed at regional and local level, for a more granular vision.

Solution ideas: a **European Observatory** building on existing efforts in skills intelligence (e.g. by CEDEFOP) could **lead a comprehensive mapping of both the demand and supply of Cyber Security jobs at regional and local level**. For the mapping of the supply side, synergies with the European Commission Cyber Security Atlas could be sought. This initiative would help shape strategic discussions and design tailored strategies, involving all the relevant players in a given geographical area.

Challenge 1.4: need for mainstreaming of Cyber Security skills in other areas.

Challenge: there is a substantial number of jobs that are not "Cyber Security jobs" but require Cyber Security skills. Thus, Cyber Security programs combined with domain specific knowledge are needed, both for digital specialists and other professionals using digital systems in their work (e.g. secure code programs for developers, data privacy and protection programs for health care providers, etc.).

Solution ideas: awareness should be raised as regards the **need to include Cyber Security skills in programmes for jobs of a different nature**. Hence, the solution proposed is to **build programmes combining cross-cutting Cyber Security competences with specialized domain-specific ones**, based on guidelines and incentives, for example by the European Commission.

Issue 2. Upskilling the labour force

The education system has to provide students and the existing labour force with the skills and knowledge needed on the labour market.

Challenge 2.1: lack of suitable resources, facilities, programmes

Challenge: there are not enough suitable training resources, cyber labs, trainers and teacher training.

Solution ideas: resources and facilities for training and learning **need to combine an academic orientation and a setup relevant for businesses**. A good example mentioned was the Fraunhofer Cyber Security lab in Germany. This would also allow more SMEs to be involved in Cyber Security programmes.

The lack of teaching resources needs to be addressed by creating **more permeability among higher education, businesses and the public sector**. Professionals need to be incentivized to share their knowledge and experience with students, an action that would also contribute to make skills acquired at the University more relevant to businesses' needs.

Challenge 2.2: university leavers

Challenge: often, students leave university with only basic knowledge, do not complete the studies or stop at the bachelor degree (because they are lured away by attractive jobs). The challenge is twofold: first, to create opportunities for university drop outs who have useful skills for companies; secondly, to create incentives for students to continue studying and get a master's degree whilst working.

Solution ideas: **special courses** could be created **for drop-outs and career shifters**. To keep students after a bachelor degree, there is a need for more **"dual degree" flexible MSc courses**, **combining part time work in the Industry and study at the University**, modelled along existing good practices in a number of Member States. This combination would help student to implement their Cyber Security skills and to better understand real-life security issues. In parallel, by offering more flexibility, these hybrid courses could contribute to retain students in education.

Challenge 2.3: SMEs unaware of or unable to tap into training

Challenge: most SMEs have a local reach and do not have information about or the means to participate in EU programmes devoted to SMEs.

Solution ideas: in order to support SMEs, it is necessary to create an appropriate **collaboration with SME associations**, and promote **networking through Cyber Security clusters and specialised regional innovation hubs**.

Issue 3. Building a pipeline of talent

Building a pipeline of talent means attracting enough students in this field. These efforts need to start in school and need to be supported by all stakeholders.

Challenge 3.1: attracting students

Challenge: a major issue is to attract enough students to university courses in Cyber Security, including women. However, next to the lack of clarity on the skills needed in order to qualify as a Cyber Security expert, there is also a low awareness about cyber risks and the need to be protected.

Solution ideas: **building awareness of the importance of Cyber Security**, and the implications of cyber risks, is a first step towards the creation of interest in this field and the attraction of students. Communication and awareness raising should start with pupils in primary school, and be continued in secondary schools, to increase interest in these technical topics and facilitate the selection of a degree in Informatics or Cyber Security later on.

Secondly, it is important to **communicate about the job opportunities offered by an education in Cyber Security, the quality of these jobs**, the **possibilities to expand** in other areas and the **overall societal implications**. Young people are motivated by the challenge of making the world a better place. Convincing them that digital technology is an essential tool to achieve this will attract more of them to enter into these degrees and professions. Student associations may play a major role in this respect.

Challenge 3.2: transfer of knowledge

Challenge: raising awareness about Informatics as a discipline at school is valuable, but there needs to be collaboration between higher education, companies and schools that, currently, rarely exists.

Solution ideas: to address this issue, it is necessary to empower students to build a sort of cascade system, with the support of stakeholders (businesses, cyber law enforcement agencies, higher education). The idea is to create a **cascade of trust to transfer Cyber Security knowledge and experience and raise interest**. **Students are the key connectors in this chain**, so that knowledge is transferred from university to secondary school pupils, and down to primary school. Teachers and parents should get involved along this chain with an active role on Cyber Security awareness raising.

3.3. Conclusion

The workshop session represented an opportunity to discuss a number of issues and provided several suggestions that can be further developed in the context of EU policies. At this stage, some general reflections can be made.

First, there is a need to **build a common understanding of the set of knowledge and skills needed for a person to be qualified as a Cyber Security expert**. Such effort could build on and bring together the work already ongoing at the EU and international level.

Secondly, exploring new ways to strengthen collaboration and **creating permeability between businesses and university** emerged as an important underlying topic. **Dialogue and constant exchange between education institutions and businesses are crucial** to improving the match between supply and demand of Cyber Security skills, but also to ensuring mutual learning, pooling resources and overcoming constraints. In this view, **new models are required**, **allowing experts from Industry to contribute to teaching and vice versa**, **students and academic staff to develop experience in Industry**.

Strictly linked to the point above, another message emerged between the lines: **Universities and other higher education institutions are called to adopt more flexible approaches and expand their offer**, **in order to remain relevant and respond to a rapidly changing context and Industry needs**. On the one hand, this means designing flexible learning pathways, allowing students to combine academic assignments with hands-on experience in businesses. On the other hand, higher education institutions should provide more options and extend their reach to, for example, students from other disciplines who want to turn towards Informatics studies, drop-outs or professionals in search of a career change or upskilling opportunities.

Finally, although the focus of the workshop was on higher education, a pipeline of Cyber Security talents can only be built by a combination of actions at different levels. In other words, **already in primary and secondary schools**, it is necessary to **strengthen the understanding of security risks** posed by digital technologies and **raise awareness of the main mechanisms to protect** one's own digital devices and data.

4 Software Engineering

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4.1. Scene Setter

Software is a key factor of any innovation of today. Advances in mobile data networks and embedded systems have enabled the advent of the software-everywhere era, where computational resources are available in cloud, as well as in mobile and IoT devices. Thus, the development of new software as well as the migration, evolution and adaptation of existing software, due to changed requirements, is at the core of new products or services in any application domain. This is paired with a highly increased complexity of nowadays software as well as steadily decreased time-to-market demands. Also, the role of humans as users of software has changed, as users are nowadays more demanding and expect systems that are easy to use and understandable. Thus, it is expected that systems adapt themselves (both in their user interface and behavior) to the needs of individuals to gain appropriate acceptance. Lastly, software has not only to comply with standard quality characteristics, but also to obey social, legal, moral and ethical values.

All this has not only lead to an enormous demand for software engineers during the last decade, but in particular for highly-skilled people who are able to cope with the novel challenges of human-centric, intelligent software systems deploying novel technologies, while requirements and contexts are changing continuously.

Modern software engineers need to have multifaceted skills. They have to understand application domains and be able to speak to domain experts with an education in another discipline. They have to master agile development techniques, to deploy novel technologies and tools, to incorporate algorithmic services based on AI and machine learning techniques. They have to understand the role of humans as users and prosumers, they have to understand the potential of new network models and connected devices, to be able to exploit frameworks to enhance productivity, and to cope with the right choice of values.

There have been various international initiatives in the past, to come to a uniform view on what Software Engineering is and what is an appropriate curriculum for an academic degree program in Software Engineering.

The most prominent initiatives are, first, the SWEBOK, the *Guide to the Software Engineering Body of Knowledge (SWEBOK Guide)*. It describes generally accepted knowledge about Software Engineering. Its 15 knowledge areas summarize basic concepts and include a reference list pointing to more detailed information. The *SWEBOK Guide* has also gained international recognition as ISO Technical Report 19759.

Second, the IEEE/ACM 2014 Curriculum Guidelines provide detailed information on an appropriate curriculum content for undergraduate degree programs in Software Engineering.

While these documents provide excellent information about Software Engineering as a subject, as well as appropriate curricula, it is a matter of fact that there is a huge shortage of software engineers in Industry. And due to the very low numbers of Informatics students in academic studies, this shortage will tend to increase in the future. All this will seriously hinder a surely desired socio-economic growth in Europe.

Thus, the main questions addressed during the parallel session were:

1. What are the required skills of modern software engineers in Industry?
2. What can we do to increase the number of modern software engineers in Europe?

3. What can we do to provide on-the-job learning and qualification processes to software engineers in Industry?
4. What can we do to attract more students to become a modern software engineer?
5. How can we incorporate Software Engineering concepts in studies of other disciplines?

4.2. Methodology and Process

These questions were discussed by around 30 representatives from Industry, Academia, and Policy at the Software Engineering parallel session of the Talent Gap Workshop in Rome. The session was organized as a highly interactive event. It consisted of two iterations of 125 and 85 minutes, respectively. The **first iteration** started with a **plenary brainstorming on exploring challenges and discussing ideas for reducing the size of the talent gap**. Each participant contributed with several post-its naming possible challenges. At the end, the mentioned challenges were clustered by identifying three main thematic topics:

1. The inside view of Software Engineering
2. The outside view of Software Engineering
3. The interrelation of Academia and Industry

Following, in the **second iteration**, **the whole group was split into three subgroups according to the three identified thematic topics**. Each of them focused on and refined one thematic topic and came up with identification of challenges, derived solution ideas and recommendations which can be implemented in short-term. The whole process was guided by the facilitator of the parallel session, while the rapporteur took notes and gathered the results.

4.3. Identification of Challenges and Solution Ideas

Iteration 1. Collecting challenges and clustering them

The outcome of the first iteration was a clustering of challenges named by participants into three thematic topics. For each thematic topic, we list some of the mentioned challenges.

Topic 1: the inside view of Software Engineering

The inside view of Software Engineering deals with a thorough understanding of what Software Engineering should cover thematically. This should directly be reflected in the design of appropriate Software Engineering curricula.

While there are standardized descriptions of what Software Engineering is (e.g. SWEBOK) and how a standard curriculum should look like (e.g. ACM/IEEE Guidelines), it became obvious in the discussion that those documents were not well-known by the participants. Thus, the outcome was indeed a broad list of personal opinions about what Software Engineering is. Besides standard topics, **the role of human factors, soft and communication skills, as well as social aspects and creativity in Software Engineering were stressed**. There was also an agreement that **there is a cultural shift from programming to model-driven development**.

Concerning learning and teaching Software Engineering, it was agreed that **there is a need to teach more effectively, to let the students "feel" the need of Software Engineering techniques in commercial software**

development. **Life-long learning** and **mass education**, as well as **new forms of agile teaching**, are key in Software Engineering.

Finally, it was agreed that, to attract more talent, the fact that Software Engineering provides a great opportunity to solve and contribute to the 17 sustainable development goals defined by the UN should be mentioned to young people with a possible interest in the domain.

Topic 2: the outside view of Software Engineering

The outside view of Software Engineering deals with the image of Software Engineering as it is understood by stakeholders in Academia and Industry. **A realistic understanding of what Software Engineering is**, might **help to make the profession of software development more attractive**, as well as **to prevent misconceptions of prospective students** looking and deciding for the right study program.

The outcome was, also in this case, a broad list of suggestions of what might help to improve the image of Software Engineering. Important suggestions were e.g. **to clearly define what Software Engineering is**, to **clarify and valorize the role of a software engineer**, and to **understand how we can offer a much better perception of what we are as software engineers**. This might even end-up in a new attractive name for Software Engineering that encompasses much better its close links to many other disciplines, and its social and creative aspects.

Topic 3: the interrelation of Academia and Industry

Besides an academic view on Software Engineering and an academic understanding of what are the right topics of a Software Engineering curriculum, it is important to clarify the needs of companies to define the right skills of software engineers.

The outcome of the discussion was that **a closer cooperation between universities and potential employers in the co-design of modern Software Engineering curricula might help**. This might end up **in a Software Engineering skills catalogue from an industrial viewpoint**, which **expresses that companies need problem solvers and application engineers with Software Engineering skills**. In addition, **university degrees might be coupled with university-led certifications**, and a **Software Engineering certification scheme acknowledged by the Industry** might be set up.

Iteration 2. Identification of solution ideas and recommendations

In the second iteration, the three subgroups focused on and refined the thematic topics to identify challenges, stakeholders, causes, solution ideas, recommendations and needed resources, which might be installed in the short term.

Topic 1: the inside view of Software Engineering

Challenges: the main challenge is related to gaining an **understanding of Software Engineering teaching at all levels of a University study programs**, as well as in the context of re-training and upskilling of professionals. In addition, it was stressed again that there is **need for a better understanding on how to attract more students aiming at becoming a software engineer, in particular more female students**. All this should be reflected in the design of appropriate Software Engineering curricula and training programs for these diverse groups.

Stakeholders: Designing appropriate Software Engineering curricula and training programs involves many different stakeholders. They range from **professors** and **teaching staff members** to **students** on the university side, but also from **ICT professionals** to **potential users of ICT** systems on the industrial side.

Causes: The participants agreed that there seems to be a strong misconception, by many stakeholders, of what a software engineer is. It seems not to be broadly known that there are different roles in Software Engineering, ranging from requirements engineers, architects, designers, coders to maintenance people as well as to project managers, method engineers, masters of agile methods and so on. **An understandable definition of the mission of a software engineer is missing**, something that young people can think of and decide to pursue, which includes also social skills and values.

Solution Ideas: There was a strong agreement that **already in the design of appropriate Software Engineering curricula and training programs all potential interested groups should be involved**. It has to be conveyed that **Software Engineering is about creating trustworthy, dependable software systems to support all aspects of human life and society**. This does not mean programming and coding only, but also understanding the problem domain and define the boundaries between this domain and the software system, to identify and evaluate various different alternative solutions, to plan for and develop a solution, and to verify and certify it.

Nowadays systems are complex systems, which have to be developed in a multidisciplinary way. Thus, **students' participation in multidisciplinary projects – across faculties at universities – has to be fostered**. **There should also exist a much better story-telling of what Software Engineering is**. This might be done by a kind of **Software Engineering manifesto, which includes examples from AI/Machine Learning and Informatics**.

Lastly, **it should be shown more explicitly how Software Engineering can contribute to the 17 sustainable development goals defined by the UN**.

Recommendations: modern Software Engineering curricula should benefit from a closer collaboration between universities and companies.

This might happen by **dual study programs**, where students focus on conceptual and theoretical aspects at universities and on practical ones at companies. The study content at universities could be improved e.g. by videos or webinars provided by industrial partners where realistic, industrial requirements analysis activities are shown to the students. Also, **companies might open internal project management meetings to students as visitors to illustrate realistic case studies**.

On the other side, guidelines should be developed for universities on how **to involve students in multidisciplinary projects** during their Informatics study.

On the industrial side, **certification programs for the profession of a software engineer** should be developed. This will allow to clarify and improve the role and image of a software engineer in industrial projects for developing complex systems.

All these recommendations should be further elaborated by a **working group at the European level** where **stakeholders from universities and companies** jointly develop **guidelines and recommendations on how to close the gap between a research-oriented education and industrial needs**.

The results of the working group should be **disseminated by an appropriate communication campaign** in a broad way at all European universities and companies who deal with the development of complex software systems of the future.

Resources: the intended working group as well as the planned communication campaign needs additional financial support to bring together experts, to conduct appropriate empirical studies, to develop dedicated guidelines, and to disseminate them. To support these actions, additional resources are needed. Informatics Europe could bring its broad network of academic institutions and industrial research labs in support to initiate and lead such a working group and to disseminate its results.

Topic 2: the outside view of Software Engineering

Challenges: the outside view of Software Engineering deals with a redefinition of its image in and for the society. As said above there seems to be **strong misconception by many stakeholders of what Software Engineering is**. This hinders the attraction of more software engineers as students and as future employees. In addition, this issue does not incentivize existing programmers in Industry to participate in upskilling programs to become a modern software engineer.

Stakeholders: a better understanding of the benefits of high-quality Software Engineering affects many different stakeholders. This ranges from **customers and potential future users of software systems** to **software developers** and **programmers** on the industrial side, but also to **researchers** and **teaching staff** members on the university side.

Causes: the benefits of applying rigorous Software Engineering techniques are at a first glance intangible. Thus, customers are quite often not willing to pay a huge amount for deploying Software Engineering techniques as they do not see any immediate impact on the quality of software. They do not understand that intensive efforts in e.g. eliciting requirements, in designing extensible software architectures, or conducting an extensive testing have an impact on software development costs on the longer run. In general, an understanding of the economical reward for Software Engineering is missing.

Solution Ideas: Software Engineering as a discipline has grown up to be well established within the last 50 years. However, **society still lacks an appropriate understanding of what Software Engineering is** and what software engineers are doing. **A communication campaign** might enhance this understanding, **by presenting real-life examples and demonstrating the practical impact of Software Engineering on our society and the life of individuals**.

Also, **the image of the profession should be strengthened**. This might be realized by introducing internationally recognized Software Engineering certifications for professionals which allows to check and state dedicated skills of a Software Engineer. Synergies can be exploited with existing awareness-raising campaigns aimed at bridging digital skill gaps.

Recommendations: measures are needed to **communicate the role and benefits of deploying Software Engineering techniques to a broad audience in society**. Communication experts should be engaged to disseminate the characteristics of Software Engineering. Modern dissemination techniques like blogs, webinars and maybe even a dedicated TV soap might be used. Also, existing software engineers in Industry might be trained as ambassadors.

As a base, **convincing industrial examples** showing the benefits of Software Engineering should **be collected** and should **be made accessible in open-access repositories**. Altogether, the discussion on the image and definition of Software Engineering should be renewed.

Resources: additional resources are needed **for the planned communication campaign**, for **building the open-access repository of best practices** and for a **working group for renewing the definition of modern Software Engineering.** Successful communication/awareness-raising/literacy campaigns can be taken as a model and possibly leveraged to expand the outreach and the impact. Informatics Europe could offer an excellent environment to initiate such a communication campaign, to set-up a repository of best practices and to lead the mentioned working group and to disseminate its results.

Topic 3: the interrelation of Academia and Industry

Challenges: Software Engineering is an engineering discipline with close links between research-based concepts and techniques and their applications in an industrial context. It is a discipline where both sides – Academia and Industry – can benefit of each other, and where each side needs the other one to improve. Research relies on concrete experiences with applying methods and tools in an industrial context, while Industry deploys research outcomes to improve efficiency and effectiveness of software development. Measures are needed for a better exploitation of research results in Industry as well as a better use of industrial experiences in an academic Software Engineering education.

Causes: the amount of industrial software development has dramatically increased during the last decades. Thus, due to the insufficient availability of trained professional software developers, career changers were employed to work on software systems. In addition, due to the steadily increasing time-to-market pressure, software development focus quite often on a fast implementation by coding in a programming language, and spending less time on activities like a deep requirements elicitation or sufficient testing. Thus, there was insufficient capacity and skills available on the industrial side to disseminate successfully research results in Software Engineering to industrial applications. On the other side, advanced industrial ICT companies developed their own dedicated Software Engineering techniques as academic researchers did not always address the real needs of industrial software development. Altogether, the gap between academic Software Engineering research and industrial usage of Software Engineering techniques increased during the last decades.

Solution Ideas: in order to make Software Engineering research results deployable in industrial applications and in order to let Software Engineering research understand the real needs of industrial software development, the gap between these two sides has to be decreased. **Flexible academic study programs are needed that react to the dynamism of industrial Software Engineering advances in a timely manner**. This might be realized **by promoting dual programs where companies and university closely cooperate**. In order to **upskill industrial software developers including career changers, specific programs and measures should be established.**

Recommendations: specific **projects on cooperative programs must be initiated**, **where both universities and companies have to be active players**. Those projects might range from **cooperative projects where experiences and best practices of Software Engineering are mutually exchanged** to educational **up-skilling programs**. Mechanisms might be found to ease the participation of professionals in academic programs. This ranges from academic course materials which are made available to those who are already working in Industry to involving industrial professionals in academic teaching programs.

Resources: additional funding is needed to realize above mentioned measures. As this is of high relevance for both Industry and Academia, **a combination of public and private funding might be aimed at**, especially for those activities involving up-skilling programs. Informatics Europe could bring its broad network of academic institutions and industrial research labs in support to initiate and coordinate those cooperative projects where Academia and Industry are involved.

4.4 Conclusion

As software is everywhere and software is the key of any innovation nowadays, effective and efficient Software Engineering techniques are urgently needed for a healthy grow of the European economy and society. The discussions within this parallel session on Software Engineering have shown that there is a strong need in increasing the number of high-quality software engineers in Industry. Discussed measures are that the number of enrolled students as well as graduates in Software Engineering have to be dramatically increased. Also, the number of upskilled employees in Industry has to be increased. Furthermore, the image of Software Engineering and a broad public understanding of its benefits have to be improved. All this can only be achieved by a much closer cooperation between Academia and Industry, as modern Software Engineering techniques rely on the interplay of academic research results and industrial deployment and experiences. To achieve this, additional resources are needed for cooperative measures. Informatics Europe could offer an excellent environment to initiate and coordinate those cooperative measures on Software Engineering topics where Academia and Industry are involved.

5 Overall Conclusions and Recommendations

The Digital Talent Gap Workshop featured in-depth discussions in three different areas of Informatics: Artificial Intelligence, Cyber Security and Software Engineering. Each area has its own challenges and issues, however they share many common foundational problems and some of the solutions proposed by the participants would be beneficial to all them. Here we summarize a few common emerging points, and some general reflections.

First of all, the need for a **more open cooperation between Industry and University**, that, while respectful of their diversity of goals and approaches, enables both spheres to use the rapid evolution of digital technologies for mutual advantage. A workforce with a solid academic foundation is better prepared, in the long run, to reap the full benefits of the ongoing digital transformation in society and the economy. The capability of Industry to rapidly answer to these changes is something that can be of great help in students' education. Creativity and availability to collaborate without the fear of losing identity are qualities that will be essential for this to succeed.

Second, the need of **being interdisciplinary and open to societal inputs**. Our society is clearly more and more depending on and affected by digital devices and applications. Both University and Industry have to open themselves to these challenges and work on them with an interdisciplinary approach to avoid on one side the risk of demonisation of ICT and on the other, the danger of transforming technology in a tool for oppressing freedom and democracy.

Third, there is an **absolute need to raise interest, among students, in the knowledge that will be more and more shaping every aspect of our life**. This process has to start much earlier than when students choose their professions. Scientific disciplines that are at the basis of the current industrial society are present since the very first years in school. This allows children to become aware very early of the fact that science and technology are not magic, but a rational construction of humankind. This awareness also enables them to decide, should they wish, to take a job in a technological area later on, with a reasonable understanding of its nature and to contribute to the design, deployment and maintenance of digital systems. For our society to be able to have enough students, including enough female students, entering academic studies aiming at ICT professions we need to introduce Informatics as a scientific subject since the early years of school. We also need an appropriate communication campaign enabling every citizen to understand the true nature and the importance of this science.

Last, but not least, all parallel sessions have acknowledged that the European Commission and European associations have a key role in nurturing and fostering the cooperation and openness described above, also through actions aiming at developing European approaches and platforms allowing the EU to be a leader in technology and to attract and keep digital talent. These challenges equally affect all Member States, independently from their size and their industrial profile, and addressing them requires high levels of private and public investment.

These challenges have to be tackled collectively, by pooling resources and expertise across Europe and encouraging Universities, research institutions and businesses from Member States to cooperate, increase the relevant training offer and contribute to create digital ecosystems able to attract, train and retain digital talent. EU funding can support these efforts, by contributing to overcome resource constraints and the lack of scale in specialised educational offers in digital. The forthcoming **Digital Europe Programme (DEP)** will be a **key instrument to trigger the digital transformation of the European economy and society** and build **advanced skills** in **key digital technology areas such as AI, Cyber Security and High-Performance Computing**. Among its actions, DEP will support the development and delivery of specialised Master's programmes in advanced digital technologies, short term training courses and job placements, by bringing together Academia, Research and Industry. Joint action by all stakeholders across the European Union is crucial to increasing our talent pool and making sure that Europe and its Member States develop and progress together.