OPENING DOORS

Opportunities and education in networked innovation for new graduates with PhDs using open online resources

Science with and for Society in Horizon 2020

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Skill profiles of PhD graduates for open science and open innovation environments

D1.2

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List of Acronyms

Acronym	Explanation
OS	Open Science
OI	Open Innovation

Executive Summary

The study presents findings from skills intelligence in open science (OS) and open innovation (OI) within Opening Doors project. Employers both within and outside the academic world and employed PhD graduates and students in the Czech Republic, Ireland and Denmark were interviewed. Job postings aimed at research vacancies were reviewed to identify key skillsets useful in broadly defined OS and OI environments, to serve as a basis for a design of a corresponding online PhD module. Five skill profiles of PhD graduates have been identified:

1) Collaborative and interdisciplinary research – ability to create a collaborative network consisting of researchers and other professionals with various backgrounds, awareness of different expectations.
2) Practical applicability of research results – identifying users of research outputs, goal-oriented approach to research, seeking practical experiences during a PhD.
3) Involving wider public in research – realising a value of research for society, explaining research to non-experts, defending the need of funding.
4) Use of open science tools – considering benefits of open access publishing of data, code or outputs, ability to find and use available open data, creating open education resources.
5) Career planning – considering future career options early enough during a PhD study, realizing of own skills, acquired during a PhD, ability to see them in outside a research project topic.

Introduction

This report presents the findings from Work Package 1 of the project Opening Doors. The work package was focused on identifying highly qualified workers' skills required by employers active in open science (OS) and open innovation (OI) in the Czech Republic, Ireland, and Denmark ("skills intelligence"). The aim of the work is to provide a basis for a subsequent design of an open online PhD course aimed at skills needed in OS and OI. The skills intelligence consisted primarily of semi-structured interviews with employers, employed PhD graduates or students and educators of PhD students, and of job postings review.

Methodology

The skill analysis as well as the entire project rests upon the concepts of open science and open innovation. We understand **open science** as practices that enhance accessibility and transparency of scientific procedures and outputs (open access, open data, open source code), and as efforts to encourage scientific cooperation within and across organisations, disciplines and individuals. Under **open innovation** we understand cooperation of organisations in innovating products, services and processes, and sharing of relevant valuable knowledge.

The core method of the skills intelligence was semi-structured interviews. Three groups of respondents were recruited: employers (from academic, state, business and NGO sectors), PhD graduates or students employed outside academia and representatives of institutions that provide education in fields related to OS, OI or entrepreneurship (educators). In April and May 2021, a total of 35 interviews were carried out in Ireland, Czech Republic, and Denmark, out of which 18 were with employers (6 academic, 2 state, 9 business and 1 NGO), 9 PhD graduates and 1 PhD student in employment, and 7 educators. The full list of the conducted interviews is in an appendix, including codes of interviews that we will be using throughout the study. The codes consist of a country marker (IE for Ireland, CZ for the Czech Republic, DK for Denmark), of a respondent type marker (EMP for employers, PHD for PhD graduates or students, ED for educators) and of a number of the interview within each group of respondents within each country.

The interviews explored the following core topics:

- What transversal (field-unspecific) skills employers active in OI / OS value the most at their highly qualified workforce
- What skills (specific for OI / OS but also other skills) do PhD-level employees lack and/or need to develop for the future
- What is employers' experience with hiring PhD graduates
- How has PhD education prepared the students and graduates for their current roles
- Where the employers and PhD students/graduates see possibilities for PhD education to improve

The respondents were also asked about their understanding of open science / open innovation, about activities of their organisation or their own activities within the organisations with a focus on research and innovation. Interview guides were developed to structure the interviews, based on a previously agreed framework (please Deliverable 1.1 "Guidelines for skills intelligence in Open Science & Open Innovation").

In addition to the interviews, a review of job advertisements of research-related vacancies was undertaken. Academic (universities, academies of science) and other job postings, potentially aimed at PhD graduates, academic and other job postings were reviewed to identify skills and tasks related to teamwork and cooperation, and skills associated with other fields than the focus of the positions (in search for interdisciplinarity) and other transversal skills. Vacancies were retrieved from popular national and European job portals and from the websites of academic institutions. The following keywords were used for filtering relevant non-academic advertisements: “open science”, “open innovation”, “PhD” (as a requirement or advantage for the candidates) and “research” (limited to university-degree jobs). In total, 443 academic and 408 other job postings were reviewed across the three countries. We will refer to the three country reviews as “Job postings CZ”, “Job postings IE” and “Job postings DK”. A non-exhaustive review of existing courses for PhD researchers in open science and/or open innovation was also undertaken in April 2021, reported in Appendix 1.

Research and innovation activities other than typical for academic job roles

Universities traditionally carry out long-term research as one of their core activities and can use direct and grant-based public funding for it. The position of research in private enterprises, state organisations and NGOs is much less clear-cut and more diverse in their motivation, forms and funding. In this section we will present modes of research and innovation and related activities in the interviewed organisations that diverge from typical academic research.

Research and development for own commercial use

The clearest reason for research and development (R&D) in enterprises is subsequent sales of new or innovated products or services. However, such activities can be demanding on funding and don’t always lead to successful sales, especially if complex solutions are researched and developed. Long-term R&D can much more easily be done in businesses with large reserve funds or with access to public funding for R&D. For example, a biotechnology company (CZ_EMP_03) was founded as an investment project of a large financial group. The company develops a specific medicine and so far, has not generated any profit which may only come after the product will be introduced to the market. A department dedicated to (partly even basic) research was found in a multi-national IT company (CZ_PHD_03) and in companies who were successful in applying for publicly funded grant projects (CZ_PHD_02), for which personnel links to a university is an advantage (CZ_EMP_04). Another large company is currently allocating more attention and funds to research in order to make a technology-driven change in their business (DK_EMP_03). On the other hand, start-ups and other small companies usually cannot allocate resources to R&D oriented at insecure goals in a distant future and instead are driven by current needs of the customers and by ideas, collected along the way (IE_EMP_05, CZ_PHD_01). However, even among start-ups and small companies, a strong commitment to R&D is sometimes found, usually with a significant technology dimension (DK_EMP_01, CZ_EMP_05). *The focus of PhD education on a single several-year long project is clearly a format very rarely seen in commercial R&D.*

Institutional or personal links to academia

Among the interviewed public-sector employers, museums in Denmark (DK_EMP_04, DK_EMP_05) and a Czech hospital (CZ_PHD_05) had specific institutional connections to a specific university in their respective cities. The connections in all these cases involve hosting PhD students of the universities for significant periods of time. The interviewed museums and hospital create conditions for an interaction between academic research, applied research and practical application or popularisation of the research results. In case of private companies, various forms of contacts with academia were reported by the interviewees. These include the origin of a company in a university environment (IE_EMP_05, DK_EMP_01, CZ_EMP_04), activities in transferring technologies or knowledge from academia to other sectors (IRL_ED_02, CZ_EMP_05) or continuing engagement of staff at universities (CZ_PHD_01). All these settings and situations more or less systematically facilitate spreading research mindsets and practices outside academia.

Research projects with outputs used outside the organisation

Some organisations across sectors are applying for state funding of applied research projects, whose results are used elsewhere than in the organisation itself. The clearest example of such an orientation is a Czech private company (CZ_EMP_02) that focuses on projects in natural sciences, especially circular economy and related fields. These projects are usually carried out in cooperation with other organisations and the users of the outputs are regional authorities and other public sector entities. The company pursues a specific employment strategy that is based on ad hoc hiring of experts for specific projects while maintaining a minimal core team. Similar forms of research are also found by other employers, e.g., contract research for public authorities, although to a relatively smaller extent compared to the overall activities of a given organisation (DK_EMP_04).

Promoting science to wider audiences

Some jobs include a emphasis on communicating one's own or colleagues' research results to non-expert public. Strong commitment to promotion of research is demanded from museums (DK_EMP_04, DK_EMP_05). A specific job role aimed at promoting science, called education and outreach manager, is performed by a PhD graduate at an Irish university (IE_PHD_04). Such jobs broaden employment opportunities for candidates with a science background or at least interest, and are in line with the requirement that science follows societal needs and not only individual passions of the researchers (DK_PHD_01). As a consequence, scientists need to be able to communicate their research in different ways than they are used to when addressing fellow experts.

Innovation consulting

Another indirect form of engagement with R&D is business-to-business (B2B) consulting services in the area of innovations, which is a case of the employer of an interviewed PhD graduate (IE_PHD_03). While the company consults innovations in sports technologies, the interviewee spoke about blending technical knowledge with social sciences, arts, and humanities, in order for their clients to understand the effects of the technologies on individuals and on the society. Innovation consulting is an important part of business also for some other interviewed employers with a significant share of PhD-level employees (CZ_EMP_02, CZ_EMP_05).

Understanding and practising of open science among employers and employed PhD graduates / students

The interviewees were asked what they understand under the terms open science and open innovation. For open science, the first connotation was usually open access publication of research outputs or of data. This was by some respondents recognised as a generally positive phenomenon with growing promotion on the EU level, although specific strategies in this respect are often lacking by employers, as admitted, for example, by DK_EMP_05. Among the benefits for individual researchers, visibility of their work is the clearest one (CZ_ED_02). The same principle may be the case at the level of organisations – a Danish employer who carries out both academic and commercial research attracts potential customers by open access publishing (DK_EMP_04). A strongly demotivating factor for researchers is a pressure to publish in high-impact publications that are usually closed behind a paywall (IE_ED_03, CZ_ED_02). Among broader concepts related to interviewees' understanding of open science, democratisation of research appeared. According to the representatives of the field of digital health, the worlds of clinical and technical research should open to the needs of all societal segments that they want to serve by their solutions and so become more democratic than now (IE_EMP_08), more diverse in representation (IE_EMP_06) and give the public who is impacted by the research a voice (IE_PHD_04). A similar trend is also seen in the field of architecture where the affected citizens have been given more of a voice than in the past (CZ_PHD_01). Interviewees across sectors and disciplines spoke about the need of opening of the traditionally individual "siloed"[1] research on three levels: to immediate collaborators, to other researchers including those from different disciplines, and to the general public.

"Open innovation" resonated less with the interviewees. When asked about practices, possibly related to the concept, private-sector employers mentioned various forms of research collaboration but mainly with academia (IE_EMP_06) where open innovation might resemble commercialization (IE_ED_02). For other entities, collaboration on innovations lies in outsourcing of activities that are outside of the core business of the company (e.g., CZ_EMP_05, CZ_PHD_04). Important know-how is usually protected during collaboration with other companies or universities[2] and a trend for relieving this approach in the interest of gaining benefits from thoroughly collaborative R&D did not really emerge from the interviews. On the contrary, scepticism was expressed regarding the possibility to reconcile truly open innovation with generating profit (IE_EMP_01, IE_PHD_03), which was confirmed by employers' ideas that PhD students should be taught more about patent procedures (CZ_EMP_01), and specifically that they should not publish their commercially valuable results before patenting them (CZ_EMP_05). An exception might be the use of increasingly available open-source codes in IT, created by crowdsourcing, by spontaneous activities of enthusiasts or by large companies, afterwards usable by others (CZ_EMP_04, CZ_PHD_02, IE_ED_03). Some open science educators see open innovation as a separate concept that they are not familiar with (IE_ED_01, CZ_ED_01) and vice versa for an open innovation educator (IE_ED_02).

[1] DK_PHD_01, IE_ED_02, IE_EMP_02, IE_EMP_05, IE_EMP_07, IE_EMP_08, IE_PHD_02, IE_PHD_03, IE_PHD_04.
[2] CZ_EMP_03, CZ_EMP_04, CZ_PHD_01, CZ_PHD_02, CZ_PHD_03, CZ_PHD_05, IE_PHD_01.

Usefulness of a PhD for non-academic work

While the link between PhD education and potential subsequent academic employment is obvious, in case of other careers the usability of the skills obtained during a PhD varies more. The PhD graduates and students we spoke to had chosen their non-academic jobs usually on purpose, often with the intention to do practical work with an impact in the real world. Nevertheless, they mentioned many benefits of their PhD experience for their work even if they believed they would be hired without a PhD. Methodological rigour and awareness about the limits of methods are one of these because they are hard to develop outside academic research (IE_PHD_03). Relatedly but more broadly, critical thinking is what a PhD medicine graduate feels distinguishes him in treatment of patients and in processing of information from drug distributors (CZ_PHD_05). Scientific knowledge is useful to better understand the background of practical solutions and increases the ability to explain them to clients (CZ_PHD_01). Resilience and independence naturally needed for the ability to finish a long-term PhD project are useful at any demanding job (IE_PHD_02). Besides the scientific core of the PhD education, teaching experience, conference and international activities have been important for improving confidence and gaining valuable contacts (IE_PHD_01), even in case of graduates who look on their PhD as a closed chapter (CZ_PHD_03, CZ_PHD_04).

These opinions of PhD graduates are mostly in line with those of employers. Independence of PhD graduates is highly appreciated, as much as their ability to see things in a broader context and to look for new knowledge in individual learning, where the capacity to read scientific articles might be an added value (CZ_EMP_04, CZ_EMP_05, DK_EMP_03). Employers also like the PhDs' willingness to look for answers to complicated problems (CZ_EMP_05). This can be also seen as courage to start solving a problem that nobody has solved before and a willingness to face large uncertainty, as every PhD student has to start their projects in this way (DK_EMP_01). On the other hand, employers listed also disparities between business-related work and the PhD experience, especially a very different ratio between the focus on a method and on an output, problems with deadlines, detachment from practical problems and little knowledge of the market (CZ_EMP_02, CZ_EMP_04).

Skill profiles of PhD graduates related to open science and open innovation

The main aim of the skills intelligence was to identify key skills of PhD-level employees and job candidates related to broadly defined open science or open innovation. Based on the interviews and job postings, the skills can be grouped in five skill profiles, presented below.

Collaborative and interdisciplinary research

The core of PhD studies is an individual research project that lasts several years. Similar conditions, however, are hard to find to the reality of research jobs where work in teams and in collaboration with experts from different disciplines is common and increasingly necessary (CZ_PHD_01, IE_PHD_01). Under the circumstances of an individual PhD project, often an early career researcher is not incentivised to engage in collaborative work which would be beneficial to the quality of research outputs and which also helps in generating new ideas on an individual level. Thus, PhD education is carried out in a manner that very much differs from what graduates face at their jobs and that might not help the students in developing the full potential of their research ideas nor in developing a network of contacts, useful for their subsequent careers. At the same time, it should be kept in mind

that some disciplines, e.g. history and music, have a strong tradition of individual work and a collaborative research can be more difficult to design (DK_EMP_05, IE_EMP_04).

In the view of employers and of PhD graduates, it is highly desirable that teamwork and interdisciplinary skills are developed more during PhD education. A pre-condition for that is the ability to see one's own specialisation in a broader context. The PhD students should regularly dive out from their deep work on a narrow topic in order to see, as one interviewed educator put it, "that the airplane for which you design the metal for the propellor has to fly in the sky" (IE_ED_02). It's a more system thinking approach that is also in line with the movement of business models away from a focus on single elements to creating whole complex solutions. PhDs should be able to think about how their research relates to other topics or fields, what is the place of their research in a bigger picture, what expertise other than their own they need and, on the other hand, how they can contribute to other topics and fields. On the part of employers, this is reflected in a common requirement for readiness to work as a member of interdisciplinary teams rather than being thoroughly interdisciplinary as a person (Job postings CZ, Job postings IE, CZ_EMP_01). Such teams may also include various types of stakeholders and professionals, sometimes called "cross-functional teams" (Job postings DK, Job postings IE). When different types of stakeholders are involved, it is necessary to bear in mind that expectations vary because, for example, value does not mean the same thing for academics and businesses (IE_EMP_01, CZ_PHD_02).

Based on such considerations, PhD students should be actively looking for opportunities to cooperate with other researchers. Participation in conferences, internships on other institutions and reaching out to potential colleagues with sensible suggestions for cooperation are all methods for connecting a narrow specialization to the outside world. Once individual researchers start creating a network around themselves, a cycle of success is started, because contacts bring about more ideas and more opportunities for future projects but possibly also for funding and employment (IE_EMP_02). Creating cooperative networks is very much facilitated by an ability to adapt one's own language style to audiences from various fields so a real mutual understanding can be reached (IE_PHD_01). On a higher level, the ability to work in interdisciplinary collective environments can be complemented by the skill to lead such diverse teams where even more perceptiveness to other colleagues' thinking and passions is necessary (IE_EMP_01). Academic employers see established professional networks as a value that job candidates bring with themselves into the organisation (Job postings CZ, Job postings IE, DK_EMP_02).

In this context, interpersonal skills play an important role. Unlike in most other roles in real jobs, a PhD student does not have to think much about colleagues' feelings and attitudes and to develop compassion and empathy which is otherwise crucial for maintaining good cooperation (IE_PHD_03). A step to change that is learning how to give feedback to others on their work and on the other hand how to accept feedback and not take personally if it is not positive (CZ_PHD_ED, IE_ED_03, IE_PHD_03). Researchers should learn how to show respect for each other's work so the interdisciplinary teams can hold together (IE_ED_01) but also for the work of non-experts in their teams (IE_ED_02). Regulation of one's own ego that is often over-blown in experts' minds would ensure that researchers don't start needless conflicts with colleagues (CZ_EMP_03, CZ_EMP_04), a phenomenon that may inform academic employers to require a "collegial approach" from their job candidates (Job postings IE). Beyond the cooperation itself, a subsequent reflection of one's own and others' experience in the joint work further enhances self-awareness and the ability to engage in other collaborations (IE_EMP_05). In this way, humility and acknowledgment of one's own limits can replace a "tunnel vision" typical for conducting an individual long-term project (IE_PHD_03).

To sum up, among the skills for collaborative and interdisciplinary research we find:

- Choosing the right consultants and collaborators
- Creating collaborative research networks during a PhD
- Identification of potential colleagues' skills
- Giving and accepting feedback from fellow researchers, empathy for their needs, switch from a competitive to a collaborative attitude, ability to reflect on an ongoing collaboration and one's role within it, readiness to ask for help
- Looking for opportunities to get experience outside of one's own specialisation to get in touch with new ideas
- Searching for common language with experts from other disciplines, ability to speak languages of other disciplines and listen to them
- Project management, leadership of research projects, including those consisting of experts with various backgrounds (interdisciplinary leadership), motivating and informing other members of a project, knowing what drives my colleagues' motivation
- Dealing with various types of stakeholders, awareness of differences in expectations
- Understanding colleagues' interests and motivation in research
- Systems thinking about the place of one's own research in the context of other scientific problems, ability to see "the bigger picture"
- Communicating with non-researchers in a team, humility towards their work.

Practical applicability of research results

One of the components of our notion of open science and open innovation is opening more possibilities for PhD graduates to find jobs outside academia. There are good reasons for the abundance of recommendations to support that. First, a tension between work habits and the mindset reproduced through university research infrastructures, and the way of work in research and innovation companies and other non-academic environments, is strongly felt by both employers and PhD graduates. Academic research, including during a PhD, is typically driven by self-interest in a specific question, not necessarily linked to the wish of someone else to hear the answer. In other work, the role of the needs of users of products or services plays a more prominent role. This is related to a different concept of timelines as there are usually less strict requirements on delivery of academic research outputs while a PhD project has very long duration itself. Moreover, many PhD students would like to find a job outside of universities, and many of our interviewed employers were quite clear that they can make use of the skills obtained during a PhD project. This is why it is not unrealistic to think that more PhDs in non-academic, high-skilled jobs would benefit customers and society in general. It is also worthy to add that in some locations in some fields there are not enough post-doc jobs at universities to absorb all the interested graduates and that such jobs are often very short-term (CZ_ED_02, DK_EMP_04, IE_EMP_04, Job postings CZ).

Already at the start of a PhD, students should ask themselves questions like who the research outputs will help, who can potentially use them and in what way, what difference will their project make, in other words, the "so what" question (IE_EMP_01, IE_EMP_08, IE_PHD_03, CZ_PHD_01, CZ_PHD_05). In case the answers to these questions are not satisfactory, the project may be re-designed with the needs of potential users in mind (CZ_PHD_02). This means shifting from, in a way, an egocentric perspective of what is interesting only for oneself to what can bring value also to someone else (IE_EMP_03) and so may require open science skill sets, especially empathy and expectation management needed for a valuable collaboration. Another component of such an approach is the

ability to build relationships with industry and other partners and to offer them value (DK_EMP_02, Job postings DK, Job postings IE), even in the role of an academic researcher who would commonly need data or other help from business entities (IE_EMP_03). Taking a somewhat different perspective, awareness of the differences between how work is organised in academia and in business may help one's employability in the latter. If the requirements of the research project allow it, regulation of one's own methodological perfectionism in favour of realising of the need to meet goals in a certain time period could be useful, not only for a future career but also in order to avoid a commonly occurring "slush" of the PhD studies, leading to a too long duration of it, to frustration and a risk of dropping out (CZ_EMP_05). A related requirement for industry research jobs is innovative thinking or entrepreneurial mindset (Job postings DK).

In order to improve the above-described thinking and skills, it is advised to PhD students to reach out of the academic world during their studies. The importance of taking opportunities for connecting the PhD project with a non-academic institution, of looking for practical internships in industry or at least talking to practitioners (DK_EMP_02) was stressed throughout our interviews. Such experience may serve as a "reality check" of one's own research interest and stimulates thinking on how the research results can be used (IE_EMP_01). Actually, in some fields practical experience may be required or appreciated even from academics, as is the case of medicine, pedagogy, social work, engineering and economic fields (Job postings CZ). But even if not, the contact with the world of practice helps academics to broaden their perspective on the issues of their interest (DK_PHD_01).

The skills in this profile can be listed as follows:

- Identifying users of my research, thinking for whom will the research provide value, asking the "so what" question
- Understanding needs and expectations of the users
- Designing research to produce useful outputs
- Looking for opportunities for practical experience beyond one's research
- Ability to offer benefits to commercial partners
- Goal-oriented approach to one's research as opposed to perfectionism regarding methodology
- Entrepreneurial mindset
- Identification of job opportunities outside academia
- Legal aspects of intellectual property (patents, licenses)
- Business skills, economy of research
- Time management, meeting deadlines, realisation that somebody needs the research results at some moment
- Ability to work in a dynamic and ambiguous environment
- Seeking beyond narrow academic experience during a PhD
- Consultations on PhD research with non-academic stakeholders.

Involving wider public in research

A large part of science circulates within small groups of experts on a specific topic who may account for the entire audience. In an extreme case, it can happen that a researcher "sit[s] on the results for 35 years and then (…) will die, and no one will get any wiser" (DK_EMP_04) or, perhaps more typically, that "hopefully 50 or 60 people have skim read" of a research paper (IE_EMP_05). Wider participation of the public in science is in the interest of many of those scientists who would like to see a broader

impact of their work, and definitely in the interest of the society that, at the end of the day, usually pays for the academic research, including that of PhD students. An important aspect of moving science out of an “ivory tower” or “siloes” therefore involves broader audiences who need to be involved in the research dialogue.

On a general level, PhD students should assess in what ways their research can offer value to society, which societal partners could inform their research through knowledge sharing and how to get acquainted with the important processes underlying these engagements. The researchers should then be able to attract the attention of non-experts while explaining their motivations, the proposed research processes and where the common ground lies. Communication of research results requires adapting the language style and an awareness of what societal groups truly need and appreciate (Job postings DK, Job postings CZ). This might not be easy because researchers often do not know how to talk about their research and how to engage the public in it, which gives rise to specialised jobs focused on research promotion, while some universities require the academics to have a certain amount of public engagement or dissemination activities (IE_PHD_04, DK_EMP_02). This obviously places some more burden on the researchers as they then have to regularly redirect their attention between different activities in order to navigate between public and research interest (DK_EMP_05). Positive experiences that were shared with us in the interviews included writing blog posts that after some time may bring opportunities coming from people who read it by chance (DK_EMP_01), running science programmes on TV (IE_EMP_04, IE_PHD_04), participation in school education (IE_PHD_04) or in public debates (IE_EMP_04).

Another component of this topic is the ability to defend the need to support certain research in front of the public or other funding authorities. A pressure on academics to do that regularly is obvious as many jobs at universities, especially post-doc jobs, are tied to grant projects and the possibility to maintain the job afterwards depends on the researcher’s ability to contribute to a new funding opportunity. In academic job postings, experience from previously funded projects and readiness to seek new funding are widespread regardless of the discipline (Job postings CZ, Job postings IE). For that, knowledge of funding opportunities and proficiency in writing grant applications is necessary. Some employers may even require candidates who could lead big projects, demanding team leadership and project management skills (DK_EMP_05, Job postings DK) but also financial management (DK_PHD_04).

Engagement of the public in science is not one-way. Some of the interviewees mentioned the need for the affected public to have a say, to give feedback and to be represented in the collected data (if it involves the population). In architecture there is an established trend of adapting the designed solutions to the opinions of the affected residents (CZ_PHD_01). Another interviewee is familiar with a project on indoor air quality that includes community workshops and identifies with the concept of citizen science (IE_PHD_04) while the need was mentioned for the medical researchers to represent more segments of population in their research cohorts, or at least to be aware of their needs (IE_EMP_08), which is something that can translate into democratisation of technology e.g. in the world of sports devices (IE_EMP_05). All these approaches require the researchers to be willing to come out of their expert environment and to modify the procedures and goals according to what they hear from non-experts.

Thus, involving the wider public in research may include these skills:

- Acknowledging the value of one’s research for society
- Ability to create outputs that can be accessed and valued by the broader public
- Explaining one’s research to non-experts

- Participation in debates in the public realm
- Creating educational materials from research results, engagement with schools
- Defend the need for funding of my research
- Ability to create funding opportunities for my institution
- Citizen science – involving wider public in my research, getting feedback from the public.

Use of open science tools

A variety of tools that help researchers to implement open science practices are already available. They were also mentioned in our interviews, either by educators who focus on them or by employers and PhD graduates for whom open access or open data were often the first concepts to associate with open science. Open science tools have got a growing prominence especially since the onset of the corresponding EU initiatives in 2016 which was followed by implementing open access policies into EU-funded programmes, by creation of digital infrastructure for open data and by setting up units or positions whose jobs are based on OS promotion and education, including those of some of our interviewees (CZ_ED_01, CZ_ED_02).

Regarding open access publishing of research outputs, the main factors featuring in our data are awareness of the advantages and motivation to prefer open access journal over others. A clear advantage for both the researchers and their institutions is better visibility of their work that can help them to get more opportunities in the future (CZ_ED_02, CZ_EMP_01, DK_EMP_04). At the same time, it is necessary to pay more attention to identify predatory journals as they may be using the growing demand to publish open access (CZ_ED_01). A serious barrier for faster development of open access publishing is the lack of incentives for choosing this way, as universities require the researchers to publish in high impact journals in the first place that commonly belong to large publishing houses with a closed access policy (CZ_ED_01). It has also to be noted that the potential of a discovery to get patented or generously sold on the market prevents its (open) publication (CZ_EMP_05) while in the humanities, on the other hand, “what can happen? We will never make a million dollars out of anything we do here which someone else can steal” (DK_EMP_04). Similar considerations can be made in relation to publishing research data (open data). Here, in the case of the absence of a requirement by an employer, funder, or publisher to do so, the motivation might be even smaller as publishing data does not bring much to the individual researcher unless he or she can expect something in exchange. Nevertheless, availability of open datasets is growing, and researchers need to be aware of them and to have the corresponding technical skills so they can exploit their potential.

The technical skills are indeed central in handling open-source codes. This is an area where we observed interest and activity in the business world, where reusing of available resources of this kind is common, often if a company does not have the capacity to create them (CZ_EMP_04). Open-source code creates a fruitful environment for creating communities that can encompass people at distant places. With interdisciplinary inputs and background, there are also persuasive sales arguments to be involved in open source as it brings useful ties with members of these communities (IE_EMP_07). For individual researchers, open source can facilitate orientation in the growing volume of scientific outputs where attempts by individuals to find and use everything relevant that has been generated on their topic previously is increasingly difficult (IE_EMP_07). Open source communities are very much spanning across the boundaries between academia and other sectors (IE_EMP_07), while competences in programming and machine learning were found to be prominent in both academic and non-academic job postings (Job postings CZ, Job postings IE, Job postings DK). Besides, there might be some unfilled space to use Deeper understandings of programming in practical jobs can fill gaps that exists around the easy-to-use, “black box” use of data analytics tool by non-experts in sometimes

rather naive ways (CZ_PHD_04). Among other tools related to open science, some interviewees mentioned the use and creation of open educational resources (IE_ED_03, CZ_ED_01, CZ_ED_02).

The core identified open science tools and related skills are:

- Considering the benefits of open access publishing of data, code or outputs even when it is not required by the funder / employer (e.g. visibility, potential to attract customers, participation in collaborating communities)
- Open access publishing
- Identification of predatory journals and publishers
- Open data, data repositories use
- Ability to find available open data
- Remote collaboration tools
- Open source code use
- Open education resources

Career planning

PhD studies are concentrated to an individual project that is supposed to initiate a subsequent research career. The work on a PhD project is very specialised, academic in its nature, and the most obvious first career option for the graduates is applying for a university post-doc position where they could work on a similar topic in a similar way. However, such an approach may be too restrictive as it may exclude in advance many other suitable options which could open the way for the skills learned during a PhD education to be used in other employment settings. Having more career possibilities in mind may lessen the feelings of insecurity that stem from the accepted position that there is a lack of suitable academic positions available post-PhD (IE_PHD_01). In an illustration by a career counsellor, when PhD graduates “approach the end of their PhD, they start worrying and think, well, 'if all I know is (…) church history between 850 and 900, you know, how is that applicable in a broader context’” (DK_ED_02). In a similar vein, an employer in humanities believes “we are educating PhD's to follow (…) university tracking, but there's not that space for them and I can see their sorrowful faces when they're like in the sixth year post PhD and they haven't got their positions and they haven't got the things they wanted to.”

An important, though not always easy task is to look to one’s own PhD experience in a broader context than the research topic itself. This means asking questions like what have I learned during the PhD apart from what is in my dissertation, how can I contribute in jobs that would not overlap with my PhD project, what skills helped me in completing my PhD. Besides identification of one’s own skills, they should be communicated in an appropriate form and style so they are accessible and understandable by potential employers. Awareness about opportunities on the labour market needs improvement – graduates should think about non-academic careers and follow information about suitable vacancies outside university (CZ_ED_02). Such considerations should start early enough so the PhD students can adapt their activities already during the work on their project, including, possibly, getting in touch with potential employers (DK_ED_02).

This way of career planning can be based on the PhD graduates’ competences that are useful in a wide range of jobs. A scientific approach in practical contexts has been reported as enriching work with clients as it includes deeper understanding of the practice (DK_EMP_03), confers a better ability to explain reasons why something needs to be done in a certain way and critically assesses the methods of one’s work and their limits (CZ_PHD_01, CZ_PHD_05, IE_PHD_03). Completing a PhD project requires designing a novel endeavour without the possibility of knowing how exactly it will be carried

out, and subsequent resilience in the face of unpredictable problems (DK_EMP_01, IE_EMP_05). Curiosity leading to asking complex questions and a courage to look for answers are also valued by employers (CZ_EMP_05, IE_EMP_08), as well as closely related willingness to learn new things and move knowledge forward (CZ_EMP_03, CZ_EMP_04). Thanks to the opportunities for various collaborations, participation in projects, foreign stays and teaching during a PhD, the graduates may also be very skilled in teamwork, project management, leadership, presentations and other activities (DK_ED_02) and, in addition, may get more aware about what kind of jobs they want to look for afterwards (IE_EMP_01). Working on interpersonal skills during a PhD is especially important because employers outside academia put more stress on these and state them in a more detailed manner than universities – for example, such demands in business include knowledge transfer and sharing, ability to train and mentor junior colleagues and guide or assist customers or partners (Job postings CZ, Job postings DK, Job postings IE).

Career planning skills for PhD students can be summarised as follows:

- Considering future career options early enough during a PhD study
- Gathering information about various options of employment not only in academia
- Realising of own transversal and other professional skills, acquired during a PhD, ability to see them outside a research project topic
- Acknowledging the value of core skills linked to a PhD for a wide range of employers
- Adapting activities during a PhD to potential career options
- Early contacting potential employers and suitable ways of communicating one's skills to them.

Recommendations for systems of PhD education

The above presented opinions of PhD graduates and of employers may be also translated into ideas on changes in the PhD educations system(s). Below we indicate the main directions in which such proposals could go.

1) Organisation of PhD studies in less individual and more collaborative ways. The traditionally individual PhD project embedded into a relationship between the student and the supervisor could be given more elements of teamwork with other colleagues including those from different disciplines. In such a way, PhD studies would move closer to the organisation of work at many potential workplaces.

2) Stays at other institutions including practical internships may get a more prominent place in the requirements of PhD programmes. Internships have been assessed as a key method by which PhDs get collaborative experience, new ideas and contact with practice. More space can be given to practically oriented PhD topics.

3) Dynamization of PhD studies progress. In cases of programmes in which it often takes students significantly more time to finish, it would be good incentivise faster progress, so the PhD studies do not differ from other projects or jobs in this respect. Systemic barriers of timely completion, including insufficient funding of PhD students, should be dealt with before any other intervention, though.

4) Business skills and patent procedures. If open science and open innovation is understood also as transfer of knowledge from university to business and more permeability between the two worlds, more room for teaching business skills (including patent procedures where applicable) can be considered.

Appendix 1: Desk research of courses in OS/OI

Within the Work package 1, desk research of courses and initiatives related to open science and open innovation was performed. The main focus was on the three countries of the consortium partners (Czech Republic, Ireland and Denmark) while initiatives from some other countries were taken into account to some extent as well. The main aim of this exercise was to identify gaps in PhD education associated with the topics of the project.

Three areas were found to be covered quite well in the existing offerings: open access publishing and open data; technology transfer; research integrity. In particular, open access publishing, open data management and related concepts are commonly and probably increasingly promoted at universities. Students and academic staff can therefore usually get guidance on why and how to make their data and research outputs public, what the risks are and how to get the most from open publishing. Such promotion includes teaching (including MOOCs), workshops and conferences,[3] and sometimes gets a shape of university organisational units.[4]

Relatedly to the scope of the Opening Doors project, significant attention is given by universities to technology transfer and, more broadly, entrepreneurship skills. In courses on these topics, students and staff are taught how to commercialise their research and use their scientific expertise to run businesses, including spin offs and spin outs, often with focus on STEM fields.[5] In the area of technology transfer, institutional units work at many universities and provide support in various forms.[6] The existing technology transfer courses are, as a rule, not targeted at PhD students.

These findings from the desk research, along with those of the semi-structured interviews and job postings review, contributed to the broader conceptualisation of the Opening Doors PhD course design where open science is understood as an approach to research and way of thinking, based on a set of transversal skill profiles. In such a way, the course will complement rather than replicate existing training offer for PhD students.

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[3] E.g. „Open access at Charles University - How to publish openly?“, https://openscience.cuni.cz/OSCI-112.html; „Research data management and the FAIR principles in Open Science“ (Roskilde University), https://study.ruc.dk/phd/allPhdCourses; „Open Science and Your Research Workshop in Cambridge“, https://www.orion-openscience.eu/activities/training/201909/open-science-and-your-research-workshop-cambridge; “Open Access Weeks” (Oxford), https://openaccess.ox.ac.uk/open-access-weeks/ ; “Open Science Workshop” (Ludwig-Maximilians-University of Munich), https://osf.io/zjrhu/; “Open Science Framework Workshop” (Harvard University), https://hlrdm.library.harvard.edu/event/open-science-framework-workshop; “Open Science Workshop” (MIT), https://libraries.mit.edu/news/science-workshop-lunch/25873/; “ORION MOOC 2.0 for Open Science in the Life Sciences”, https://www.open.edu/openlearncreate/course/view.php?id=4633&section=1

[4] Each of the 8 Danish universities has their own local Open Science Support Unit, typically based at the university libraries. In the Czech Republic, there is for example „Open science support centre“ at the Charles University (https://openscience.cuni.cz/OSCIEN-9.html).

[5] E.g.: „Management of Science and Innovation Innovation Lab“ (Charles University), https://cppt.cuni.cz/CPPTNEN-83.html; „Management of technology and innovation“ (Aalborg University). https://phdcourses.dk/Course/80430

[6] E.g. „DCU Invent“ (Dublin University). http://dcuinvent.ie/; „GMIT Research and Innovation“ (Galway-Mayo Institute of Technology), https://www.gmit.ie/knowledge-and-technology-transfer/knowledge-and-technology-transfer; „Technology Transfer Office“ (Masaryk University in Brno), https://www.ctt.muni.cz/en/about.

Appendix 2: Sample of interviewees

Interview ID	Type of respondent	Sector (business, NGO, state, academic)	Discipline / industry (where applicable)
CZ_EMP_01	Employer	Academic	Biochemistry
CZ_EMP_02	Employer	Business	Applied natural science research
CZ_EMP_03	Employer	Business	Biotechnology
CZ_EMP_04	Employer	Business	ICT
CZ_EMP_05	Employer	Business	ICT / Big Data analytics
IE_EMP_01	Employer	Academic	Data analytics
IE_EMP_02	Employer	Academic	Public health
IE_EMP_03	Employer	Academic	Business studies
IE_EMP_04	Employer	Academic	Music
IE_EMP_05	Employer	Business	ICT and electronics
IE_EMP_06	Employer	Business	Digital health
IE_EMP_07	Employer	Business	Open Science
IE_EMP_08	Employer	NGO	Digital medicine
DK_EMP_01	Employer	Business	ICT (Educational technology)
DK_EMP_02	Employer	Academic	
DK_EMP_03	Employer	Business	Publishing
DK_EMP_04	Employer	State	Culture
DK_EMP_05	Employer	State	Culture
CZ_PHD_01	PhD student	Business	Architecture
CZ_PHD_02	PhD graduate	Business	ICT (SW and HW)
CZ_PHD_03	PhD graduate	Business	ICT (SW and graphics)
CZ_PHD_04	PhD graduate	Business	Mathematics
CZ_PHD_05	PhD graduate	State	Medicine
IE_PHD_01	PhD graduate	Business	Digital Health
IE_PHD_02	PhD graduate	Business/State	Healthcare Delivery
IE_PHD_03	PhD graduate	Business	Sports Technology
IE_PHD_04	PhD graduate	State	Physics
DK_PHD_01	PhD graduate	Academic	Political Science
CZ_ED_01	Educator	Academic	
CZ_ED_02	Educator	Academic	
IE_ED_01	Educator	Academic	
IE_ED_02	Educator	Academic	
IE_ED_03	Educator	Academic	
DK_ED_01	Educator	Academic	
DK_ED_02	Educator	Academic	

The interviews were carried out April and May 2021 by interviewers from the University College Dublin, Insight Centre for Data Analytics / Ireland, National Training Fund / Czech Republic and Aarhus University/ Denmark.

Statistics of interviews

Total interviews	35
Country	
Czech Republic	12
Denmark	8
Ireland	15
Type of interviewee	
Employer	18
PhD graduate/student	10
Educator	7
Sector of employers and PhD graduates/students	
Business	15
Academic	7
State and NGO	5
Mixed	1