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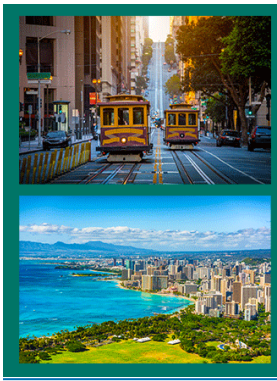

InnEO'Space PhD: Preparing Young Researchers for a successful career on Earth Observation applications

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Abstract. InnEO'Space PhD project is preparing young researchers for a successful career by developing modernised and transferable PhD courses and learning resources based on innovation skills and employers' needs as well as in-depth knowledge of high stakes and approaches of Earth Observation in many application domains. The mains objectives of Inn'EO Space PhD are to enhance and develop researchers' innovation-oriented mind-sets and skills through Earth Observation, raise awareness about employment opportunities in academia and industry among researchers and scientists, tackle future skills mismatches and create new synergies between PhD students and researchers and potential employers. The first action has been to develop the InnEOStartech where the program was set for European PhD students with the aim of developing their taste for entrepreneurship spirit through idea of founding a company or designing an application. The second action has been to develop a summer school that delivered both technical skills and soft skills, thus providing all the ingredients for an innovation-oriented mindset. From these activities we shall develop a series of SPOCs (Small Private Online Courses) that will be made available to the community for further dissemination and exploitation.

1. Introduction

Skills acquisition and development for students are essential to enhance competitiveness and employability, in a long-life learning and development perspective, especially to respond to a fast-changing global economy. Therefore, higher education institutions need to ensure that they equip graduates with relevant and up-to-date skills[5]. Since 2015, opportunities for highly-skilled individuals have grown and this will continue at least until 2025. Nonetheless, a structural mismatch between competences/jobs demand and supply skills has raised concerns.

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[5] EC, 2016, A new skills agenda for Europe https://op.europa.eu/en/publication-detail/-/publication/3339301b-4986-11e6-9c64-01aa75ed71a1/language-en

During the past ten years, the Copernicus program led by the European Commission has created a major disruption in Earth Observation (EO) services. The Sentinel satellite families within the Copernicus program[6] and other existing commercial and public satellites, associated to in-situ systems, make it possible to create new services in various downstream markets and industries: agriculture, changes detection, meteorology, pollution, environment, natural resources...[7] In addition, the Artifical Intelligence (AI) and Deep learning fast evolution are allowing researchers and companies efficient and never seen before analysis and processing the massive data sets coming from satellites. Thus the EO data market is booming and it is expected to support 12,450 jobs per year (downstream applications).[8]

Within Inn'EO Space PhD European project[9] several European universities decided to work together, with the financial support of European Commission, to improve space students employability by developing innovative e-learning programme. The project aims to lead European universities towards a new area of innovative PhD programs that will drive excellent researchers through EO to meet the needs of multi-sectorial stakeholders. Broadening the scope of PhD students and researchers' competencies combined with original research skills will enhance their employability and competitiveness.

Inn'EO Space PhD is run by five complementary partners: three top universities in the earth observations domain (University Jean Jaurés in Toulouse (FR) through IRIT laboratory, Universitatea Transilvania Din Brasov (RO) and Universita Degli Studi Di Roma Tor Vergata (IT)), one cluster that gather the main local aerospace economic actors (Aerospace Valley (FR)), and an international company expert in communication and e-learning products specialised in EO (Remedia Italia (IT)). These partners have long lasting cooperation through previous joint projects and activities, such as a FabSpace2.0[10]. In a nutshell, during three years (2016-2019), the FabSpace 2.0 project makes universities open-innovation centres for their region and improves their contribution to the socio-economic and environmental performance of societies. The project concentrates on data-driven innovation, with a particular attention to EO data. It was a success and lead to places where students, researchers and external users can make use of a data platform, design, process data and develop new applications in EO domain.

InnEO'Space PhD builds on existing initiatives to develop contents oriented towards innovation adapted to PhD students' needs and the current labor market. The InnEO'Space PhD project's activities are developed to encourage PhD students and researchers to be innovative and entrepreneurial. It is also promoting interactions with people working inside and outside academia and thus support PhD students in developing their career paths. As the sanitary crisis has dramatically shows, it is of great importance to enable physical and virtual activities. InnEO project will develop digitalised content from StartTech, summer school and additional contents to maximise the number of European students able to access these resources. Any universities will be able to implement the activities, involve local stakeholders and promote the results.

2. Entrepreneurship skills

2.1. Related activities

The involvement of non-academia actors all along the project contributes to raise awareness on the difference that may exist on the skills expected in the private sector and in academia. One of the big endeavours of the project is also to shape relevant occupational profiles in the EO sector. Such an information is considered during the training initiatives of the project and aims at being an input for PhD programmes addressing the future workforce. To fulfil such an objective and

[6] `https://www.copernicus.eu/en/about-copernicus/`
[7] European Commission – Digital transformation Monitor (July 2017) – Big Data in Earth Observation
[8] Copernicus Market report Nov 2016 `(copernicus.eu/)`
[9] `https://inneospace.eu/`
[10] `https://www.irit.fr/FabSpace/`

with the purpose of identifying weaknesses of current PhD programs a questionnaire addressing mainly Human Resources staff of SMEs, large industries and of important European entities working in the EO field has been elaborated. The questionnaire targets entities located in Europe which provide services based on, or having to do with, EO data.

A mapping of the various initiatives at the EU level and tools to support PhD students with establishing their career paths is also carried out together with two other surveys: one quantitative, to monitor PhD graduates employment evolution, and one qualitative, to assess the skills they use and they are lacking, and to investigate about their motivations and expectations in pursuing the PhD. Preliminary analysis of the answers regarding this last point shows that there are several elements which have been more or less unanimously shared by the students.First of all, at the time they were awarded their degree, the decision of pursuing a PhD was rather clear for them. The improvement of the personal cultural and scientific education has definitely been of the most important motivations. However, in terms of future career, a non-academic environment is preferred to an academic one to perform research activities. Finally, we can say that there is no much complain about the received financial support.

The project also aims at creating career development and self-assessment tools. The career development tool guides the young researchers to check and analyse their professional path and the individual standing point, also stimulating personal vision of life and work, and serves as guideposts to align skills and interests. This can be very important to help young researchers who may be very insecure about their future. In particular if they should continue, without immediate certainties in the field of academia or think of a career change. Its purpose is to assist young researchers to design an ongoing career strategy gaining awareness of their strengths and of their weak points. It is a guide to set and achieve short-term and long-term career goals. The young researchers are asked to look inward and to identify an accurate understanding of their own personality, interests, motivations, skills and values. Through self-assessment, the toolkit users gain valuable insights which will allow them to make informed decisions about their career options, identifying opportunities for progression.

Regarding the self-assessment tool, both technical and soft skills have been addressed. For the latter, the term describes those personal attributes that indicate a high level of social and emotional intelligence. Unlike hard skills, which describe a person's technical skill set and ability to perform specific tasks, soft skills are broadly applicable across job titles and industries. It is often said that with hard skills it is possible to get an interview but it is necessary to have soft skills to get – and keep – the job. For the project we have chosen to evaluate five elements. These belong to all categories of primary soft skills and they are in detail: decision making style (problem solving), visuo-spatial ability, ethics (self-mastery), conflict management (interpersonal abilities) and the cooperative behaviour.

2.2. Startech

The StarTech program[11] has been launched by WSL in Belgium in 2012, with the original idea to inspire and support students from engineering schools to test and grow their entrepreneurial skills. Within the European project FabSpace 2.0[12], Université de Toulouse has successfully transferred the Startech program for EO data-driven applications in 2019 [1, 2]. Within InnEO Space PhD, a new consortium is implementing the program for PhD students.

Within InnEO Space PhD, the Startech pilot has been set for European PhD students with the aim of developing their taste for entrepreneurship spirit through idea of a company/application creation. Students progressively expand this idea to reach a marketable prototype/project at the end of the coaching. The Startech is based on creativity methods. In groups, the students decide

[11] `https://www.startech.be/Startech/`
[12] FabSpace 2.0 `https://www.irit.fr/FabSpace/`

on an innovation (e.g. a new application that uses EO data to help monitoring the gas pollution in the seas). They are expected to expand this idea to reach a marketable prototype/project. To do so, they attend a series of sessions led by several business coaches on creativity, business models, canvas, lean start up, IP, presentation, etc.

There are 8 coaching sessions in total, which are collective (peer-learning) and, due to the Covid 19 pandemic, strictly online : introduction, value proposition, market segments, pitch preparation, distribution channels, customer relationships and revenue models, partners and resources, final public pitches.

The training encourages peers' and coaches' exchange of experiences. Courses on specific concepts and important phases of the idea/product/project development are provided. These sessions are commented, and the groups are led to apply on their project what they have learned. Along the course, the students are presented with the opportunity to work in groups on the business model canvas and to present case studies to experts and industry insiders who played the roles of clients or business advisers. At the end of the training, the students pitch their project in front of a jury made of these experts.

The Startech has been designed to give PhD students from any background essential skills in entrepreneurship and soft skills. In its first edition, the academic background of participants ranges from aerospace and data science to medicine and engineering. Whatever their experience and knowledge, the skills they learn empower them to navigate the business world and respond to the rapidly increased demands for innovation in the work market. The InnEO Space PhD Startech took place on April 2021 in Toulouse (remotely because of the COVID19 pandemia).

2.3. Lessons learned

Capturing lessons learned was an on-going effort throughout the training. This mindset was strongly encouraged from day one, representing the InnEO organisation's commitment to excellence. We distinguished two categories of lessons learned, in terms of organisation and in terms of students' management that we describe further.

The Startech **required sound preparation**. Alongside the organisational matters, such as workshop materials, booking the room etc., the preparation of the contents and order of events was key.

Need appropriate online rooms management. Due to the Covid-19 pandemic, the Startech had to be in full remote learning, which was not its initial goal, and find ways to effectively support the online delivery as a viable way of engaging students. There were plenary sessions in a main virtual room for all the attendees and separate virtual rooms for each group of students to work plus rooms to meet the experts. It can be tricky to manage several rooms on line at once; attendees need to be aware of the organisation to avoid any problems.

Build well-balanced students' groups. Working with people who are both skillful and engaged is the recipe for success. When the students have very different backgrounds it is important to know their skills and try to balance the group. Breaking ice games can be used.

Experts/mentors participation was very helpful. One of the most important things regarding an innovation is to meet with potential customers. The experts who payed these roles and were invited in the Startech were all found insightful.

Overall structure of the training. To start with, both the team building and the different types of existing EO data (that was a requirement to use such data) deserve some time. The ideation should not be neglected either.

The students need to quickly validate their ideas. Students can investigate too much time into building a complex product/service that no one wants to buy. Determining and testing the demand for the product is thus crucial.

The students need to adopt a sound marketing strategy. Most of the students did not have marketing skills at the beginning of the course, so relying on a BMC was an important

asset in order to build a strong business strategy.

3. Machine Learning and Earth Observation

3.1. Related work / programs

At global scale, climate Change is definitely the issue of our time and we are at a very crucial moment where important decisions need to be taken about how to modify the various processes causing it. The role played by EO may be very important because it provides the possibility of monitoring the impact of anthropogenic activities on the environment.

EO has dramatically changed in last decades, due to significant advances in sensor and digital technologies. The Sentinel satellites observe the Earth at various bands of the electromagnetic spectrum and provide everyday a huge amount of data which are free and openly accessible to users. It has also to be noted that Copernicus aims at guaranteeing a high level of continuity in data and service provision. For this purpose, there is a strong political commitment at EU level to provide adequate funding. Other national and international space agencies continue developing their own EO missions so as the quantity of data available is much higher, especially if we also consider commercial operators and data derived from millions of smart sensors connected to the Internet or also from Unmanned Aerial Vehicles (UAVs) systems.

This new situation opens new challenges for the exploitation of the EO data. Such a wealth of information might be difficult to manage by final users, who, therefore, might not take full advantage of the operations carried out by the space segments. If users process all the available data separately, the interesting opportunity of generating added value products by effectively combining different sources of information may be missed. The importance of techniques based on AI is steadily increasing. Sometimes the relationships among the data are very subtle and complex and might not be retrieved using more standards approaches. This goes in parallel with another interesting ongoing process which is the growing massive availability of devices characterised by high performance computing capabilities.

There is an urgent need of experts able to navigate across and provide solutions to the various issues connected to the applications of AI and Machine Learning (ML) to EO data. This is also shown by the answers to the questionnaire that within the InnEO'Space PhD project was distributed and filled in by entities working in the space and EO sector. The technical profiles requested by companies for their new open positions frequently highlight competence on AI. At European level, many initiatives supporting this technological path have been fostered. AI is a keyword in the title of many European calls aiming at funding R&D projects. Additionally, worthwhile being mentioned is the birth of the ESA Phi-Lab[13], where AI is a crucial element in the mission of accelerating the future of EO by means of innovations that completely transform or create entire industries via new technologies.

Also in the InnEO'Space PhD project a great emphasis is given to AI and EO and to cross-correlated themes. Large sections of the training activities developed in the project address these two topics from both a theoretical and a practical point of view. In particular, while in general most of the already existing tutorials of AI applications regard image processing (objects detection or classification), in the project a specific relevance is given to the use of ML for the estimation of geo-physical parameters. This typically involves a diverse approach in the generation of the training data that cannot rely, as in the image processing cases, on manual annotation or photo-interpretation. For this reason in the project the importance of radiative models for the generation of synthetic data is addressed.

[13] `https://philab.phi.esa.int/`

3.2. InnEO Summer school

The InnEO Summer School was designed for a full week, comprising both (i) high-level scientific lectures in the latest AI models (ML, Deep Learning), Remote Sensing with digital EO applications and (ii) soft and transferable skills development that foster employability and innovation. This inter-disciplinary approach aims at preparing the participants for their future career both in academia and industry. The target group was mainly PhD students and early-stage researchers. The structure of the summer school was the following: two days of excellence on applied AI for EO, both at theoretical and practical level, one day of Open Science skills courses and two days of Soft Skills development workshops. An additional career development day included a visit to the Bran Castle (known as Dracula's Castle) near Brașov.

The first edition took place in Brașov, România, in the period 19-24 July 2021 and was hosted by the R& D Institute of the Transilvania University of Brașov. It was organized face to face, as the sanitary restrictions due to the pandemic situation at global level allowed for the organization of such an event and everyone involved in it, both organizers and participants, were enthusiasts about the idea of getting back to this pre-pandemic normality. There were 33 participants in persons and 7 online from France, Italy, Germany, Poland, Lithuania and Romania, with a relatively balanced gender representation (24 males and 16 females). There were 13 lecturers in total, 8 professors (including 3 invited professors) and assisting professors and 5 post-doctoral students engaged in the project. The participants were provided with the handbook of the summer school comprising all the materials from the lectures and practical works. The lectures were interactive, most of them accompanied by practical works using Python, Matlab and Jupyter. The total number of teaching hours was 36.

The workshop days aimed at making participants aware of the importance of soft skills (or social skills) in a future society. The general pedagogical approach for the workshops on soft skills was *experiential learning* which is the results of an active reflection upon experience. This learning approach is twofold: (i) direct and concrete interaction with the environment, i.e. engaging the participants in concrete activities that enable them what they are learning about and (ii) reviewing or processing the experience which help the participants derive meaning from the experience and conceptualize it (Silberman, 2007). According to (Kolb, 2012), one of the authors who conceptualised experiential learning, "learning is the process whereby knowledge is created through the transformation of experience". An example was *wrapping the gift*, a fun activity which demonstrated the stages a team goes through for improving work performance. Another activity was a debate on a study case in an EO-related context - the participants had to analyse two potential candidates for a job in a company dealing with climate changes and emergency situations, and to argue their decision process and choice between the two candidates.

The live video transmission and interaction were ensured by a professional company delivering multimedia live transmissions and using the video conference integrated tool of the Moodle-based e-Learning platform of the Transilvania University of Brașov, România. The second edition will take place in 2022 and it will be organised only online, using the materials developed for the first edition and partially the video recordings that were performed, as a preparatory step for the deployment of the future InnEO platform.

3.3. Lessons learned

Despite the global pandemic situation, the summer school was a successful event, being organised as planned in 2020 before the COVID19 broke out. The collected feedback from the participants was positive, as well as the one from the lecturers. Perhaps there is room for improvement for the second edition of the summer school, as some participants considered that the schedule was too tight and there was too much content. Moreover, the workshops dedicated to building the teams should precede the other activities of the summer school, as this sequencing would increase the cohesion within the target group. On the other side, the workshops on soft skills

would have been more effective on a smaller number of participants. However, the organisers consider not only a second edition, but to reiterate the summer school over the years. With the new perspectives offered by this experience, to address the Doctorate Schools of the universities involved in the InnEO Space PhD project in order to adjust the PhD programs according to the latest societal challenges.

Open science is a pre-requisite for a sustainable development of our society.

The development of social skills is an indispensable condition for both personal and social development.

The participants underlined the need to find a right balance set of cognitive and socio-emotional skills in order to achieve both personal and professional success. The evolution of society must be followed by the development of soft skills.

The social competences must be redefined according to social trends. For instance, the decision process is not easy even when we have information, knowledge or experience. Today's decision processes involve moral decision, dilemmas or social implications. In the future, it is important to collaborate with others who are complementary from various points of views.

The summer school was a transformative experience for both the organisers and participants.

4. Toward SPOCs

4.1. SPOC in the e-learning scenario

The digitalisation of training and educational activities that was triggered by the digital revolution has accelerated rapidly during the pandemic, especially universities, schools and research centres, where we all used to believe that physical presence was a *"conditio sine qua non"* for the execution of educational activities. It was, therefore, necessary to analyse and adapt the various existing e-learning methods and tools, then the research group analysed the usage of a particular type of elearning tools called **SPOC (Small Online Private Courses)**, proving its applicability in the context of PhD programs. **The term SPOC was coined in 2013 by a Harvard University professor (Armando FOX) in relation to digital teaching materials for small groups of university students**. **SPOC** is a particular type of asynchronous e-learning course. Students can follow it anytime, anyplace, online or offline.

We distinguish between **synchronous and asynchronous** forms of e-learning. In **synchronous e-learning**, didactic activities are carried out in virtual classrooms in live audio-video streaming. The presence of students and teachers is simultaneous but occurs digitally and remotely. Synchronous e-learning is based on the same learning methodology as face-to-face lessons. **Asynchronous e-learning** is the one that has been developed the most. The training content is contained within a teaching unit usually called "learning object". It is common practice to divide learning objects into three main categories: **Tutorial Learning Object (TLO)** with the primary objective of transferring knowledge; **Interactive Learning Object (ILO)** centred on acquiring practical technical skills e.g. through simulations; **Evaluative Learning Object (ELO)** used to evaluate the acquired knowledge/skills.

4.2. SPOC pedagogical approach and platforms

One of the main criticisms leveled against asynchronous e-learning relates to the non-centrality of the student in the learning process: this is particularly evident in MOOC courses. **SPOCs, although belonging to the same typology, can be an exception**. The small size of the group of students, belonging to the same organisation or the same study program, gives us the opportunity to integrate the course in blended learning, where it is possible to recover the collaborative and cooperative dimension of learning and integrate moments of individual interaction with the teacher into the learning process.

The delivery environment of a SPOC is an e-learning platform. **An e-learning platform contains two main sections: one for teaching provision, another for**

management. Usually, these two sections are governed through unique interface apps, one of which is intended for students, the other for teachers and administrative staff.The two applications interface with the database, which constitutes the heart and brain of the platform.

4.3. The project InnEO SPOC

The project includes two SPOC courses, focused on EO, ML, and management of teams and research projects, thus **covering both hard and soft skills**. These SPOCs are "self-consistent", i.e. each of them gives the opportunity to acquire skills by itself and without the need for additional content.

We have estimated the course direction for each SPOC to be 25 hours, which **allows PhD students to acquire 1 ECTS** (European Credit Transfer and Accumulation System) per course. The course is comprised of micro-units alternating between short videos, materials or activities that expand on and/or practise the content presented in the videos, and intermediate assessments. This is both to improve the student's level of attention, as opposed to totally passive enjoyment, and to improve practical understanding of the content.

The PhD students and the teachers/administrators have the **opportunity to constantly monitor the course of the student**, the time spent using the platform, and the results of the assessments. The platform used for the delivery and management of the SPOC will be developed by ReMedia, one of the research consortium partners.

At the end of this course there is a final assessment on the contents of the whole course: successful completion of the final assessment will generate a certificate of acquired competencies.

5. Conclusion

Earth Observation and Artificial Intelligence developments are opening huge new opportunities for companies to create new services for a broad range of markets, from agriculture to cities, or climate changes analysis and mitigation. This need of cross-skills between EO and AI have been confirmed by the answers to the InnEO Space PhD project questionnaire filled in by companies. At a European level, such companies will create thousands of new jobs in the next coming years. Thus, students and future employees need to be aware of the skills expected in the private sector to fill in the needs. To improve students' employability, the partners of InnEO Space PhD developed various activities to support both technical and soft skills. Because a lot of small companies are at the top level of innovative topics, the entrepreneur skills have also been addressed. One of the aims of InnEO Space PhD is to develop e-learning tools and processes. Because of COVID 19 pandemic, the Startech has been directly done by a digital way, however the summer school could happened in face-to-face mode. Online courses are developed on different topics : EO, ML, and management. Each time, it was essential for the consortium to cover both hard and soft skills. Some lessons have been learned to improve the next sessions, both on the form and the content, which will allow a second session for StartTech and summer school in the frame of the project, as well as additional SPOC creation content.

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