INTEGRATING OPEN AND CITIZEN SCIENCE INTO ACTIVE LEARNING APPROACHES IN HIGHER EDUCATION

State-of-the-art report on the integration of OS (and CS) in existing HE curricula

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Abstract: This state-of-the-art report attempts to see the current status of the integration of Open Science (OS) and Citizen Science (CS) activities into the higher education (HE) curricula in Europe. First, we try to capture the concept of OS (and CS) and its integration into the HE context from the three main roles of higher education institutions (HEIs) in society: research, education, and innovation. Then, we consider what is expected in future education and how OS/CS can be integrated into curricula. Sixteen curriculum cases in European universities are selected to be analysed. The given cases provide a structure of actual OS/CS-integrated curricula and provoke insights into its potential direction and positive impact on HEIs and society.

Keyword list: Open Science; citizen Science; open innovation; active learning; higher education, curriculum

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List of Abbreviations

The following table presents the acronyms used in the deliverable in alphabetical order.

Abbreviations	Description
CS	Citizen science
DMP	Data Management Plan
HEI	Higher education institution
OER	Open Educational Resources
OEP	Open Educational Practices
OS	Open Science
RDI	Research, Development and Innovation

Executive Summary

In the 21st century, education has been inclined to more phenomenon- or topic-based learning since students are urged to acquire sufficient skills to cope with the uncertain future and tackle social, economic, and environmental challenges. While traditional subject-based teaching plays an important role in the early stage of education, universities have been trying to offer more student-centred learning projects in which students can learn the phenomena and address real-world challenges with peers. In such a context, the INOS project consortium recommends HEIs integrate OS/CS concepts and activities into learning and teaching when designing a curriculum to fulfil future needs.

Therefore, this state-of-the-art report considers how HEIs can integrate OS/CS into their curricula to design student-centred learning activities. In the first chapter, we review related literature and publications to overview the OS concept and how higher education institutions (HEIs), including academic libraries, integrate it into their operation. We also see the direction of future education; what elements are expected in European universities. From these points, HEIs' roles in OS/CS facilitation and future educational visions, we consider the practical implementation of OS/CS activities into their curricula.

Case examples are collected through contacting the LERU member universities and asking the INOS partners for recommendations. After the evaluation phase, we selected 16 existing curriculum cases of European HEIs, including accredited study modules, courses, and degree programs. Besides, nine non-accredited OS/CS activities are presented in the Annex. In the reviewing process, we focused to find 1) the way of OS/CS implementation into the curriculum, 2) external related stakeholders, 3) pedagogical approach and 4) required skill sets in participant students.

The results of the review suggest that HEIs can engage students (and academic staff) into open science and innovation processes beyond the internal context by incorporating OS/CS- related projects into study courses. Consequently, HEIs can positively impact society through the contribution to the project by turning science into practice. However, successful implementation cannot happen without solid foundations ranging from technological infrastructure to open and collaborative operation culture among the HEI staff members, including academic librarians. Therefore, a guidance document and recommendations will be created based on this state-of-the-art report in the later phase of the project.

1 Introduction

1.1. Open Science (OS) and the role of higher education institutions (HEIs)

We are surrounded by numerous social, economic, and environmental challenges in this 21st century. Public awareness of these challenges has increased in the past decades, and we are now urged to reconsider the way of living to be more sustainable. The United Nations advocated the 17 Sustainable Development Goals (SDGs) in 2015, intending to achieve global interlinked goals for a better and more sustainable future by 2030. In this era, how we get together and tackle these real-world problems has been one of the key subjects discussed worldwide.

One possible way of tackling such challenges is to bring citizens into the scientific problem-solving processes using Open Science (OS). UNESCO (2020) states in their developed recommendation draft (Towards a Recommendation on Open Science) as follows:

> In the context of pressing planetary and socio-economic challenges, sustainable and innovative solutions require efficient, transparent and vibrant scientific efforts, not only stemming from the scientific community, but from the whole of society. To ensure that science truly benefits the people and the planet and leaves no one behind, there is need to transform the entire scientific process. (UNESCO, 2020, p.2)

They define OS as "a movement aiming to make science more open, accessible, efficient, democratic, and transparent" (UNESCO, 2020, p.2). More specifically, the two-year EU funded project FOSTER (Fostering the practical implementation of Open Science) describe OS as follows:

> the practice of science in such a way that others can collaborate and contribute, where research data, lab notes and other research processes are freely available, under terms that enable reuse, redistribution and reproduction of the research and its underlying data and methods. (n.d.)

The shared core concepts are "openness" and "collaboration" across the definitions. With its nature as an umbrella term, OS includes a wide range of activities, different stakeholders (e.g., the public, researchers, policymakers, digital platform providers, etc.) and standpoints, which consequently make it difficult to explain the term simply and concisely (Fecher & Friesike, 2013). The components of Open Science illustrated by UNESCO (2020) are shown in Figure 1.

Higher education institutions (HEIs) play an essential role in fulfilling the OS visions because educational and scientific organizations positively impact society in social, economic, and cultural ways (Väänänen & Peltonen, 2016). Universities work as a central part in the various types of OS implementation and contribute to executing policies, operating services, and providing support on the institutional level (Zourou, 2020). As being educational and scientific institutions, they provide opportunities and environments for people to learn, develop and utilize new knowledge and technology which are necessary to cope with the real-world challenges. Universities also have a third mission; bringing science into society, facilitating regional economic development, and helping to overcome societal challenges by acting as regional innovation builders (Benneworth et al., 2009).

Figure 1. Components of Open Science retrieved from UNESCO (2020).

The European University Association (EUA) emphasized the impact of HEIs on society. It said, "In 2020, the need for strong universities has never been greater in addressing societal challenges – the Covid-19 pandemic and other public health crises, climate change, resource scarcity, ageing populations, migration and managing artificial intelligence among many examples" (EUA, 2020, p. 3). In their recent publication: *Universities without walls A vision for 2030* (EUA, 2021), four pillars of university missions for 2030 are introduced as follows:

- Learning and teaching
- Research
- Innovation
- Culture

Under the pillars, (European) universities are expected in their operation to:

- "nurture and enable the development of learners as creative and critical thinkers, problem solvers and active and responsible citizens equipped for lifelong learning" (p.7)
- "facilitate dialogue across disciplines and promote multi- and interdisciplinary research" (p.8) by setting OS as a "default way of producing knowledge" (p.8)
- "make human-centred innovation their trademark, aiming to achieve sustainability through cooperative models" (p.9)
- "make an important contribution to culture, the interpretation of society and the human condition" (p.9).

HE curricula need to be designed to align with these aims and prepare the students to tackle societal challenges to fulfil the visions. The future curricular design will be discussed in the later section. Before diving into it, we will first attempt to capture a comprehensive picture of OS implementation in the contexts of HEIs.

1.2. OS practices implemented in the contexts of HEIs

1.2.1. Open research point of view

HEIs implement OS practices in different ways because of the versatility of the concept. For instance, open research is more concerned with research and researchers, scientific communities, publications, and research impact, whereas open education refers to open approaches of learning and teaching in different settings such as schools, HEIs, vocational education, or other informal learning activities (Heck et al., 2020).

Regarding OS from the open research point of view, Hart et al. (2021) display the related concepts revolving around OS by the level of application in the science process (Figure 2). As the pyramid shows, Open Access to journals and articles is the most widely applied component of OS. Open source is commonly used in the digital context, such as free software or platform. Open data is represented as a pre-print server (e.g., arXiv, bioRxiv, and engRxiv) and a publicly accessible data repository (e.g., GitHub and Zenodo, etc.). Open innovation refers to the collaboration of two or more parties across organizations to achieve a joint objective without being obligated to open and share their own outputs or patents. Open collaboration, open lab notebooks, and No IP (not filling for Intellectual Property) are the ultimate format of openness in the science process (Hart et al., 2021).

As seen at the bottom of the pyramid, the scientific community, including universities, academic libraries, researchers, and funding bodies, has strived to build proper infrastructures to make research open and accessible. For example, they create open access repositories and research data archives and establish a data handling and preservation policy, the so-called Data Management Plan (DMP) (De León & de Ferrer, 2018). Academic libraries play a key role in these processes by offering a stable environment to collect knowledge and services, developing institutional policies, disseminating information about Open Access, and organizing training sessions for academic staff (Kuprienė & Petrauskienė, 2018).

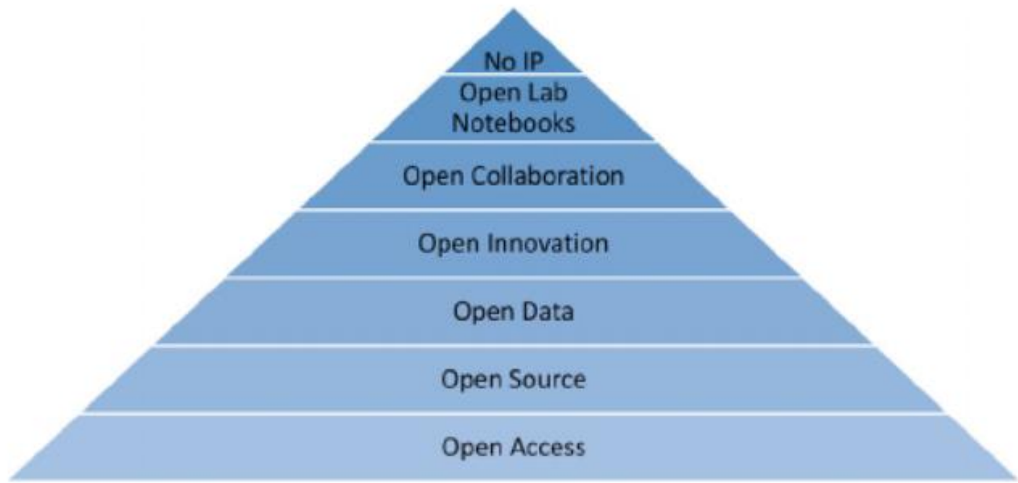

Figure 2. Open science encompasses a range of related terminology and practices retrieved from Hart et al. (2021)

OECD (the Organization for Economic Co-operation and Development) and EU policymakers envision building Open Science and research principles, but national agencies take the main responsibility for making national policies to lead initiatives at a university level (Väänänen & Peltonen, 2016). In practice, European universities have managed to develop their own knowledge pool and DMP in collaboration with various stakeholders (e.g., researchers, academic libraries, and national agencies) and provide staff training and recommendation on the operation of open access and data, implementing "openness" into their work as a science body (see example cases below).

<Example cases>

- The University of Helsinki and Helsinki University Library: Editori (Koskinen et al., 2021) https://www.helsinki.fi/en/beta/helsinki-university-library/library-researchers/open-science-and-research
- The Vilnius University and the Vilnius University Library: eLABa and MIDAS (Kuprienė & Petrauskienė, 2018)
  eLABa (the national open access repository) https://www.elaba.lt/elaba-portal/en/web/guest
  MIDAS (the national open access data archive) https://www.midas.lt/public-app.html#/midas?lang=en
- The University for Applied Sciences and Arts Western Switzerland (HES-SO): ArODES (Dardier, 2018) https://arodes.hes-so.ch/

However, current studies about OS (and CS) practices in the HE contexts mostly focus on research and its publishing process (e.g., open access and data) and scarcely discuss the impact of OS on learning and teaching activities in HEIs (Heck et al., 2020). Thereby, it is time to move on to the next step: shedding light on the educational aspects.

1.2.2. Open education point of view

Besides the open research concept, open education is another angle HEIs contribute to practicalizing OS principles. The European Commission defines open education as follows:

> A way of carrying out education, often using digital technologies. Its aim is to widen access and participation to everyone by removing barriers and making learning accessible, abundant, and customisable for all. It offers multiple ways of teaching and learning, building and sharing knowledge. It also provides a variety of access routes to formal and non-formal education, and connects. (Dos Santos et al., 2016, p. 5)

Open education contributes to the goal of SDG 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (United Nations, n.d.) by decreasing the inequalities of learning accessibility and giving learning opportunities to the citizens.

In one of the previous deliverables of the INOS project, Teo (2020a) suggested, by referring to the study of Cronin (2017), that open education includes the following four interpretations of "openness": 1) open admission, 2) open as free, 3) open educational resources, and 4) open educational practices. Open Educational Resources (OER) is one of the most common OS applications in education and learning. It refers to "digitised materials offered freely and openly for educators, students, and self-learners to use and reuse for teaching, learning, and research", according to the OECD (2007, p. 2). Creative Commons, an American non-profit organization, is one of the most famous institutions promoting educational access and harnessing creative works by helping individuals overcome legal obstacles with copyright license provision. On the other hand, Open educational practices (OEP) mean beyond just utilizing OER, but includes wider implementation such as to "use, and reuse of open educational resources (OER) as well as open pedagogies and open sharing of teaching practices" (Cronin, 2017, p. 15).

The OpenEdu framework for higher education institutions by European Commission (Dos Santos et al., 2016) presents ten dimensions to facilitate open education (see Figure 3). The six core dimensions represent what aspects of open education need to be fostered, and the surrounding four transversal dimensions describe how to achieve these goals. They suggest how the transversal dimensions, namely external support, should be placed as follows:

> For example, if a university were to decide to focus on the content and research dimensions for the institutional opening up of education, they could use a repository to share content and research (*technology*). This would be supported by a strategy to widen access to learners and increase the institution's reputation and reach by enhancing downloads of research and educational material. The process could be led by both a bottom-up and top-down approach of staff engagement (*leadership*) and would seek a high standard of education provision (*quality*). In this example, as previously indicated, the core dimensions also interact with one another, since content (courses) and research both have an intrinsic relationship to *pedagogy* and collaboration. (Dos Santos et al., 2016, p. 8)

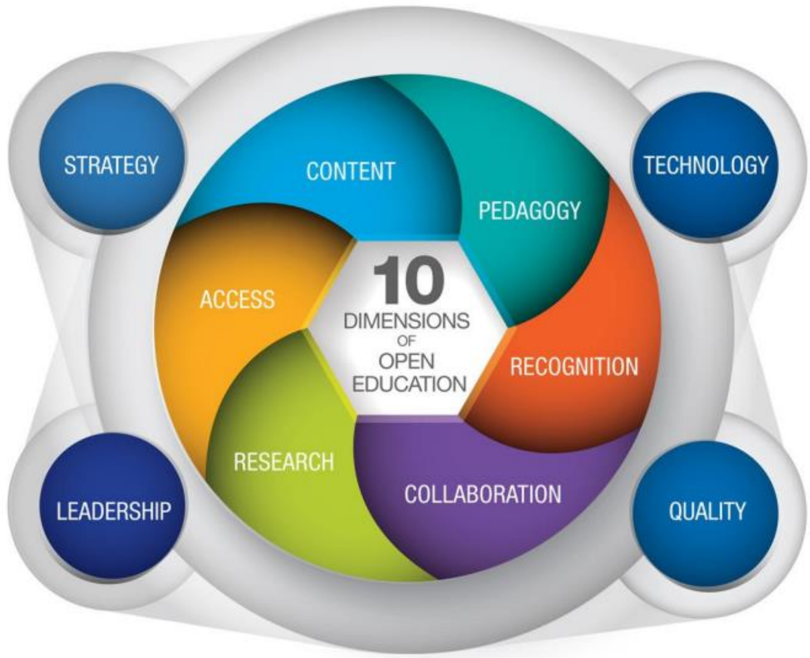

Figure 3. The ten dimensions of open education retrieved from Dos Santos et al. (2016)

In summary, HEIs are suggested to utilize their knowledge pool (e.g., repository and database) in their teaching practices with the help of technology and strategy that promotes both learner and staff engagement. Besides the infrastructural support, practitioners' mindsets and open culture are required at the institutional level to make education open. By doing so, HEIs can bridge research and pedagogy, create interdisciplinary collaboration, and provide high-quality, student-centred open education. However, Heck et al. (2020) point out that educators are not aware of the offerings for open education implementation from national or EU projects and still need assistance or support to know the concept and practical application. Thus, publishing guides and recommendations for educational practitioners is highly required.

1.2.3. Open innovation point of view

Open Science in academia is mostly discussed with the context of the open publication and data management (Hart et al., 2021); however, OS includes wider implications such as transformations of how research is being performed, which means that knowledge is shared through collaboration and the process enables wider contributions to science world and encourages effective use of research results in society (Väänänen & Peltonen, 2016). Universities can turn research into practice by connecting to society, supporting the creation of a new high-technology company, consulting for local industry and political decision making, and generating social opportunities and services (Benneworth et al., 2009). University-industry (U-I) collaboration is expected to accelerate economic development by leveraging universities' professional knowledge that supports regional development at a local and national level (Rajalo & Vadi, 2017).

The traditional form of collaboration was a partnership where the business practitioner provides a research topic and funding to the researchers to generate an innovative solution for their business activities (Rajalo & Vadi, 2017). However, a new type of U-I collaboration has emerged initiated by universities and other related players in the form of a collaborative arena that supports a more flexible co-creation and innovation process (Germundsson et al., 2020). Accordingly, a great deal of open and social participatory programs, collaboration with private and public sectors, and public science projects have been conducted across the world, and HEIs attempt to create new or updated, or another way of connecting to the society through these activities (Király & Géring, 2021). Research, Development and Innovation (RDI) is facilitated by transdisciplinary collaboration in which research systems are highly interactive, transparent, practice-based, and respond to future needs (Väänänen & Peltonen, 2016). Thereby, "regional development can no longer rely solely on a tradition of innovations stemming from research, but instead, an open innovation model needs to be applied more efficiently" (Väänänen & Peltonen, 2016, p.291).

1.3. OS and CS implementation in curricular design

1.3.1. The future direction of HEIs

Universities shape society and create social values by training students who will use skills and knowledge to make a better society as responsible citizens (Király & Géring, 2021). Therefore, how to cultivate ´human value´ has been the forefront of discussion among HEIs while the "traditional" teaching methods, namely knowledge transmission, no longer work for that goal (Davidson, 2017, as cited in Király & Géring, 2021). In other words, the required skills and knowledge for the 21st century are hardly developed through the traditional teaching methods and curricula designed with passive lectures to teach domain-specific content. Accordingly, the European Consortium of Innovative Universities (ECIU) suggest how future education needs to be as follows:

> "The ECIU University will change the way of offering education from being degree-based to being challenge-based. Our learners and researchers will contribute to solving climate crises and other urgent challenges that Europe will face. The ECIU University will constitute be a real European university where learners, teachers and researchers cooperate with cities and regions, businesses, and citizens to solve real-life challenges in a unique and, flexible way. Furthermore, the challenges will focus on the UN Sustainable Development Goal 11: Sustainable cities and communities. This means learners at ECIU University will be tackling real and important problems in society and help shape a better world" (ECIU, n.d.).

The statement emphasizes that education should be delivered in societal problem-solving processes and supported in multidimensional collaboration across sectors (e.g., students, teachers, researchers, HEIs, SMEs, regional communities, etc.) and disciplines. Future-focused education can be designed with OS/CS approaches in which students and other stakeholders can work together to deal with social challenges and construct new knowledge.

What skills and knowledge are expected to be cultivated in such a learning environment? Our previous work (Teo, 2020a) analysed collective case studies and found out that various OS-, CS- and open innovation-based learning activities aim to address the following knowledge gap despite the diversity:

1. Knowledge or awareness of a particular topic (ubiquitous to all activities)
2. Soft and technical skills needed for proper and open science/innovation practice
3. Knowledge of the scientific inquiry method
4. Open data skills

Besides subject knowledge, students need to learn and become competent with any digital tool, from working in a collaborative platform to creating digital content. Technical skills and various soft skills such as communication, problem-solving, creativity, and other interpersonal competencies are required through the learning processes. They are expected to be gained as learning objectives. Similarly, science attitude and inquiry ability to define the problem and seek the solution is particularly important, especially for challenge-based learning activities. Last but not least, cultivating open data skills is essential in any OS-based activity since it requires the processes of accessing an open database, reusing open data, and publishing new knowledge artefacts. These skills mentioned above, and knowledge are required in the practical OS/CS and open innovation scenarios. Therefore, it is expected for HEIs to equip students with such skills through their teaching activities.

1.3.2. OS and CS in teaching practices

In teaching practices, OS and CS can be implemented in two ways: being taught as learning content or being utilized as a learning methodology. Regarding OS as learning content, the aforementioned HES-SO, which developed an internal data archive and repository system, offers a study course for students and training modules for the researchers and information professionals to teach them how to manage the research dataset and its life cycle. The work was supported by the national university consortium Swissuniversities and aimed to train the HEI staff and students with open access principles at a national level (Dardier, 2018). By training HE students and staff members, including teachers, researchers, and librarians with OS practices, HEIs can cultivate an 'open' culture and mindsets at an institutional level.

From a methodological point of view, the CS approach is a great way to design student-centred and problem-oriented learning approach. Situational interest driven by curiosity positively impacts student attitude and motivation towards learning, which leads to better engagement and deeper learning (Flowerday et al., 2004). For instance, Borrell et al. (2016) investigated how the CS approach can improve HE students' motivation and engagement for the topic of genetics and food control. In the three Master and Bachelor level courses (food production, molecular biology, and genetics), students brought real food samples consumed at home and did laboratory experiments using them. The survey results show that students who worked on their own samples from local markets were significantly more motivated and better evaluated their laboratory practices than control students. They concluded that citizen science approaches can be useful for improving teaching subjects (e.g., genetics) in universities but also for involving students and citizens into the topic as (e.g., food control) as active agents (Borrell et al., 2016).

From both content and methodological perspectives, Jekel et al. (2020) introduced a good example of the use of OS activity in teaching Master's level students in their study: How to Teach Open Science Principles in the Undergraduate Curriculum—The Hagen Cumulative Science Project. The University of Hagen carried out the Hagen Cumulative Science Project (HCSP) to make students internalize the OS principles through their thesis work in Bachelor and Master curricula. Students are assigned to re-analyse the original empirical studies picked up from the university's database to examine the replicability of the study. The students write reports (theses) to reflect on the applied theories and discuss the results of the original studies and upload the documents on the Open Science Framework platform (OSF: https://osf.io/) to make them accessible. The project was expected to increase students' feeling of contribution to cumulative science, understand the transparency and OS principles, and equip them with scientific thinking and practical methods.

These examples provide insight into how we can efficiently integrate OS/CS activities into the HE curriculum to enhance students' engagement in their learning. In the later section, we will present various types of existing curriculum cases to find possible ways of developing OS/CS-oriented learning approaches.

1.4. Purpose and audience of the report

The INOS project (Integrating Open and Citizen Science into Active Learning Approaches in Higher Education) aims to identify how universities can better encourage public participation, facilitate OS/CS activities in a pedagogically sound way, upskill the students and staff members in HEI, and upgrade their curricula in order to incorporate OS/CS into education. This state-of-the-art report overviews the current status of OS/CS implementation into HE curricula and provides the readers with real example cases of OS/CS integrations in leading European universities. We hope this information will be useful for HE practitioners and decision-makers, including national educational agencies, curriculum developers, course designers, university teachers, researchers, and other academic staff members.

2 Methodology

2.1. Research questions

This state-of-the-art report (O5A1) will investigate the most recent stage of the practical implementations of OS/CS into teaching and learning activities in European HEIs. We also attempt to analyse the selected cases to get insights into potential educational implementation to improve current curricular and teaching practices. To fulfil the aims, the following research questions were developed:

RQ1. How are OS/CS activities implemented into curricula in European HEIs?

RQ2. Who are the other stakeholders involved in the learning activities?

RQ3. What kind of pedagogical approaches are used in OS/CS implemented curricula?

RQ4. What kind of skillsets are required in participant students?

2.2. Searching criteria

To present the most relevant examples, the cases were collected and selected from the following sources:

1) The League of European Research Universities (LERU) member universities
2) Recommendation from the INOS partners

The following sub-sections will explain the rationale for selecting these sources (2.2.1 and 2.2.2).

2.2.1. LERU member universities

LERU (https://www.leru.org/) is a European university association consisting of 23 most renowned research universities in 12 countries. The member universities were "periodically evaluated against a broad set of qualitative criteria and quantitative, such as research volume, impact and funding, strengths in Ph.D. training, size and disciplinary breadth, and peer-recognised academic excellence" (LERU, n.d.). The selection criteria seem promising that the member universities are leading European HEIs positioned at the most recent research and educational activities. Another rationale for selecting this league is that they have published several papers upon OS (e.g., Open Science and its role in universities: A roadmap for cultural change, Ayris et al., 2018) and CS (e.g., Citizen science at universities: Trends, guidelines and recommendations, Wyler et al., 2016) and introduced some CS initiatives of LERU universities and beyond. For these reasons, we consider that selecting these universities is reasonable, and reviewing their curricula may provide us with great examples of cutting-edge OS/CS implementation in education.

The LERU member universities are as follows:

- University of Amsterdam (in the Netherlands)
- Universitat de Barcelona (in Spain)
- University of Cambridge (in the UK)
- University of Copenhagen (in Denmark)
- Trinity College Dublin (in Ireland)

- University of Edinburgh (in Scotland in the UK)
- University of Freiburg (in Germany)
- Université de Genève (in Switzerland)
- Universität Heidelberg (in Germany)
- University of Helsinki (in Finland)
- Universiteit Leiden (in the Netherlands)
- KU Leuven (in Belgium)
- Imperial College London (in the UK)
- University College London (in the UK)
- Lund University (in Sweden)
- University of Milan (in Italy)
- Ludwig-Maximilians-Universität München (in Germany)
- University of Oxford (in the UK)
- Sorbonne University (in France)
- Université Paris-Sud (in France)
- University of Strasbourg (in France)
- Utrecht University (in the Netherlands)
- University of Zurich (in Switzerland)

To these universities, we reached out by sending survey questions including the typologies (see section 2.4).

2.2.2. Recommendation from the INOS partners

Besides the given universities, other cases from the INOS partners were included in this report. The partner institutions are experts of OS/CS principles and they have deep knowledge of the topic and the latest information on the ongoing developments, especially in their own countries. Thus, including the recommended cases makes more sense to present the state-of-the-art report of the comprehensive European situation and expands the possibility of finding a more variety of cases.

2.3. Case study selection

The case locations are specified in the European region but not limited to EU member countries. Although the INOS project uses the term HEI(s), including academic libraries, this report focuses on the actual curricula or educational activities of universities or equivalent educational institutions (e.g., a university of applied science). The curricula may include accredited courses, study modules, EU projects, and other learning activities. The websites of the HEIs and other related resources were explored and reviewed by the INOS partners to find the relevant information of OS/CS implementation into the HEIs' curricula. The case was excluded from the final presentation if a case did not mention 'open science' or 'citizen science' or other related terms of OS principles (e.g., open research, open education, open innovation, etc.) in a written form. After the evaluation, a total of 16 cases were selected (and nine cases are displayed in the Annex).

2.4. Typology and category applied to the cases

The selected cases will be presented with the following typologies to standardize the layout and make further evaluation steps easy and coherent.

Website: URL of the case program

Location: where the HEI that carry out the case program is located

Foundation: the starting year of the case program (not HEI)

Curriculum design: accredited courses, study modules, EU projects, and other learning activities

Duration: The length of the case program

Teaching language: in what language the case program is conducted

Target: the participant students or other external learners

Outline: the short explanation of the case program

OS/CS implementation: how is the OS/CS concept is integrated into the case program

OS/CS dimensions: (category: citizen science, open innovation, open data, etc.)

External stakeholders: people or institutions that are involved in the case program

Pedagogical approach: (category: problem-based learning, inquiry-based learning, etc.)

Required skillsets: students' (or teachers') skills or competencies required to take the case program

OS/CS dimensions illustrate what kind of OS aspect is integrated into the case project. The categories are based upon the presented elements by the United Nations (see Figure 1) but slightly adjusted by excluding irrelevant ones and integrating other elements from our previous work to better fit the aim of the report. The categories are Citizen Science, Open Innovation, Crowdsourcing, Open Labs, Open Data, Open Education (Including both OER and OEP), Open Access, Open Source, and Open Evaluation.

The category of **Pedagogical approach** utilizes the Learning Design Framework (LDF), which has been developed by the INOS consortium (see Teo, 2020b). The categories consist of five different learning activity types:

1. Passive Learning Activities
2. Informal Science Learning Activities
3. Discussion-based Learning Activities
4. Inquiry-based Learning Activities
5. Problem-based Learning Activities

The evaluation criteria of each activity are shown in Table 1 (Teo, 2020b). In addition, if the case program specifically mentions another learning approach in their source (e.g., Peer-to-peer Learning), we also write such information besides the above categories.

Table 1. Popular types of OS/CS/OI Learning Activities organised by HEIs and academic libraries can be represented by the following activity formats. All formats can be conducted online or at a physical venue. All are flexible to any field (e.g., science, social science, arts, design etc.). It is possible for organisers to combine multiple formats into their activities from Teo 2020b.

	Passive Learning Activities	**Informal Science Learning Activities**	**Discussion-based Learning Activities**	**Inquiry-based Learning Activities**	**Problem-based Learning Activities**
General task	• Learning comes from observing a lecture-style presentation. • Typically, no learning artifact (i.e. an object created by students that demonstrates their learning).	• Learning comes from being involved in part of a research project led by experts/organisers. • Typically, no learning artifact.	• Learning is centred around a discussion that produces a new knowledge artifact. • Final output is a collaborative artifact (e.g. concept maps).	• Learning is centred around a research question that is answered via the scientific inquiry method. • Final output is a research finding.	• Learning is centred around a problem that needs solving. • Final output is an innovative product or service.
Learning goals and outcomes	• General and open learning goals e.g. to understand or raise awareness of certain topics. • Learning outcomes are typically not assessed in detail.	• General and open learning goals e.g. to understand or raise awareness of certain topics. • Learning outcomes depend on the type and level of participation. • Learning outcomes are typically not assessed in detail.	• To understand or raise awareness of certain topics. • To generate new ideas. • To enable joint decision-making. • To reflect on a topic. • Idea mapping. • To gain insight on various viewpoints.	• To understand or raise awareness of certain topics. • To improve understanding of the scientific inquiry method and how scientists work. • To develop technical skills in particular tools and technologies in science.	• To develop soft skills needed for open collaboration, with emphasis on teamwork, communication and methodologies. • To develop technical skills in particular tools and technologies in science and innovation.
Activity examples	• TED Talks – Experts share their knowledge in talks that are posted online for free distribution. • Pint of Science – Scientists share their latest research to a public audience in their local pub, bar or café. • Webinars	• iNaturalist – Participants map and share biodiversity field observations via a mobile app, producing open data. • Galaxy Zoo – Volunteers classify galaxies from telescope images. • Smithsonian Digital Volunteers – volunteers transcribe historical documents • Shakespeare's World - a project to transcribe handwritten documents by Shakespeare's contemporaries. • Wikipedia Edit-a-Thons by 500 Women Scientists	• Sharing Cities Action's co-creation activities – Groups of different stakeholders discuss • Knowledge Café – A group of people discuss a topic to better understand it. • Reversed Science Café, Science Expresso, and Scenario Workshop by The Sparks Project (Sparks Project, n.d.). • Dotmocracy Workshops – a simple method for group prioritisation or decision-making.	• nQuire – A platform where citizens conduct scientific projects of their own interest, with guidance for each inquiry step (Aristeidou et al., 2017). • iSCAPE Living Labs – Citizens and experts investigate local air pollution issues and collaborate on solutions. • iSpot – iSpot's embeds inquiry-based learning into their CS activity (Ansine et al., 2017)	• #EUvsVirus Challenge – Online-based hackathon in 2020 to develop innovative solutions for coronavirus-related challenges. • Challenge Based Innovation – Innovation program for university students to develop projects that solve complex societal problems.

	Passive Learning Activities	Informal Science Learning Activities	Discussion-based Learning Activities	Inquiry-based Learning Activities	Problem-based Learning Activities
Activity examples based on descriptions by the [Engage2020 Action Catalogue]	• Science Café	• Participatory Sensing • Participatory Modelling • Serious Games	• Citizens Hearing • Citizens' Assembly • Civic Dialogue • Consensus Conference • Consensus Workshop • Crowd Wise • Deep Democracy – The Lewis Method • Deliberative (Mini-publics) Workshops • Deliberative Mapping • Deliberative Online Forum • Democs Card Game • E-conference • Future Search Conference • Future Workshop • Intake Question into Research Question • Perspective Workshop • Q methodology – stakeholder selection • Research Agenda Camp • Resource Flow Map • Scenario Workshop • Science Theatre • Serious Games • Stakeholder Working Groups • World Café • World Wide Views	• Action Research (also known as Participatory Action Research) • Citizen Science • Community-Based (Participatory) Research • Demand Driven Research in Curriculum • Science Shop • Science Week	• Challenge Prizes • Enrich by Co-design • Hackathon • Interdisciplinary Work Groups • Knowledge Atelier • Participatory Design (Co-design and practice-based research) • Reflexive Interactive Design

2.5. Limitations

It is important to note that it was difficult to conduct g a systematic review due to the nature of the core topic “curricula,” which is usually not visible in academic literature. For example, we first attempted to search for the example cases in major academic databases (e.g. Ebsco, ProQuest, Scopus) with the following search strings: (“open science” OR “citizen science”) AND (“higher education” OR universit* OR curricul*) to access related information for the past five years. Through this search, we identified 25 papers about Europe out of a total of 73 papers; however, most of the found articles focused on the open research aspect (e.g., open access, open data, open publication, etc.) rather than OS/CS implementation in education. This result gives evidence to the claim that current studies of OS (and CS) in HE contexts discuss the practical implementation of open research processes and scarcely focus on the educational side of HEIs (e.g., Hart et al., 2021; Heck et al., 2020). In addition, a specific curriculum design is usually not visible on a university website, and some universities use their national languages in such information, which also hinders us from the maximum access to the resources.

For these reasons, we should acknowledge the limitations to systematically search and present “the best leading cases”, yet this report still provides several current example cases based on the INOS partners’ recommendations and the aforementioned selection criteria.

3 Selected cases

Through the reviewing process, a total of 16 cases were selected to be introduced. The selected examples are all accredited learning activities and displayed by application type: study module, course, or degree program. The difference between the study module and course is explained as follows:

> Most higher education courses have a 'modular' structure. This means that you can build a personalised course by choosing modules or units of study from different subject areas. For example, if you are studying English literature, for your first year you could choose one module on Science fiction, one module on Children's literature, and one module on Short stories. (British Council. n.d.)

Based on this idea, we define 'study module' as a themed subset of a course and 'course' as a larger component including several study modules. A 'degree program' is composed of a set of courses. Table 2 shows the overview of the selected cases. Each case shows the typologies set in the methodology section (2.4). We also found several examples of non-accredited learning activities, but they are separately introduced in Annex.

Table 2. An overview of the selected cases

No.	Name	Type	OS/CS dimension	Learning methods	HEI
1	Basics of Open and responsible Science: Open Access Publishing and Research Data online course	Study module	Open Access, Open Data, Open Evaluation, Citizen Science	Passive Learning	University of Eastern Finland, (Finland)
2	Citizen Science and Scientific Crowdsourcing: an Introduction	Study module	Citizen Science, Crowdsourcing, Open Data	Passive Learning	University College London (England)
3	ECIU University Challenge platform	Study module	Open Innovation	Challenge-based Learning	12 ECIU member universities
4	Geo-Python course	Study module	Open Education, Open Source, Open Access	Experiential Learning, Passive Learning, Peer-to-peer Learning	University of Helsinki (Finland)
5	Global Engagement Module	Study module	Open Innovation	Challenge-based Learning, Peer-to-peer Learning	9 ENLIGHT partner universities
6	Integrated Responsible and Open Research training cycle for PhD students	Study module	Open Access, Open Data, Citizen Science	Passive Learning, Discussion-based Learning	KU Leuven (Belgium)

7	**Research data management – survey and interview data**	Study module	Open Data	Problem-based learning, Inquiry-based Learning, Passive Learning	Tampere University (Finland)
8	**WaterAct**	Study module	Citizen Science, Crowdsourcing, Open Data	Informal Science Learning, Research-based Learning	Tallinn University (Estonia), University of Latvia (Latvia)
9	**BOKUroadkill**	Course	Citizen Science, Crowdsourcing	Inquiry-based Learning	University of Natural Resources and Life Sciences Vienna (Austria)
10	**Challenge Based Innovation (CBI)**	Course	Open Innovation, Open Labs	Peer-to-peer Learning, Project-based Learning, Challenge-based Learning	Across Europe + Australia and the U.S.
11	**Citizen Science Talent Programme**	Course	Citizen Science	Inquiry-based Learning, Informal Science Learning	University of Southern Denmark (Denmark)
12	**LIFE course**	Course	Open Innovation	Project-based Learning, Problem-based Learning,	Tallinn University (Estonia)
13	**MSc Course in Citizen Science, Natural History Museum of Denmark**	Course	Citizen Science, Open Data, Crowdsourcing	Problem-based Learning, Inquiry-based Learning	Natural History Museum of Denmark, University of Copenhagen (Denmark)
14	**Service-Learning Course**	Course	Open Innovation	Service-learning, Project-based Learning, Challenge-based Learning	KU Leuven
15	**HDip Irish Folklore**	Degree program	Citizen Science, Open Access, Open Data	Inquiry-based Learning	UCD School of Irish, Celtic Studies and Folklore (Ireland)
16	**Master AIRE**	Degree program	Citizen Science, Open Innovation	Project-based Learning, Challenge-based Learning, Inquiry-based Learning, Peer-to-peer Learning	University of Paris, CRI Campus (France)

3.1. Study module

In this category, we introduce eight case examples (case 1-8). Usually, a study module represents themed subset of a course, namely series of lectures, and provides 1-5 ETCS. The order of appearance is alphabetical.

1 Basics of Open and responsible Science: Open Access Publishing and Research Data online course

Website: https://blogs.uef.fi/ueflibrary-bors/

Location: University of Eastern Finland (Finland)

Foundation: 2021

Curriculum design: Course (2 ETCS) for graduate students as a part of UEF Doctoral School's studies.

Duration: The course is open for almost the entire academic year (1.9.2021 – 12.6.2022).

Teaching language: English/Finnish (study material in English, study assignments can be completed in English/Finnish)

Target: UEF and YUFE (Young Universities for the Future of Europe) network's graduate students.

Outline: The course is available for UEF and YUFE network's graduate students. Study material is constantly openly available for everyone interested in open science.

OS/CS implementation: The course is an introductory online course on the elementary issues of open science, focusing on two focal perspectives: open access (OA) publishing and open research data.

OS/CS dimensions: Open Access, Open Data, Open Evaluation, Citizen Science

External stakeholders: The study material is produced in co-operation with the library, University services, Doctoral school, Department of computer science, and Department of applied physics.

Pedagogical approach: Passive Learning

Required skillsets: No special skills required. Having a PhD project helps integrate OS into one's research project.

2 Citizen Science and Scientific Crowdsourcing: an Introduction

Website: https://www.ucl.ac.uk/short-courses/search-courses/citizen-science-and-scientific-crowdsourcing-introduction

Location: University College London (England)

Foundation: n.d.

Curriculum design: online course

Duration: 30 hours (2-3 hours for a topic)

Teaching language: English

Target:

- those involved in citizen science and public engagement with science
- scientists who are considering developing a citizen science project

Outline: This online course will introduce you to citizen science and scientific crowdsourcing theory and practice. You will explore the history, theoretical foundations, and practical aspects of designing and running citizen science projects. By the end of the course, you will understand citizen science and be familiar with the academic literature in this area.

OS/CS implementation: Citizen Science and Crowdsourcing as learning objectives.

OS/CS dimensions: Citizen Science, Crowdsourcing, Open Data

External stakeholders: not mentioned

Pedagogical approach: Passive Learning

Required skillsets: No pre-requisites, digital learning skills in MOOC environment

3 ECIU University Challenge platform

Website: https://challenges.eciu.org/

Location: Online among the 12 ECIU University member institutions

- Aalborg University, Denmark
- Dublin City University, Ireland
- Technische Universität Hamburg, Germany
- Kaunas University of Technology, Lithuania
- Linköping University, Sweden
- Tampere University, Finland
- Autonomous University of Barcelona, Spain
- Aveiro University, Portugal
- University of Stavanger, Norway
- University of Trento, Italy
- University of Twente, The Netherlands
- Groupe INSA, France

Foundation: n.d.

Curriculum design: Optional study module for 1-6 ECTS (depending on the duration of the project)

Where traditional approaches are based on first to learn and then apply, ECIU University offers starts from the challenge. It helps you understand the needs, analyse what knowledge the team is missing to come to a solution, and support the team to acquire the necessary know-how and competencies to come to their solution and a pathway to implement (challenge-based learning approach).

Duration: Depends on the project (1-6 ETCS)

Teaching language: English

Target:

- be a student of one of the 12 ECIU University member institutions
- be enrolled in a master's degree programme or final year of a bachelor's degree programme
- have completed 120 ECTS of higher education studies at the undergraduate level
- have a B2 level of English language proficiency (Self-assessment, CEFR of languages)

Outline: At ECIU University, learners, teachers, researchers, representatives of businesses and public organisations - join forces across various disciplines to solve real-life problems using the challenge-based learning (CBL) education model.

OS/CS implementation: The challenges are provided by a city, region, or business stakeholder of the ECIU University. Then each member university selects several challenges provided by their region, city, or community and invites learners and students to explore the challenge-solving team.

OS/CS dimensions: Open Innovation

External stakeholders: a city, regional community, or business stakeholder

Pedagogical approach: Challenge-based Learning

Required skillsets: B2 level of English language, multidisciplinary team skill

4 Geo-Python course

Website: https://geo-python.github.io

Location: University of Helsinki (Finland)

Foundation: 2016

Curriculum design: 5 ECTS in the associated BSc or MSc degree programs

Duration: 7 weeks (21 hours of lessons + exercises with 2*4 hours per week of 'help sessions')

Teaching language: English

Target: BSc/MSc students in geology or geography (mainly), some other natural science students

Outline: The Geo-Python course introduces students to programming in the Python language and other related topics assuming no previous programming experience. We introduce the programming concepts and syntax through live demonstrations where students follow a ready-made weekly lesson as the teacher leads them through it. Both parties are typing in commands simultaneously, allowing students to learn the material through doing the lessons and asking questions to the teachers during the lessons as they arise. The students also complete weekly exercises (in pairs) to apply the lesson materials in new ways to deepen their understanding. We provide two four-hour exercise support sessions each week to answer student questions and help ensure they can progress with the exercises. In addition to the above, we introduce students to common tools used by professional software developers and best practices to ensure they learn how to program optimally.

OS/CS implementation: Open science is deeply integrated into the course, from the collaborative coding platform used in the course (GitHub.com) to the motivations introduced on day one of the course: namely documenting our programs and ensuring our results are always reproducible. We introduce the students to a programming application called Jupyter notebooks. Students generate both documentation and code together, including plots, tables, and other information that results in a single document that can be shared to show exactly how results have been calculated and how data have been processed. We also introduced them to using the collaborative coding website GitHub.com, where millions of projects are shared online, many of them open-source. We hope this process will encourage the students to share their code online and other open-source projects. To further promote code sharing, we also introduce the students to good coding practices, such as including descriptive comments in their programs and following standards for code formatting that make it easier for others (and themselves) to understand the code they have written. Finally, all course materials are available online through our course website and associated GitHub.com organization (https://github.com/geo-python/). We promote the course online and encourage teachers and students to share the materials with anyone interested. One of our favourite cases so far was one teaching assistant's mother, who decided to learn to program using the course materials available on the website.

OS/CS dimensions: Open Education, Open Source, Open Access

External stakeholders: Finnish IT Center for Science (CSC), teachers at various Finnish universities coordinate teaching of local versions of the course

Pedagogical approach: Experiential Learning, Passive Learning, Peer-to-peer Learning

Required skillsets: High school education is probably sufficient. We do not assume deep geological or geographical knowledge.

5 Global Engagement Module

Website: https://enlight-eu.org/index.php/news-events/enlight-courses/item/25-global-engagement-module

Location: Online among 9 ENLIGHT partner universities + onsite meeting at the University of Groningen (the Netherlands)

- University of the Basque Country (Spain)
- University of Bordeaux (France)
- Comenius University Bratislava (Slovakia)
- National University Ireland Galway (Ireland)
- Ghent University (Belgium)

- University of Göttingen (Germany)
- University of Groningen (The Netherlands)
- University of Tartu (Estonia)
- Uppsala University (Sweden)

Foundation: 2022 spring

Curriculum design: Study module (5ETCS)

Duration: 1.5 months (1st of March to 13th of May) + on-site week (from 23-30 April 2022, if circumstances permitting)

Teaching language: English

Target: 45 Participating students, five from every ENLIGHT partner university

Outline: The 5-ETC module will be piloted with a small group of students in the Spring of 2022. 45 participating students, five from every ENLIGHT partner university, will be divided into three Learning Communities (LCs) of 15 students each. The Global Engagement Module will consist of two phases: An online preparatory unit, with a welcoming activity, course introduction and a theoretical part and a challenge-based collaborative phase in which students will work intensively together in self-steering groups to tackle the challenge assigned to them with being coached by two (junior) professors.

OS/CS implementation: In collaboration sessions with peer-learning modalities, students divided into three "Learning Communities" will work intensively together to create solutions for three real-world challenges assigned to groups. The problems are 1) public health care and well-being, 2) migration and mobility, and 3) climate change from socio-cultural perspectives. Each learning community comprises 15 students from different nationalities, genders, scientific fields, and PISA Global Competence-Scores, one flagship expert and two junior teachers. This module will be further developed notably thanks to a Professional Learning Community supported by a virtual platform: the objective is to implement strategies for Challenge-based learning promoting collaborative, interdisciplinary and self-regulated learning with particular attention paid to diversity and inclusion.

OS/CS dimensions: Open Innovation

External stakeholders: Not specified

Pedagogical approach: Challenge-based Learning, Peer-to-peer Learning

Required skillsets: Skills students will learn (and need) through the course:

- apply a challenge-based approach
- collaborate effectively within a diverse team
- communicate ideas, visions, and project results to a wide range of audiences

actively and respectfully engage with different perspectives to achieve comprehensive solutions

6 Responsible and Open Research training path for PhD researchers

Website: Generic website with Open Science training overview: https://www.kuleuven.be/open-science/open-science-training-courses-events

Web pages for specific training activities

-Research Data Management training: https://www.kuleuven.be/rdm/en/training/overview

-Research integrity lecture for starting PhD researchers: https://www.kuleuven.be/english/research/integrity/training/phdlecture

-Open Science Discovery for PhD researchers: https://www.kuleuven.be/open-science/events/2021/OSD4PhD (spring 2021 session, next session in fall 2022).

-Open Science study day: https://www.kuleuven.be/open-science/events/2021/OS-study-day-3May/ku-leuven-open-science-study-day (annual event, 2021 page)

Location: KU Leuven (Belgium)

Foundation: Mandatory lecture about research integrity for PhD researchers since 2014. 2021: Proposal to create an integrated **Responsible and Open Research** training path for PhD researchers. To be approved by the University's Executive Board and Academic Council.

Curriculum design:

Mandatory elements

- Discuss and sign the Charter of the PhD researcher and the supervisor (at the start of the doctoral training)
- Research integrity lecture for starting PhD researchers (at the start of the doctoral training)
- Read the ALLEA European Code of Conduct for Research Integrity (at the start of the doctoral training)
- For Biomedical Sciences: Experience based research integrity workshop (middle of the doctoral training)
- Plagiarism check of the PhD manuscript (at the end of the doctoral training)
- Research Integrity declaration after the viva (at the end of the doctoral training)
- In some discipline-specific doctoral schools, the following elements may be mandatory: write a data management plan, research data management workshop, Open Access information session (mostly at the start of the PhD)

Recommended elements

- Online training modules at the start of the doctoral training: VLIR online research integrity tool "Mind the Gap", available in the LIRIcs (Leuven Institutional Research Integrity - culture and self-reflection) community, GDRP e-learning tool.
- Data management plan writing, follow-up, finalization
- Generic Open Science Discovery

- Information sessions and workshops: Open Science, Open Access, Research Data Management, Research Integrity
- Thematic workshops, depending on the research field
- Generic Open Science Discovery
- Open Science study day

Duration: Duration of doctoral studies programme

Teaching language: English, some courses may be available in Dutch

Target: PhD researchers and other researchers are welcome.

Outline: The integrated training path for PhD students aims to support their development as researchers. PhD researchers learn to conduct their research in a reliable, honest, and transparent manner. The training path enables them to communicate about their research openly and responsibly and share their knowledge and results with other researchers and the broader community. The focus lies on acquiring transferable skills, which can be used in academia and other professional environments.

Researchers are not obliged to follow all training activities which are part of the learning path. Some elements are mandatory, the rest of the learning path is flexible. PhD researchers choose their training activities depending on their specific needs. Some departments or faculties may include more mandatory elements of this training path in their doctoral schools.

OS/CS implementation: The training path is a university-wide overarching programme for open and responsible research for doctoral researchers. Some elements are mandatory for all PhD researchers at KU Leuven. Local doctoral schools manage the more specific implementation, which follow PhD researchers for the whole duration of their trajectory.

Following the Open Science pillars of the European Commission and the LERU Open Science roadmap, (https://www.leru.org/publications/open-science-and-its-role-in-universities-a-roadmap-for-cultural-change), research integrity is considered as an essential part of Open Science.

OS/CS dimensions: Open Access, Open Data, research data management, research integrity. Citizen Science is a minor dimension, included in one of the training activities (Open Science Discovery for PhD students)

External stakeholders: External speakers may be invited for some training activities (e.g., Open Science study day)

Pedagogical approach: Passive Learning, Discussion-based Learning (including lecture, workshop, experience-based case studies, online courses, performing tasks such as DMP writing)

Required skillsets: No prerequisites

7 Research data management – survey and interview data

Website: https://www.tuni.fi/studentsguide/curriculum/course-units/otm-dc386ab9-b284-4bc4-a260-d351aa5734e2?year=2021

Location: Tampere University (Finland)

Foundation: 2020

Curriculum design: The course is a part of Tampere University Doctoral School's curriculum (1ETC).

Managing Research Information course (3ETCS) is recommended as a prerequisite (not mandatory) https://www.tuni.fi/studentsguide/curriculum/course-units/otm-56a8a16c-c9f4-4f04-bb41-b7c084952d88?year=2021

Duration: Approximately two months per semester, organised twice a year

Teaching language: Finnish and English

Target: PhD students

Outline: The course aims to deepen the skills needed in managing survey and interview data. The contact teaching ensures that participants understand how important responsible data management is in his/her own research. Research data management is a core skill for researchers. It supports practical work, gives merit to a researcher, and increases the impact of research in society.

To pass the course; the participant has to participate in the lectures and complete the exercises via Moodle on time.

OS/CS implementation: The course is constructed around responsible and open science requirements, especially opening and sharing research data.

OS/CS dimensions: Open Data

External stakeholders: Tampere University only

Pedagogical approach: Problem-based Learning, Inquiry-based Learning, Passive Learning (Moodle)

Required skillsets: Basic understanding and knowledge of open science and research data management, skills acquired in MA studies, research skills

8 WaterAct

Website: https://allikad.info/

Presentation of the project activity (Estonian):
https://www.facebook.com/watch/live/?v=191883009400084&ref=watch_permalink

Location: Tallinn University; Institute of Ecology (Estonia), University of Latvia; Faculty of Geography and Earth Sciences (Latvia)

Foundation: n.d.

Curriculum design: A mandatory part of study module in the master's course of ecology (Tallinn University; Institute of Ecology)

Duration: Not specified (a part of summer field practice of master's degree program)

Teaching language: Estonian

Target: Master's degree students of the related field

Outline: Within the framework of the project "Joint actions for more efficient management of common groundwater resources" (WaterAct) close co-operation will continue between the Estonian and Latvian organizations involved in the preparation of River Basin Management Plans in order to improve the efficiency of joint groundwater resources management in the transboundary area. The project aims to promote the sustainable management of shared groundwater resources in a transboundary area. The goal will be achieved by

1. development of a common approach for status assessment of groundwater bodies,
2. implementation and testing of developed approach in the Latvian-Estonian transboundary Gauja-Koiva and Salaca-Salatsi river basin districts,
3. development of common understanding about groundwater-dependent ecosystem management,
4. raising public awareness and interest in groundwater management and protection.

OS/CS implementation: TU, School of Ecology, has an open science data collection project in Springs. As part of learning activities and anyone in public, the students are mapping the data of springs. Students of geoecology must do field practice in which they take measurements and analyse the summary results as part of their master course (Tallinn University).

OS/CS dimensions: Citizen Science, Crowdsourcing, Open Data

External stakeholders: Besides the above-mentioned universities, the following institutions are involved.

- Latvian Environment, Geology and Meteorology Centre, Hydrogeology Division (lead partner)
- Ministry of the Environment of the Republic of Estonia
- Geological Survey of Estonia
- Nature Conservation Agency, Nature Protection Department (Latvia)
- Vidzeme Planning Region (Latvia)
- Estonian Environment Agency

Pedagogical approach: Informal Science Learning, Research-based Learning

Required skillsets: Not specified

3.2. Course

In this category, we introduce six case examples (case 9-14). Usually, a course is composed of multiple study modules or lectures and requires a longer period (e.g., several weeks to one semester) to complete. The order of appearance is alphabetical.

9 BOKUroadkill

Website: https://boku.ac.at/en/citizen-science/publikationen/2014

Location: University of Natural Resources and Life Sciences Vienna (Austria)

Foundation: 2013

Curriculum design: Mandatory course for the Bachelor programme of Environment and Bio-Resources Management

Duration: 12 weeks

Teaching language: Not specified

Target: Students who enrolled in a semester-long course "Biology of Terrestrial Animals" in the above-mentioned Bachelor programme

Outline: The course consists of a lecture, a laboratory, a field excursion, and a student project. In the lecture, students get acquainted with the theoretical background of animal biology and ecology. Students learn animal identification skills in the laboratory and how specific groups of animals characterise different ecosystems. During the field excursion, students are guided through three different ecosystems near Vienna (a riparian forest, a backwater, and a grassland), collecting and describing animals (e.g., invertebrates, vertebrates) inhabiting these ecosystems. Participants must write a brief scientific report on a research question for the student project. Three different project choices were offered during the semester, including participation in BOKUroadkill (Heigl & Zaller, 2014).

OS/CS implementation: A citizen Science and crowdsourcing approach is used in the course design. The project engaged students in reporting road killed animals they observed daily using a freely available, customized mobile app (EpiCollect) or an additional online reporting form for students without smartphones or tablets.

OS/CS dimensions: Citizen Science, Crowdsourcing

External stakeholders: Not mentioned

Pedagogical approach: Inquiry-based Learning

Required skillsets: Basic digital competency to use the mobile app or an online reporting form

10 Challenge Based Innovation (CBI)

Website: https://www.cbi-course.com/

Location: Across Europe (see below Target) + Australia and the U.S.

Foundation: 2013

Curriculum design: (Accredited) course or study module (decided by a participant university)

Duration: 1-2 weeks, 3-6 months (depending on the project)

Teaching language: English (or national language based on the project location)

Target: Examples are:

<CBI Barcelona>

- ESADE Business School (Spain)
- Istituto Europeo di Design (Spain)
- Polytechnic University of Catalonia (Spain)

<CBI ER>

- University of Bologna (Italy)
- University of Modena and Reggio Emilia (Italy)
- University of Ferrara (Italy)

<CBI 2014-2015>

- Aalto University (Finland)
- ESADE Business School (Spain)
- Istituto Europeo di Design (Spain)
- Polytechnic University of Catalonia (Spain)
- Norwegian University of Science and Technology (Norway)
- Swinburne University of Technology (Australia)
- University of Modena and Reggio Emilia (Italy)

Outline: Challenge-Based Innovation is a short-term program where teams of university students develop projects that solve complex societal problems, inspired by technological ideas that come from instrumentation development or basic research at CERN and its experts, to create solutions that contribute towards the United Nations Sustainable Development Goals. This program works based on collaboration with universities. Together we create the curriculum, methodologies, and timeframe of each program. Therefore, CBI does not exist on its own, only through collaboration, which makes it a very diverse program in constant change.

OS/CS implementation: Bring together university students to address societal challenges in the spirit of open science and open innovation, inspired by CERN and its experts, to create solutions that contribute towards the United Nations Sustainable Development Goals.

OS/CS dimensions: Open Innovation, Open Labs

External stakeholders: CERN IdeaSquare (a test facility), researchers, engineers, industrial partners

Pedagogical approach: Peer-to-peer Learning, Project-based Learning, Challenge-based Learning

Required skillsets: Not specified

11 Citizen Science Talent Programme

Website: https://mitsdu.dk/en/mit_studie/sdu_talent/talentprogrammer/cs_talent

Location: University of Southern Denmark (Denmark)

Foundation: n.d.

Curriculum design: Spring course (20 ETCS) and autumn course (10ETCS), grading pass/fail

Spring course includes:

- Masterclasses (10 classes about different disciplines)
- Hands-on workshop (2 full-day workshops to develop citizen science methods)
- Small-group coaching
- Conference (The programme will sponsor your participation at the Engaging Citizen Science Conference in Aarhus in April 2022)
- Study trip (In May, we visit the Citizen Science Center in Zürich and the Citizen Cyberlab at CERN in Geneva)
- Summer school (In August, we will complete the Citizen Science projects in a 4-day summer school)
- Scientific co-publication

Autumn course includes:

- Masterclasses (6 classes about citizen science research methods)
- Individual research
- (Degree with distinction)

Duration: Spring semester + August / Autumn semester

Teaching language: English

Target: 25 top-grade master's students and final year bachelor's students from any SDU (the University of Southern Denmark) programme.

Outline: In this talent programme, you will experience innovative ways of engaging citizens and get a chance to collaborate with students across the natural sciences, health, engineering, business, and humanities. You will learn what it takes to make your science matter in society and become a talented, visionary, high achiever! You will learn to:

- Co-create and manage citizen science projects

- Employ digital media to engage citizens
- Critically argue for the inclusion of citizens in your field
- Support the sustainability agenda through citizen engagement
- Unfold your profession in a cross-disciplinary team
- Contribute to citizen science research

OS/CS implementation: SDU Citizen Science Knowledge Centre gathers research frontrunners across all five faculties who work with participatory research. The knowledge centre will support the talent programme with cases that can benefit from citizen engagement. You get to work with some of the most progressive SDU researchers, and you get support from professors who understand the principles and techniques of citizen science. Overall, the programme addresses Global Development Goal #17 on 'Multi-stakeholder partnerships' (17.16 Enhance the global partnership for sustainable development), but the individual Citizen Science projects will also respond to other goals.

OS/CS dimensions: Citizen Science

External stakeholders: Public participants, CS-related institutions (e.g., Citizen Science Centre in Zürich and the Citizen Cyberlab at CERN)

Pedagogical approach: Inquiry-based Learning, Informal Science Learning

Required skillsets: See below:

- Scientific comprehension – research flair from the current education programme.
- Urge to experiment – daring to try new ways, to observe and reflect.
- Initiative – drive to take initiative and responsibility.
- Communicative skill – ability to express complex ideas orally, visually, in text, etc.
- Social engagement – ability to establish networks inside and outside the university

12 LIFE course

Website: https://www.tlu.ee/en/life

Location: Tallinn University (Estonia)

Foundation: n.d.

Curriculum design: The LIFE course is assessed on a non-differentiated assessment scale (pass/fail) and has a course volume of 6 ECTS. Work is carried out in teams that consist of six students, including students from at least three different study areas.

Duration: four months (one-semester project) or eight months (two-semester project)

Teaching language: Both Estonian and English-based groups

Target: Compulsory for all Bachelor and Master level students (except for students from the following study programmes: Film Arts, Art Teacher, Music Teacher, Cinematography, Digital Library Learning, Mathematics Teacher, Vocational Teacher, Teacher of Several Subjects, Adult Education for Social Change).

Outline: LIFE is a university-wide project-based course where students from different study areas collaborate with academics to carry out projects focusing on interdisciplinary problems of their own interest. The main objective of LIFE is to support the development of general competencies and teamwork skills, which would foster the development of the competence of resolving interdisciplinary problems.

OS/CS implementation: The course is supported with external reviews in the middle and end of the project, as well as there are extra tutorials of design thinking. Results contribute to society as the client of the problems is often external from the university. Student project could be:

- be the beginning of a start-up company
- be a means to contribute to the society
- result in the development of a new technology
- result in a study including different areas and which can be developed into your final thesis
- enable the organisation of events, exhibitions and project days etc. to promote science

OS/CS dimensions: Open Innovation

External stakeholders: Start-ups, companies, public sector

Pedagogical approach: Project-based Learning, Problem-based Learning

Required skillsets: Collaboration skills, problem-solving skills

13 MSc Course in Citizen Science, Natural History Museum of Denmark

Website: https://kurser.ku.dk/course/nnmk21000u

Location: Natural History Museum of Denmark, University of Copenhagen (Denmark)

Foundation: 2021 (originally scheduled to start in 2020 but canceled that year due to COVID19)

Curriculum design: Intensive Summer Course, 7.5ETCS

Duration: 11 days

Teaching language: English

Target: Course is for Full Degree Masters Students at the University of Copenhagen or International universities. The Course is also available as continuing and professional education

Outline: This intensive course offers an introduction to citizen science: the involvement of the public in all levels of the scientific process. The development and application of citizen science are increasing worldwide to collect large amounts of data and make research relevant for the public by co-creation. Students are presented with various projects and citizen science applications through lectures and discussion seminars. The course includes several expert guest lecturers from Denmark and Europe from academic and non-academic institutions, representing natural science, social science, and the humanities. Students get experience with data handling in exercises, and during the course, there will be fieldwork opportunities and workshops focusing on motivation, communication, and evaluation processes. By the end of the course, students design their own project to answer a specific research question using citizen science.

OS/CS implementation: Citizen Science is introduced as one of the eight pillars of open science recognized by LERU. Students receive an overview of OS activities and strategies at the University of Copenhagen.

OS/CS dimensions: Citizen Science, Open Data, Crowdsourcing

External stakeholders: Researchers, communication specialists, information specialists at university and non-academic institutions and companies in Denmark and elsewhere in Europe/UK.

Pedagogical approach: Problem-based Learning, Inquiry-based Learning

Required skillsets: Registration in a full degree master's programme

14 Service-Learning Course

Website: https://www.kuleuven.be/english/education/sl/servicelearning

Location: KU Leuven (Belgium); six campuses in Flanders

Foundation: First service-learning course at KU Leuven was established in 2016

Curriculum design: In the academic year 2020-2021, 20 accredited service-learning courses have been running

Duration: Courses of one semester or one academic year

Teaching language: Some in English, most in Dutch

Target: KU Leuven students, collaborating with external civil society organisations

Outline: Service-learning (also known as community service learning, community-based learning, etc.) is an educational approach in which the central concepts are 'serving', 'reflecting', and 'learning'. Students serve society by engaging themselves in a specific community. Meanwhile, they reflect in a structured and critical way on their experiences. In this way, they learn on an academic, civic, and personal level.

OS/CS implementation: Students collaborate with external stakeholders (society organisations) to create solutions for existing issues while learning related knowledge and skills through the community

OS/CS dimensions: Open Innovation

External stakeholders: Around 200 civil society organisations in 2020-2021

Pedagogical approach: Service-learning, Project-based Learning, Challenge-based Learning

Required skillsets:
https://www.kuleuven.be/english/education/sl/whatisservicelearning/whatisservicelearning

3.3. Degree program

In this category, we introduce two case examples (case 15 and 16). Usually, a degree program is composed of a set of courses (e.g., 60-120 ETCS) and provides an official degree certificate as an outcome of completion. The order of appearance is alphabetical.

15 HDip Irish Folklore

Website: https://hub.ucd.ie/usis/!W_HU_MENU.P_PUBLISH?p_tag=PROG&MAJR=Z086

Location: UCD School of Irish, Celtic Studies and Folklore (Ireland)

Foundation: n.d.

Curriculum design: 60-credit course at NFQ Level 8 (higher diploma)

Duration: 1 year

Teaching language: English

Target: Students and scholars without any previous background in general folkloristics or comparative ethnology

Outline: The HDip in Irish Folklore should provide students with the requisite skills, knowledge, and experience to enable them to formulate and complete their own research projects in the field of folklore studies

- Designed for students and scholars without any previous background in general folkloristics or comparative ethnology
- Training in original archival and fieldwork research and methods.
- Access to the specialist library and archive holdings of the UCD Delargy Centre for Irish Folklore and the National Folklore Collection

The National Folklore Collection (part of the Dúchas project) was created by a community transcription project to digitise archives of Irish Folklore. The project asks local volunteers to transcribe hand-written stories that were collected as part of the Schools' Collection to document Irish Folklore.

OS/CS implementation: Open access database dúchas.ie (duchas.ie) is used as a learning material and method

OS/CS dimensions: Citizen Science, Open Access, Open Data

External stakeholders: Citizen participants to the National Folklore collection project

Pedagogical approach: Inquiry-based Learning

Required skillsets:

- A primary degree at the third level and a complete transcript of academic history, including grades for each subject taken.

- Names and contact details of two referees who can assess your intellectual ability, maturity, and motivation.
- Other documentation as required by the University.
- A basic reading knowledge of the Irish language is also required for this programme. This skill may be acquired concurrently with the student's Higher Diploma studies.

16 Master AIRE

Website: https://master.cri-paris.org/en#04._our-campus

Location: University of Paris, CRI Campus (France)

Foundation: 2006

Curriculum design: Master's degree program (Life sciences / Learning sciences / Digital science)

Duration: 2 years

Teaching language: English

Target: Students who already have a solid background and can develop their own projects.

- Many students in Learning, Life and Computer Sciences courses, at the end of Bachelor or Master.
- Biologists, doctors, educators, psychologists, lawyers accompany or anticipate the change of their activity.
- Engineers, researchers, designers, innovators who exploit research fields through experimentation and want to get their hands on the technical paste.

Outline: The curriculum includes innovative courses and learning-by-doing training through internships in different labs, start-ups, and other companies. Every year, the 100-plus students we welcome in the AIRE Masters are people who think and act critically about the world's most pressing problems and want to work towards attaining the UN's Sustainable Development Goals.

OS/CS implementation: Drawing on open-science approaches, collaborative interdisciplinary projects, and a challenge-based approach to learning, the many renowned researchers, teachers, and mentors involved in teaching the programme are what make it truly exceptional. The Institute hosts several Citizen Science initiatives and weekly seminars and events, with the scope of promoting quality research and sustainable development in science, education, and the digital revolution.

OS/CS dimensions: Citizen Science, Open Innovation

External stakeholders: researchers, teachers, professionals (mentors), start-ups, companies

Pedagogical approach: Project-based Learning, Challenge-based Learning, Inquiry-based Learning, Peer-to-peer Learning

Required skillsets: Collaboration skills, acceptance of diversity (discipline and culture), solid background of scientific work, the capability of developing own project

4 Discussion

4.1. RQ1. How are OS/CS activities implemented into curricula in European HEIs?

The concept of OS and CS has been integrated into HE curricula mostly in a study module or course, and in some cases, as a degree program. The duration of the learning activity varies from several weeks to months, depending on the course design. OS/CS can be taught as learning content in a short-term study module (e.g., lecture or MOOC), or it can be incorporated as a learning method in a long-term activity (e.g., project-based learning course). Through the reviewing process of the case examples, we found three broad trends of OS/CS implementation in the curricula as follows:

1) Teaching OS/CS as learning content to encourage open research practice
2) Utilizing OS/CS as a learning method to learn CS processes and leverage rich data
3) Providing Open Innovation opportunities to tackle real-world problems

The first way of integration, OS/CS being learning content, is often seen in a training course for PhD students, especially in the open research perspective (e.g., the University of Eastern Finland, KU Leuven, and Tampere University). The lectures teach basic data management principles such as GDPR and FAIR data and how to write DMP. In this digital era in which data drive the economy, research, and industry, special attention to data management and administration in HE contexts are significantly required (Demchenko & Stoy, 2021). Many funding bodies request researchers to make their work more open and comply with Open Access, Open Data, and Open Evaluation policies. Thus, training modules for current and future researchers are crucial in HEIs. However, although much attention has been increasing, Demchenko and Stoy (2021) suggest that most of the existing HE curricula and training programs are not sufficiently covering a set of required skills and knowledge for data management and stewardship, which plays an important role in research and industry.

Regarding the second approach, Citizen Science and Crowdsourcing methods were well integrated into the fields such as biology, ecology, ethnology, and history (e.g., WaterAct, BOKUroadkill, MSc Course in Citizen Science, Natural History Museum of Denmark, and HDip Irish Folklore). The crowdsourcing approach is incorporated in the course design to encourage students to collect data as Citizen Science participants and utilize the accumulated data as researchers in the ongoing project. National or EU funding bodies often fund such integrated projects. For instance, the WaterAct project is funded by EU Interreg to facilitate cross-border cooperation between Estonia and Latvia to efficiently manage the common groundwater resources. Students act as public contributors through the project and learn professional skills and knowledge in an active learning approach. Such public projects can also be applied in informal learning activities (e.g., Transcribe Bentham and Ocean i3 in the Annex). Both projects were funded by a national foundation and EU-related projects such as Horizon 2020 and Interreg.

Lastly, Open Innovation is facilitated by HEIs by leveraging a university network and public project (e.g., Challenge Based Innovation, ECIU University Challenge platform, and Global Engagement Module). The project goals and activities are shared with the several European universities that constitute an alliance (e.g., ECIU and ENLIGHT), and the students at the member universities work together to create solutions for real-world challenges. The problems are often related to SDG topics. Students can select the most interesting or relevant topic, which enables student-centred learning to deepen their prior knowledge on their own choice. Group formation is based on students' interests and backgrounds, and usually, 'diversity' is appreciated as various expertise and cultures facilitate the innovation process. As Király and Géring (2021) mentioned, open and social participatory projects are running across the world and HEIs are striving for making a new way to collaborate with society across sectors through these activities.

4.2. RQ2. Who are the other stakeholders involved in the learning activities?

Many OS/CS-related curricula involve external stakeholders such as public organizations, research institutes, local communities, and private companies. HEIs can connect to society through the learning activities and bring academic knowledge and skills into practice. For instance, KU Leuven's Service-Learning Course facilitates students' learning opportunities through real job settings by collaborating with local communities. On the course website, the purpose of service-learning pedagogy is explained as follows:

> With this pedagogy, students learn to put theory into practice and to reflect on that process in an academic context. Moreover, service-learning contains the idea that "giving something back to the community is an important college outcome, and that working with community partners is good preparation for citizenship, work, and life. (KU Leuven, 2019)

The curriculum design aims to prepare students to become active citizens through interactions with society from an academic standpoint. Other CS-related curricula are also designed to collaborate with public institutions such as museums, libraries, and research institutes. For example, CERN (the European Organization for Nuclear Research), one of the largest science research centres located in Switzerland, is supporting such HE curricular as a stakeholder by offering a facility, equipment, and professional staff across borders (e.g., Challenge Based Innovation (CBI) and Citizen Science Talent Programme).

In Open Innovation projects, the public and private sectors can join the project and tackle a real-world problem. The curriculum incorporating such a project often provides students with a cross-border, multidisciplinary opportunity. For instance, Challenge Based Innovation and ECIU University Challenge platform offer diverse learning environments in which several universities, city or regional organizations, business stakeholders including start-ups, and research institutions will work together. In such a cross-sector situation, usually, there is a common working platform (e.g., project website or crowdsourcing portal) where stakeholders can find problems, communicate with each other, and share solution ideas.

4.3. RQ3. What kind of pedagogical approaches are used in OS/CS implemented curricula?

When OS (or CS) is a learning objective, the Passive Learning method is commonly used. Students can study the related topics in a digital learning environment such as MOOC. Some lecture-style courses include peer discussion and collaborative experiments as a part of learning activities, but usually, it does not require group work at a deep level.

On the other hand, a project-based course often requires collaboration and knowledge artefacts as learning outcomes. For example, Open Innovation-related study courses or programs are often designed with a

Challenge-based (or Problem-based) Learning approach and Project-based Learning approach (e.g., ECIU University Challenge platform, Global Engagement Module, Challenge Based Innovation (CBI), Master AIRE etc.), which includes thorough collaboration among students. Through the course, students pursue learning goals and create a final solution with other peer pupils; thus, these learning methods and Peer-to-peer Learning are well interconnected.

Citizen Science activity can be nicely integrated into Inquiry-based Learning, or Informal Science Learning approaches. Students can learn phenomena by participating in their research project, which triggers their personal interests in the topic. As is evident from the previous studies (e.g., Borrell et al., 2016; Flowerday et al., 2004), CS integrated learning can induce situational interest by letting students learn based on their curiosities, increasing students' motivations towards their learning and engagement in the activities. Thus, integrating CS projects into a curriculum design is highly recommended to engage students in learning.

4.4. RQ4. What kind of skillsets are required in participant students?

Some curricula designed with Project-based Learning or Challenge-based Learning approaches mention several recommended competencies. For instance, problem-solving skills and collaboration skills are frequently mentioned due to the nature of the learning activity. During the problem-solving process, students are required to communicate with other peers and various external stakeholders to address the issue together. Since open Innovation projects are often conducted among several parties across countries; thus, multicultural communication skills are also expected. Some curricula require cultural competencies, including accepting diversity, multicultural collaboration, and a certain level of English proficiency (e.g., CEFR B2 level).

In addition, students need to handle their project or research questions throughout the course. Thereby, scientific inquiry skills (attitudes) and a capacity to develop own projects are important. In a MOOC environment where OS/CS-related training is provided, students' self-regulation skill is also essential to maintain their own learning in an environment where much freedom is given to them (e.g., time, place, and study pace, etc.).

Although few courses specify prerequisite knowledge or technical skills, basic digital skills seem to be essential for collaboration-driven learning activities. Since many projects are carried out in a specific digital environment such as collaboration platform (e.g., Microsoft Teams, Google drive, Slack etc.), app, project portal, or data cloud, the skills to access and utilize the platform is necessary. Besides, having data management competency is highly recommended in dealing with open data.

Considering the above, required skill sets are connected to the skills that OS/CS activities are trying to cultivate in participants, as presented by our previous publication (see Teo, 2020a).

1. Knowledge or awareness of a particular topic (ubiquitous to all activities)
2. Soft and technical skills needed for proper and open science/innovation practice
3. Knowledge of the scientific inquiry method
4. Open data skills

4.5. Summary and future implication

In the 21st century, pedagogical expectations towards phenomenon-based or topic-based learning have been increasing when students need to acquire sufficient skills to cope with the future. While traditional subject-based teaching plays an important role in the early stage of education, HE has been inclined to offer project-based and student-centred learning in which students can get to know the phenomena by tackling social challenges collaboratively. Thus, we recommend integrating OS/CS ideas and activities into HE curricula, suggesting the three possible directions: teaching OS/CS related content, utilizing the OS/CS method in teaching, and creating Open Innovation opportunities as part of the curriculum (see section 4.1).

However, successful implementation cannot happen without solid foundations: technology, collaboration, and culture (see Figure 4). First, the technical infrastructure is necessary to operate OS/CS activities, such as a repository or data cloud for reusing data, a shared platform for cross-sector collaboration, and large storage and robust technology for data protection. Accordingly, rigorous data management strategy and policy should be made in the institution, for example, complying with GDPR and FAIR data principles, writing DMP, assigning data stewards, etc. (De León & de Ferrer, 2018, Demchenko & Stoy, 2021). Second, internal, and external collaboration plays a key role in operating such open activities with the public. Academic libraries can become a central hub to connect a university faculty to public institutions and the citizens and establish an open platform for multiple sectors (Kupriené & Petrauskiené, 2018).

Lastly, cultivating open-minded culture across the university is a key element in successful OS/CS implementation. Although a university is well equipped with the right infrastructures and communities, they might not be effectively utilized if their meanings and impact on society are not explained well to the HEI staff. In addition, open projects occur across the faculties and beyond the university context; thus, shaping common ideas and goals for the OS/CS among the academic staff members and students by giving them the right training is very important.

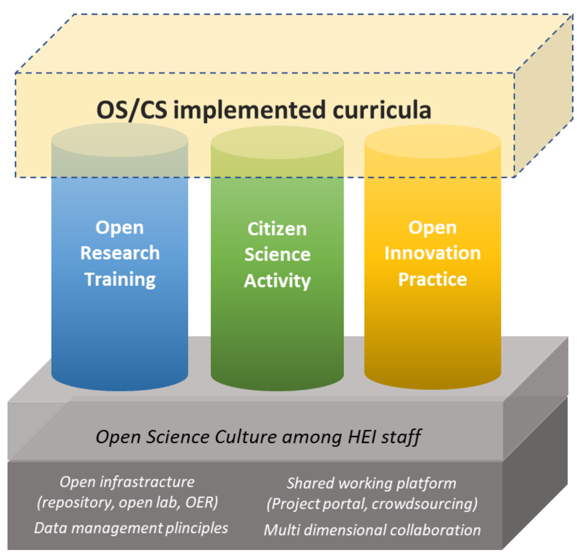

Figure 4. The model of OS/CS implementation into HE curricula

5 Conclusion

This state-of-the-art report (O5A1) attempted to see the current status of the integration of OS and CS activities into the higher education curricula in Europe. In the introduction part, an overview of OS/CS integration in HEIs' contexts, the roles of HEIs in the facilitation of the process, and the direction of future education were considered. HEIs organise OS/CS activities as educational and scientific bodies and regional innovation builders. Especially, the academic library works as a hub to manage data and information and a connection builder between academic and non-academic, and public and private. Through the process of OS/CS implementation, HEIs can collaborate with various stakeholders and make science open to them, which leads to turning science into practice, bringing a positive impact to society.

A total of 16 existing curriculum cases (and nine non-accredited learning activities) from European universities were collected and analysed. Selected cases include various study modules, courses, and degree programs consisting of different OS/CS elements. They provoked insights into the possible directions to design HE curriculum revolving around the OS/CS concept. Some learning activities were in collaboration with EU funded or national projects. Students can learn the topic or phenomena by contributing to the project as citizen science participants and academic researchers.

Integrating public science projects in educational settings generates positive synergy on both the project and HEI sides. Through the integration process, HEIs can create an interdisciplinary collaboration ecosystem, open up their knowledge to society, and provide high-quality, student-centred open education with the help of the project. On the other hand, the public project can get support from HEIs by means of environment and equipment for research (e.g., laboratory, professional tools, and resources) and knowledgeable, competent human resource including HE students. By integrating such projects into teaching activities, universities can scale up their research and innovation because they can involve students, citizens, and external stakeholders into the scientific processes. Such collaboration may facilitate future Citizen Science activities as students have already experienced being citizen scientists.

Lastly, it is important to mention that solid foundations, including technological infrastructure, cross-sector collaboration and open culture are the keys to successfully implementing OS/CS into HEIs' operation and curriculum design. Although a university has well-established infrastructures and communities, those resources cannot be well utilized if the academic staff and students are not equipped with the right mindset and skills to use OS/CS opportunities. Thus, upskilling HEI students and staff members, including teachers, researchers, and librarians, are very important. We will address the matter in our upcoming project publications.

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Annex

In this section, we will introduce several example cases that are not accredited curricula but are useful for planning to integrate OS/CS elements into HE studies. Typology "curriculum design" is excluded because the presented cases are not a part of the curriculum. The order of appearance is alphabetical.

1 Crowd4SDG

Website: https://crowd4sdg.eu/

Location: Coordinated by the University of Geneva (Switzerland) and the following partners: CERN, UNITAR, the University of Paris (France), IIIA-CSIC and Politecnico di Milano (Italy)

Foundation: 2020

Duration: 36 months

Teaching language: English

Target: over 16-year-old, mainly young people with social innovation ideas focusing climate change.

Outline: Innovation methodology provides online and in-person coaching for transforming participant ideas into SDG innovation and SDG data. Gather, Evaluate, Accelerate and Refine (GEAR) are the four phases of the propose

OS/CS implementation: We integrate CS and OS at different levels: (1) Challenge based innovation; we open call for ideas to solve global issues regarding SDGs. People from all around the world contribute with ideas for a given challenge. (2) Participants selected are coached on innovation and CS techniques, including tools for implementing citizen science projects. (3) We coach on the principle of open data and open software, helping them accelerate the creation of prototypes.

OS/CS dimensions: Citizen Science, Open Innovation, Open Data

External stakeholders: In addition to the partners, GoodWall (private company), and National Statistical Offices, which are interested in using CS data and non-traditional data sources, in general.

Pedagogical approach: Problem-based learning

Required skillsets: No specific skills for the participants. Regarding the teachers we are people from different disciplines with experience in innovation, open science, CS tools, community building, etc. In addition, we bring experts on the specific challenge/topic.

2 Innovative with Open Knowledge

Website: https://openinnovation.is.ed.ac.uk/

Location: University of Edinburg

Foundation: Not mentioned

Duration: Continuous

Teaching language: English

Target: Leiden University staff members and students

Outline: Innovating with Open Knowledge is a series of resources and case studies created by the University of Edinburgh that aims to help innovative individuals and entrepreneurs to develop the knowledge and skills to find and access free content, data and research produced by the university sector. It includes video case studies, interviews, how-to guide, text transcripts, learning activities and short exercises. All resources are licensed under a Creative Commons Attribution Share Alike licence and can be downloaded and reused free of charge.

OS/CS implementation: Open science as learning content and methods

OS/CS dimensions: Open Education, Open Data, Open Access, Open Source

External stakeholders: Not specified

Pedagogical approach: Informal Science Learning

Required skillsets: No experience is needed

3 Intensive Course in Layered Materials and Applications

Website: https://athena-uni.eu/school-in-layered-materials/

Location: Online (no limitation for participation)

Foundation: 2021

Duration: July 12-16th, 2021

Teaching language: English

Target: University students, PhD students, researchers, and scholars especially in the following field: Physics Department, Materials Science, Electronic Engineering, Department of Chemistry

Outline: This intensive course envisions introducing graphene &2D materials and the related applications. Speakers are distinguished scientists in the topics they will present. This course is expected to inspire participants to follow more modules on the topic and join the world effort to advance the related technology.

OS/CS implementation: All webinars were open to the public and free of charge. Lecture videos are openly available on the project website.

OS/CS dimensions: Open Education

External stakeholders: The project organizers are the ATHENA European University, Hellenic Mediterranean University, the University of Cambridge and CRETE project (Critical Skills for Electronic Engineers of 2020 An Erasmus Plus Strategic Partnership Project)

Pedagogical approach: Passive Learning

Required skillsets: Prior knowledge and skills of the specific science topic

4 Ocean i3

Website: https://oceani3.com/en/inicio-english/

Location: University of Bordeaux (France) and University of the Basque Country (Spain)

Foundation: 2018

Duration: One academic semester

Teaching language: Spanish, French, Basque, English

Target: University students (Batchelor, Master, and PhD levels)

Outline: Ocean i3 is a university project of educational innovation with the territory and for the sustainability of the oceans born in 2018 and co-financed by the ERDF through the INTERREG-POCTEFA programme for the years 2020-21. The project was developed during the second semester of the academic year. Each student is integrated with his or her individual project that corresponds to a curricular activity of the curriculum of his or her degree (Bachelor's thesis, Master's thesis, subject work, PHD, or internship). The tutoring faculty proposes that they carry out their work in coordination with the Ocean i3 activities.

OS/CS implementation: Co-definition of the challenges (call of applications with socio-economic actors and co-design with the participants), transdisciplinary teams (mixing students and teachers from both universities, and external stakeholders) and organization of side-activities (citizen science workshops, internships)

OS/CS dimensions: Citizen Science, Open Innovation

External stakeholders: Actors from civic society (public and private actors from the Basque country)

Pedagogical approach: Challenge-based Learning, Research-based Learning

Required skillsets: Skills to use digital platforms such as Oktonine, collaborative working skills for a project in a multicultural group

5 ODEdu

Website:

https://ec.europa.eu/programmes/erasmus-plus/project-result-content/4f5330c0-bc53-4b24-94c0-6d402672aae0/ODEdu_D63_FinalDisseminationActivitiesReport_V1.pdf#:~:text=The%20objective%20of%20the%20ODEdu%20Project%20is%20to,which%20will%20boost%20Open%20Data%20education%20and%20training.

Location: ODEdu project partner universities: University of Macedonia (Greece), Aalborg University (Denmark) and other stakeholders in Europe

Foundation: 2016

Duration: 1-3 months depending on the course

Teaching language: English

Target: University students, VET students

Outline: ODEdu developed an Open Data course model for university-level education and an Open Data VET course model for private and public sector employees. Based on problem-based learning: the OD-PBL design pathway aims to guide educators when designing learning processes that aim to teach Open Data using the PBL learning strategy (Open Data-driven PBL model).

OS/CS implementation: Students learned Open Data as learning contents

OS/CS dimensions: Open Data, Open Education

External stakeholders: Organizations, enterprises, and other educational institutes directly involved in developing open data / open content culture and/or having relevant teaching activities at the European and/or national level.

Pedagogical approach: Problem-based Learning

Required skillsets: Not specified

6 Open for you! An introduction series to open science

Website: https://4euplus.eu/4EU-273.html

Location: Online webinar hosted by the 4EU+ Alliance:

- Sorbonne University (France)
- University of Copenhagen (Denmark)
- University of Milan (Italy)
- Heidelberg University (Germany)
- Charles University (the Czech Republic)
- University of Warsaw (Poland)

Foundation: 2021

Duration: 8th November 2021 – 4th July 2022 (14 series of the webinar)

Teaching language: English

Target: PhD students, senior researchers, research support or anyone just curious—everyone is welcome to learn about open science

Outline: The vision of science we champion at Sorbonne University, Charles University, the University of Copenhagen, the University of Milan, Heidelberg University and the University of Warsaw is free from paywalls or borders. Our institutions, united within the 4EU+ Alliance, invite you to our monthly training meetings, starting in November 2021, to discover and explore all aspects of open science.

OS/CS implementation: The series of the webinar includes the following topics:

- What is Open Science?
- Cycle of scientific publication: an overview
- What are my funders requirements on Open Science? A focus on Plan S
- Strategies for publishing in Open Access journals
- Data Management Plans - one tool with many applications
- Predatory publishers and identity fraud - how to identify dubious providers
- Publication strategies for monographs in Humanities and Social Sciences
- Research Data Management - Introduction to FAIR and Open Data
- Open Research Software
- Manage your rights! [provisional title]
- FAIR data in Humanities: how to manage your data? [provisional title]
- Citizen Science: producing data with people for innovating research
- Research Integrity and Open Science: Is sound science open science?
- Research Impact & Bibliometrics: open science, society, innovation

OS/CS dimensions: Open Access, Open Data, Citizen Science

External stakeholders: Not specified

Pedagogical approach: Passive Learning

Required skillsets: Not specified

7 Open Science Community Leiden

Website: https://www.universiteitleiden.nl/open-science-community-leiden

Location: Leiden University

Foundation: Not mentioned

Duration: Continuous

Teaching language: English (or national language)

Target: Leiden University staff members and students

Outline: OSCL is a learning community where Leiden University employees and students learn and talk about open science practices. Example events are Open Science cafés, workshops, and walk-in-hours.

OS/CS implementation: Open science as learning content

OS/CS dimensions: Open Science (including the following topics: transparent methods, pre-registration, sharing data/code and research tools, reproducibility, replication research, citizen science, open peer-review, publishing open access, diversity and inclusion, research integrity, uploading preprints and (meta) research about scientific methods)

External stakeholders: Not specified

Pedagogical approach: Informal Science Learning

Required skillsets: No experience is needed

8 The Alan Walks Wales Dataset

Website: https://alanwalks.wales/

Location: University of Birmingham (UK) and University of Konstanz (Germany)

Foundation: Not mentioned

Curriculum design: Part of course or study module (the amount of credit was not mentioned)

Duration: not mentioned

Teaching language: English (or German)

Target: a group of computer science and interaction design masters students (in the University of Birmingham) and a computer science bachelor's degree students (in the University of Konstanz)

Outline: This is the educational use of an open dataset collected as part of a thousand-mile research walk. Intentionally the project student was not given a specific brief other than to use the data in whatever way he chose. This open brief allowed significant autonomy in choosing which kinds of data to focus on and what approaches to use, aiming to develop the student's initiative and sense of ownership of the project outcomes. The raw data is supplemented by detailed technical documentation, YouTube videos and extensive online reports and published papers.

OS/CS implementation: An open dataset collected as part of a thousand-mile research walk was used as educational material. The data includes vital recordings, GPS traces, texts, pictures, and other sources.

OS/CS dimensions: Open Access, Open Data

External stakeholders: Not mentioned

Pedagogical approach: Flipped classroom, Inquiry-based Learning

Required skillsets: Basic data analysis skills

9 Transcribe Bentham

Website: https://www.ucl.ac.uk/bentham-project/transcribe-bentham

Location: University College London

Foundation: 2010

Duration: The project started in 2010 and the website is still working (also another continuous project started in 2018).

Teaching language: English

Target: Public

Outline: A participatory initiative that launched in 2010. It aims to engage the public in the online transcription of original and unstudied manuscripts written by Jeremy Bentham, his correspondents, and his amanuenses.

OS/CS implementation: Students learned Open Data as learning contents

OS/CS dimensions: Citizen Science, Open Access

External stakeholders: The Arts and Humanities Research Council, the Andrew W. Mellon Foundation, and the PRHLT research centre at the Universitat Politècnica de València as part of the READ project

Pedagogical approach: Informal Science Learning

Required skillsets: Not specified

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https://inos-project.eu