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

Report on upskilling HE academics, students and library staff through OS with a focus on skills and innovation potential.

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Abstract:

This report (O5A4) compiles the evaluation of the past Open Knowledge Activities (OKAs), and Open Innovation Activities (OIAs) organised in 2020 and 2021. We reviewed the participants' reflections on their developed skills, knowledge and attitudes and investigated how OKAs and OIAs can upskill HE students and staff, including librarians. We also consider the innovation potential of such open activities by analysing the participants' feedback.

Keyword list:

citizen science, higher education, open innovation activities, open knowledge activities, open science

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1	Aalborg University	AAU	Denmark
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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
HEI	Higher education Institution
OER	Open Educational Resource
OKA	Open Knowledge Activity
OI	Open Innovation
OIA	Open Innovation Activity
OS	Open Science

1. Introduction

The INOS project (Integrating Open and Citizen Science into Active Learning Approaches in Higher Education) aimed to enrich Open and Citizen Science in Higher Education Institutions (HEIs) by integrating the concepts into their pedagogical design.

Open Science (OS) is an umbrella term including various types of open principles from research to education. It is defined as "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" (FOSTER, 2016). The United Nations Educational, Scientific and Cultural Organisation (UNESCO)'s definition emphases more on public inclusion in open knowledge creation:

> Open science is defined as an inclusive construct that combines various movements and practices aiming to make multilingual scientific knowledge openly available, accessible and reusable for everyone, to increase scientific collaborations and sharing of information for the benefits of science and society, and to open the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community (UNESCO, 2021, p.7).

Citizen Science (CS) is a form of OS which is an inclusive concept for all the open practices that share the same vision - public participation in science and knowledge creation. Similarly, Open Innovation is also a component and enabler of OS as it facilitates multidisciplinary, multi-sector collaboration and open discussion, fostering the creation of new solutions for societal problems.

The INOS project emphasises that HEIs take key roles in fostering and implementing OS practices. They can initiate OS projects and activities, support them by providing knowledge and resources, and cultivate active citizenship through education. Therefore, it is important to upskill HE students and staff, including academic librarians, through exposure to public engagement (such as OS and CS) and modernise HE curricula by integrating the open concepts into teaching and learning. We conducted various open knowledge and innovation creation activities with such aims and invited the targeted audience. In this report, we will reflect on these activities and analyse participants' developed competencies, considering innovation potential in such open activities.

2. Open Knowledge Activities and Open Innovation Activities

The INOS project has conducted various public activities involving HEI staff, students, and citizens to create new knowledge and solutions openly and collaboratively. In total, we have organised 12 Open Knowledge Activities (OKAs) and 10 Open Innovation Activities (OIAs) between 2020 and 2021 and invited 408 and 312 participants, respectively.

The INOS consortium defined OKAs as "bottom-up technology-mediated open knowledge building activities that HEIs co-create together with students and external stakeholders for engaging wider public for social and community purposes" (Pata, 2021a, p. 13). We invited citizens, HE staff, and students, including academic librarians, from our partner networks to various CS projects and encouraged them to create new knowledge collaboratively. OKAs can be designed with many forms of OS activities, such as Datathon, Data

expedition, Knowledge Café, Service jam, Dotmocracy workshop, Gamified Design Thinking interdisciplinary problem-solving, Sensor-based CS problem-solving for civic society, Citizen science knowledge construction camp, Gamified outdoor problem-solving event, Scientific crowdsourcing event, and Edu-game jam (Pata, 2021a). Technological tools and digital environments often mediate the knowledge creation process to facilitate communication and discussion between participants.

Open Innovation is defined as the opportunity to "open up the innovation process to all active players so that knowledge can circulate more freely and be transformed into products and services" (European Commission, 2016, p.11). OIAs are the means of bringing diverse people, including academic staff and students from different disciplines, external experts and other stakeholders, into the knowledge transformation processes; co-reflect, co-develop and apply their knowledge to address a technical challenge or social problem (Blanchard & Schwalm, 2020). In the context of the INOS project, we focused on the pedagogical value of OIAs, for example, applying challenge-based learning methods to equip students with transversal competencies through open innovation. The organised OIAs in the INOS project took the forms of a Digital hackathon, Collaborative problem solving and other group learning activities.

3. Audience

The aim of this report is to highlight evidence-based knowledge from the evaluation processes of the past OKAs and OIAs. We analyse what kind of knowledge and competencies of the participants were developed through the open activities and how the activity design helped such new competence acquisition. Moreover, we consider the innovative potential of open activities through upskilling HE students and educators, including academic library staff.

The main target audience is HE educators who will design curriculum and learning activities because they can get insights into what kind of student competencies can be developed through OS-integrated learning and how. Institutional administrators who will train teachers and educators providing pedagogical support to students can learn from our evidence-based knowledge and practices of open activities. Not only HE staff but also public organisations (e.g. NGOs, libraries) who want to collaborate with HEIs to initiate OS activities may benefit from the present report.

4. Methodology

4.1 Participants of OKAs and OIAs

A total of 408 and 312 participants participated in OKAs and OIAs conducted between 2020 and 2021. In both cases, a large number of the participants were HE students from the INOS partner organisations. It includes Bachelor's and Master's level students, PhD students and alumni. Some students were workers, such as in-service teacher-training students and life-long learners studying in a special course on weekends. Thus, the ages and backgrounds of participants varied depending on the activities. HE educators, including teachers, lecturers and researchers, participated as mentors or organisers of the activities. Some activities recruited citizen participants such as visitors of museums and libraries, employees from public/private organisations and external stakeholders who are experts on the activity's topic.

4.2 Data sources

The present report deepens the evaluation of the past OKAs and OIAs by referring to the related materials of the activities. The main data sources are the previous reports on the implementation of OKAs (O3A3) and OIAs (O4A3). The authors of each report have conducted post-event surveys to gain participants' feedback on OKAs and OIAs. Feedback includes the participants' reflections on acquired competencies developed through participation in the activities and general evaluation of the activities (e.g., satisfaction, potential improvement, etc.). In addition, video testimonials of the participants (available on INOS Project YouTube) that the INOS consortium collected after the events are also reviewed to gain more detailed feedback and reflection on the activities.

4.3 Analysis

The collected text data from the evaluation of OKAs and OIAs (O3A3 and O4A3 reports) were first analysed with a text mining method using a qualitative data analysis software called NVivo (version 12). Only the related parts regarding participants' reflection on their upskilled elements were extracted from the reports and synthesised into one document for analysis.

The text-based data was cleaned to detect only the relevant words, although NVivo automatically omits the stop words. For example, the author excluded less-related words to the participants' upskilled elements, such as a subject of a sentence (e.g. participants, teachers etc.) and modifying words (e.g. very, regarding etc.) to avoid counting these words. Word Frequency Query of NVivo was applied to investigate frequently appearing keywords. It filtered the texts including stemmed words (not exact matches), meaning that similar words can be counted as one word (e.g., 'collaboration' and 'collaborative' can be counted as the same word). In the end, the system displayed the 50 most frequent words for OKAs and OIAs in a word cloud format (see Figures 1 and 2).

Next, the author analysed the whole texts referring to keywords generated by the pre-analysis to investigate key domains of the participants' developed competencies. In the end, the findings with similar elements were summarised under an umbrella theme like 'digital competencies'.

4.4 Limitation

Firstly, a limited number of participants answered post-event surveys, and the answer rate varies depending on the activity. Thus, resources for participants' evaluation of their upskilled competencies were scarce in some activities. Secondly, different evaluation formats were applied in OKAs and OIAs due to different activity types and responsible authors of the reports. It also hindered analysing the accessible data systematically and cohesively. Lastly, we did not collect detailed information about each participant (e.g. professional background and experiences etc.) because the main purpose of organising activities was not to conduct research. This approach limited a deeper analysis of the participants' evaluations, considering their level of prior knowledge and skills related to the activity.

5. Overview of OKAs and OIAs

Table 1. 4 shows an overview of OKAs (pink) and OIAs (blue). Detailed information about the activities (e.g. participants, materials, operation etc.) can be found in our previous reports (see O3A2 and O4A2).

Table 4. Overview of OKAs and OIAs

Name of the activity	Duration	Topic	Activity design and approach
Noise pollution at Reidi road	One month	Natural Sciences	Crowdsourcing and field research
Designing public services for the elderly with external stakeholders	Two days	Service design	Online collaborative problem solving
Integrating Citizen Science at Universities: from 'What' to 'How (four events)	Three sessions (1h each)	Citizen Science integration in Universities and Research Libraries	Online webinar and group discussion
Why Universities and Libraries Should Get Involved in Citizen Science?	1.5 hours	Open Science and Citizen Science	Online webinar and group discussion
Edit-a-thon Wikipedia	One day	Depending on the participants' thesis topic	Online lecture and workshop (Wikipedia editing)
SPINE	Two days	Health / Neuroscience	Online lecture and hands-on group activity (image analysis)
CATCH UP! @LET	Three hours	Learning science, work-life skills	Online group activities, networking
"LIFE IN FARMS", A Minecraft-based Environmental Science Module	One or two meetings /week (45 min) for four weeks	Environmental science and STEAM education	Gamified learning (Minecraft)
Rover Adventure	Three hours	STEAM education	Maker space, programming, robotics, storytelling
Data Workshop for "Technological and Organizational Trends in Service Design"	Three days	Service design	Utilising open data (data scraping, visualisation, discovering etc.)

Climackathon	Two days	Behaviours and mechanisms of the decision facing climate change	Online hackathon, design thinking approaches
DigiEduHack	Two days	Digital learning, service design	Online hackathon
Thessaloniki Citizen Science INOS	Two days	Language learning as a means to strengthen active citizenship	Online hackathon
SPIRIT	Half day	Trends in education	Online group activities
Civic engagement project	Ten days	Civic engagement, service design	Online long-run hackathon, inviting external stakeholders (digital civic engagement community)
Cultural data interaction in spatial location	Three weeks	Cultural data, Open data	Online classrooms, Field excursions, Collaborative problem solving, inviting external stakeholders (the Music and Theatre Museum)
Ocean I3	One semester	Ocean sustainability, Plastic pollution, Climate change	Online group learning, Challenge-based learning, inviting external stakeholders (socio-economic actors)
Technology & Migration	One semester	Technology and Migration	Online collaborative problem solving, inviting external stakeholders (UN Refugee Agency)
Opening up and redesigning the values of public services	One semester	Public digital services, Open data, Collective intelligence	Online video lectures and face-to-face group learning sessions
Collaborative problem solving	One semester	Educational technology, working-life competencies	Hybrid collaborative problem solving, inviting external stakeholders (a local Edtech startup)

6. Upskilled competencies

This section summarises the results of participants' skills, knowledge and attitudes developed through OKAs and OIAs based on post-event surveys and video testimonials. First, Figure 1 and 2 shows the most frequently appeared words in the participants' reflections related to their takeaways after OKAs and OIAs.

Figure 1. Frequently appearing words in the participants' reflections (OKAs)

Figure 2. Frequently appearing words in the participants' reflections (OIAs)

Next, we present the main results of the participants' competencies by synthesising similar findings (key areas). The results are supported by examples of OKAs (pink) and OIAs (blue). Detailed evaluations of all the activities are available in our previous reports (see O3A3 and O4A3).

Collaboration with diverse people

Participants appreciated the opportunities to collaborate with diverse people from different fields and disciplines. They liked to find different perspectives on the topic from other participants and mentioned that diversity empowered a collective process such as ideation and task execution among the groups. For example, the participants in Noise pollution at Reidi road were in-service teachers from different subjects such as mathematics, biology, social science and health science etc. They collaboratively executed tasks outside using a digital tool and created a digital track map with the collected data. A participant (computer science field) mentioned that such activities (e.g. measuring noise and speed etc.) are a new approach to him, which can be integrated into their subject differently.

Technology & Migration allowed the participants to collaborate with external professionals in the humanitarian field, including UN Refugee Agency Copenhagen (UNHCR) workers. Participants appreciated a chance to discuss a problem with other group members and deepen their ideas with the field experts. This collaboration allowed participants to realise a gap between their theoretical knowledge and practical issues, which cannot be raised without communicating with external experts.

As many participants reported, the biggest strength of collaboration is a collective capacity to exchange different ideas and discuss the topic from various angles. It accelerates the understanding of the problem and helps find more inclusive solutions.

Mindset change towards OS and CS

Participants reported that they deepened their understanding of OS/CS and changed their mindsets. Many participants of OKAs became aware of the accessibility to knowledge and learned how they could contribute to new knowledge creation (e.g. Edit-a-thon Wikipedia). Introductory activities like Integrating Citizen Science at Universities: from 'What' to 'How could broaden participants' knowledge base on OS/CS concepts by showing examples of open knowledge, open innovation, social engagement and the HEIs role in society. Fostering a theoretical understanding of OS/CS helps open participants' minds and encourages them to take action in practice.

Participants could also learn practical skills of OS/CS, such as handling **open data** (e.g. collecting, using and sharing open data). For example, SPINE included a hands-on group activity to learn biomedical image analysis to detect neurodegenerative diseases. Noise pollution at Reidi road involved participants in public data collection activities using a sensor-based tool and crowdsourcing platform. Both activities allowed the participants to experience practical steps to collect/generate data, utilise it for their own analysis and share it in open environments. Data Workshop for "Technological and Organizational Trends in Service

Design" engaged participants in considering how to make experiences of cities as cultural districts legible by mapping social media data enriched by vision AI algorithms. Participants learned data scraping and visualisation with various open-source software and got insights into the creative use of data in the design process of services.

Awareness of the need for social engagement

When the activity is designed to deal with societal problems, participants naturally realise the importance of social engagement and start feeling encouraged to take action.

Noise pollution at Reidi road aimed to develop participants' citizen science competencies by letting them consider the environmental challenges of a newly constructed local road with a crowdsourcing approach. The participants could learn how open data they produced can help make public awareness of the issues of the road and collect public opinions. In this way, the participants learned how they could contribute to making a local area better and realised the potential of OS/CS.

In the Thessaloniki Citizen Science INOS, the participants reported that they learned the importance of committing to social action. Such actions can be enhanced in many forms with the help of digital technologies, even in language learning. It is also suggested that learning should be more socially oriented. For example, learners can develop competencies by engaging in social actions and problem-solving.

Provoking awareness of the power of social engagement is very important to promote active participation in OS. OKAs and OIAs can cultivate such positive attitudes by exposing participants to actual social engagement.

New method and approach for problem-solving

Some activities implemented Design thinking, a creative problem-solving process to respond to the user's needs with a human-centric approach (Schwalm et al., 2022). It can support problem-solving processes by dividing a whole journey into small, iterative steps. This method seemed new to many participants. They appreciated getting to know a new thinking approach. They enjoyed exercising its implementation into a real problem case (e.g. Designing public services for the elderly with external stakeholders, Climackathon, DigiEduHack, Civic engagement project, Cultural data interaction in spatial location). They learned how to open up ideas from scratch, narrow them down after brainstorming, and structure a path to a final solution. It was also mentioned that this thinking approach helped them address users' different needs by considering various personas, which are imaginary persons needing a solution.

In Collaborative problem solving, the activity was structured with Collaboration Problem Solving (CPS) model[1], which provides a macro script to guide group working processes. Participants are encouraged to follow the steps like understanding an open problem, modelling the problem in the given context, planning a group process, etc., and to monitor their performance as a team with the help of the CPS model and tutor's intervention. The participants stated that they learned the ways of self-management to accomplish the task, for example, how to keep up their motivation and good working attitudes.

Project management and teamwork

Similar to problem-solving skills, collective project management (teamwork) is also an important skill when participating in OKAs and OIAs. Long-term projects such as Opening up and redesigning the values of public services and Collaborative problem solving (both were one semester long) cultivated the participants' project management skills as a group. Some participants said they learned how to collaborate with others, such as organising group work, understanding other members (empathy) and accepting different ideas and opinions.

Time management issues were frequently reported because the participants needed to understand the concept, work on the topic as a group and create a final solution or outcome within a limited time. Some participants reflected on their collaborative work and admitted that proper task understanding and goal setting as a group are important. Such awareness is a great takeaway from an experience of long-term collaborative work.

Digital and technological skills

All the OKAs and OIAs applied digital environments to carry out the activity online due to the pandemic. Many participants were already quite experienced with digital environments like Microsoft Teams and ZOOM as they had used them in their study or work after the Covid pandemic started. In addition to such basic communication tools, many activities integrated new digital platforms and apps for creating a mind map, profiling a user's persona, brainstorming on a whiteboard etc. Many participants who used these tools for the first time appreciated an encounter with the new opportunities, although they struggled with mastering the tools at the beginning.

Some activities integrated unique gamified educational tools such as geolocation tracking[2] (see Noise pollution at Reidi road), location-based game[3] (see Cultural data interaction in spatial location), and 3D block building game[4] (see LIFE IN FARMS). Participants liked the aspects of gamification and got insights

[1] Siklander, P., Impiö, N. & Rawat, B. (2021). Solving problems collaboratively, but remotely in higher education: Relevance of pedagogical design. Paper presented at the EARLI 2021 Conference.
[2] Avastusrada (https://avastusrada.ee/en)
[3] RADA (https://rada2.smartzoos.eu/)
[4] Minecraft Education (https://education.minecraft.net/en-us/homepage)

into how this new approach can be integrated into future teaching practices to make it more fun and engaging.

Public Maker Space can be used for OKAs and OIAs to enhance participants' technological skills and OS mindsets with hands-on activities in both tangible and intangible ways. Rover Adventure invited 4th grader students and their parents to a FabLearnLab[5] in a local school. It engaged them in a set of tasks that required using various digital fabrication equipment. Especially parents (citizens) are unfamiliar with technical machines and gadgets like vinyl cutters, 3D printers, open-source hardware and programming tools. They could learn the basic functionality of the machines and their application into designed ideas to solve the problems.

Domain knowledge

Last but not least, participants also learned new knowledge of the specific domain in addition to the above-mentioned general, transversal competencies. For example, Technology & Migration allowed participants to get to know the humanitarian field and its practical challenges, Ocean I3 engaged participants in considering ocean sustainability, plastic pollution and climate change, and SPINE introduced basic knowledge on the health and neuroscience field using biomedical image analysis.

Acquiring new knowledge of a specific field increases participants' satisfaction with their learning experiences because such new addition is easily recognised as a learning outcome. In fact, some participants suggested as an improvement that the activity should have given more time to get to know the concept of the topic in the beginning phase. The balance between inputting new knowledge and applying the learned knowledge is a key to successful learning. When integrating OS into the pedagogical design, a developer should ensure a space where students can learn theoretical concepts and scientific knowledge of their learning field.

7. Innovation Potential

OKAs and OIAs are designed to apply to different fields. The aforementioned skills (e.g. teamwork, project management, problem-solving, creative thinking and digital skills etc.) are useful in any field and context. They are called '**transversal competencies**' and are regarded as important skills for living and working in the 21st century (e.g. International Labour Organization, 2021). Participants valued such transferability of the acquired knowledge and skills - how these learnings can be extended in other ways. For instance, teacher-student participants realised that experiences of utilising new digital tools in a learning activity gave them new ideas to design digital learning experiences for their students in any subject and age (e.g. DigiEduHack, Cultural data interaction in spatial location). The participants of Noise pollution at Reidi road commented that the activity (e.g. making a digital track with various information like visuals, speeds, noise etc.) could

[5] FabLearnLab (https://fablearn.org/labs/)

be applicable in other subjects, such as mathematics, biology, geography, environmental study or even tourism.

Transversal competencies and open activity experiences can lead to another future innovation. Participants learned **how to initiate open innovation** by participating in the designed open activities. For instance, facilitating idea generation with various methods (e.g. design thinking, empathy map, making persona profiles etc.), utilising social space and community (e.g. Cultural data interaction in spatial location), and other practical techniques and tips (e.g. useful digital tools, recruiting participants, project management etc.) are mentioned as learning outcomes.

Participants also mentioned that open activities were good opportunities to **network with diverse people** inside and outside the institutions, including external experts in the field and people from communities of similar interests (e.g. Civic engagement project, Technology & Migration). In Particular, participants can build sustainable relationships if they have close interests in a certain topic or are invited from a related community. For instance, SPIRIT invited current and graduated students of an international master's degree program in an open problem-solving session on future education. A participant answered in the interview that everyone felt comfortable in a small group discussion as they are from the same community, although they have not known each other. Another participant said that people instantly got tuned and started discussion owing to the same knowledge base or background. Such 'rapport' contributes to innovative conversations among diverse collaborators, and later, created relationships may continue in the future and trigger another innovative occasion.

8. Conclusion

This report compiled the evaluation of the past OKAs and OIAs between 2020 and 2021 and investigated the participants' developed competencies through the activities. We analysed the characteristics of the organised activities and investigated how they supported the acquisition of new knowledge and skills, leading to innovation potential. Through a content analysis of the participants' reflections, we found some elements frequently mentioned as learning outcomes of the participation of OKAs and OIAs.

Transversal competencies such as teamwork, project management, problem-solving, creative thinking and digital skills were focused on and cultivated in the OKAs and OIAs. Digital environments, technological tools and innovative facilitation methods mediated the activities and helped participants develop different types of competencies and specific domain knowledge. Some activities were achieved to enhance the participants' interests and understanding of OS, inspiring them to take social actions to solve surrounding problems. Besides skill and mindset development, widening personal connections with diverse people and building sustainable relationships is another positive outcome of such open activities.

As evidenced by the OKAs and OIAs, HEIs can develop citizens' new competencies, mindsets and networks by providing them with hands-on experiences with OS. Upskilling people, especially triggering positive mindset change, is vital to foster active participation and engagement in OS. Once people learn how to participate in OS and what impact it will bring to society, they can more actively participate or even initiate further innovation in the future. Designing and implementing OKAs and OIAs, and ultimately mainstreaming OS-integrated curricula, is an important step to achieving such a vision.

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