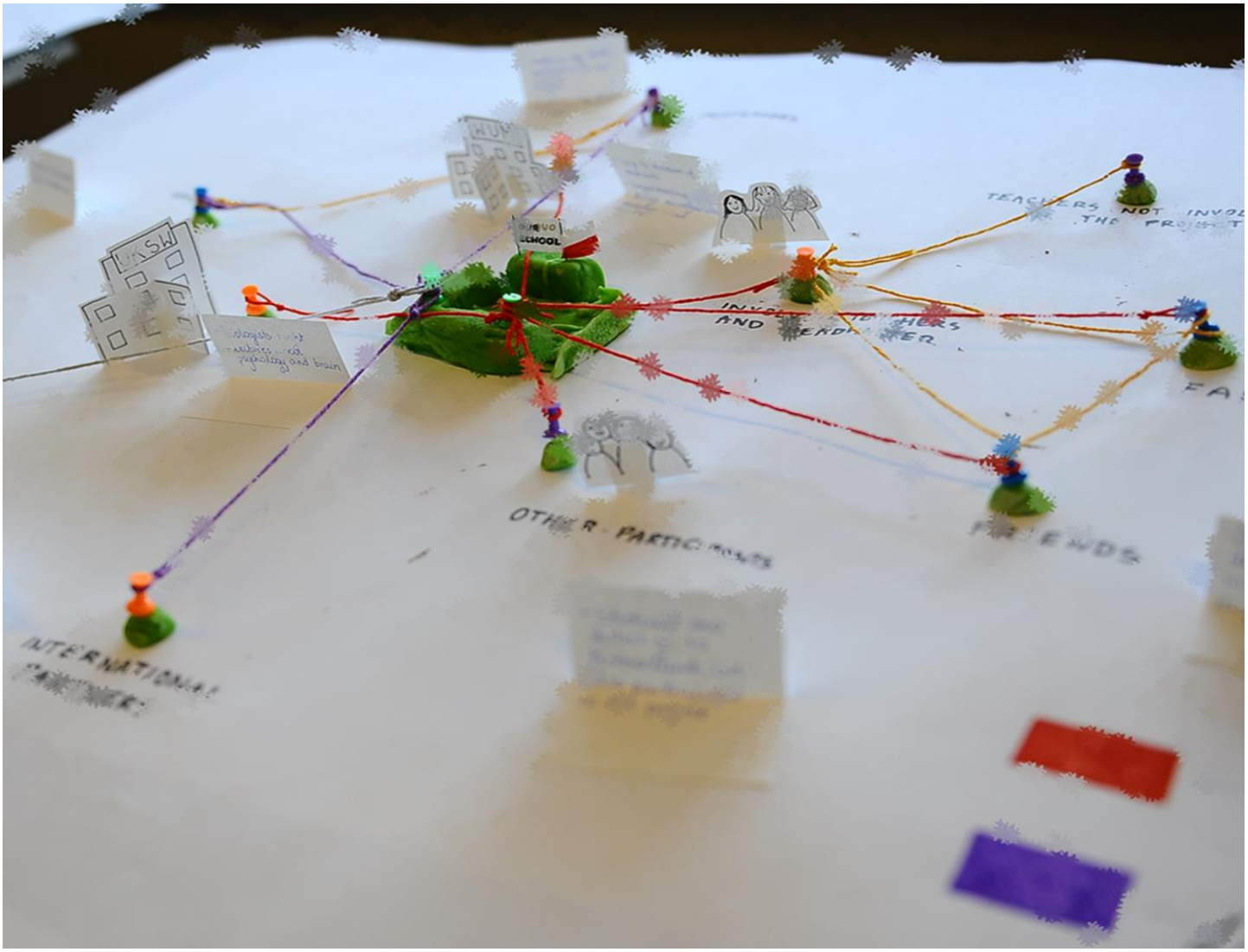

Implementation of Ecosystems of Open Science Schooling: Challenges and Insights

Dadi Chen, Hanna Rahma Abdelwahab, Thi Ngoc Tram La, Aydan Ismayilova, Selina White,

Somayeh Mouri and Maggie Feng

Wittenborg University of Applied Sciences 10/12/22 Ecosystems of OSS Project IO4

Project Intellectual Outcome 4, created in collaboration with Joanna Bunikowska, Calkin Suero Montero, Malavika Jaikumar and Mireia Masgrau. Input materials and data received from all school partners:

Wittenborg University of Applied Sciences, The Netherlands

ITA-SUOMEN YLIOPISTO (University of Eastern Finland, UEF), Finland.

Working with Europe/Treballant amb Europa Associació, Spain.

Liceum Ogólnokształcące z Oddziałami Dwujęzycznymi im. Adama Mickiewicza, Poland.

Pasvalio Levens pagrindine mokykla, Lithuania.

Scoala Gimnaziala Gheorghe Titeica, Romania.

ELAZIG DOGA ANADOLU LISESI (Elazig Egitimcilik Tic.ve San. A.S), Turkey.

Implementation of Ecosystems of Open-Science Schooling: Challenges and Insights

EXECUTIVE SUMMARY

Science education in primary and secondary schools was previously delivered in an enclosed and independent way, but in recent years it has gone through a paradigm shift. Evidence has shown that learning science simply by doing activities in laboratories falls short of enhancing students' potential, especially in terms of problem-solving skills or constructing relevant science knowledge to understand societal issues. Because of this, schools are now more interested in finding ways students can integrate science into their daily lives. Science learning involving external partnerships allows students to integrate their knowledge as they delve into real-life problems with a community of practitioners and utilize powerful scientific tools and other facilities not available in schools. However, integrating external partnerships into school curricula is not without obstacles and requires careful planning, effective collaboration and general acceptance by the community.

Open Science Schooling (OSS) related to science learning is advocated by the European Commission in its 2015 report, where schools, in cooperation with other stakeholders, become an agent of community well-being; families are encouraged to become real partners in school life and activities; professionals from enterprise, civil and wider society are actively involved in bringing real-life projects into the classroom. The Erasmus+ Programme of OSS project, which was funded

by the European Union, was first carried out between 2017 and 2020. The project aims to find real science in the community through students' involvement in local practical activities outside school and bring the acquired knowledge back to school. The findings from that project showed how, through the OSS approach, educators and students were able to make significant progress towards enhancing their digital competence as well as developing their cognitive skills. The follow-up project called Ecosystems of Open Science Schooling (Eco-OSS), which was headed by Wittenborg University of Applied Sciences, together with knowledge partners University of Eastern Finland and Working with Europe/Treballant amb Europa Associació from Spain, was launched in October 2020 and ended in September 2022. The main aim is to help secondary schools and science teachers to be involved in changing traditional science teaching into mission-based science learning with other members of the ecosystems, such as families, professionals and institutions. During the two-year period, partner schools from Lithuania, Romania, Spain and Turkey conducted various interesting science missions and activities in their respective countries. The successful activities have not only enhanced the learning of science on the part of the students, but have also brought big social impacts to the local communities.

Besides this successful outcome, as part of the intellectual output, a research study was also carried out. The objective of the research study is to identify the challenges in the implementation of the Ecosystems of Open Science Schooling (Eco-OSS) project that need to be addressed in the European funding priorities, and to identify research needs in the field of Eco-OSS. Based on surveys and interviews with the students, teachers, school administrators and ecosystem partners, the ideas about the project implementation and challenges in the perspectives of four national groups (Romania, Lithuania, Poland and Turkey) were reported in the case studies,

and ideas and challenges from the four stakeholder groups were visualised and analysed by the online analytical tool InfraNodus.

This research is based on the theoretical learning framework of constructivism, Urie Bronfenbrenner's Ecological Systems Theory and Lev Vygotsky's Sociocultural Theory, specifically the principle of the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD).

The survey revealed that the first experience of students and teachers with the Ecosystem OSS was challenging because the concept of ecosystem itself was unfamiliar to them. Despite that, students and teachers found working with the ecosystem partners easy and that they are appreciative of the support provided by their schools. Participants also commented positively that they have gained knowledge and skills in other areas besides science, such as art, design, team building, negotiation and collaboration, communication, research, problem-solving skills, and have also enhanced their emotional, social, linguistics and interpersonal intelligence. The findings also revealed that not all teachers are willingly participating in the project and this could therefore challenge the sustainability of the OSS. Some other challenges cited by school administrators are organisation of activities, time reconciliation, adaptation of the OSS methodology into practice, low motivation of teachers and lack of communication between external partners and the school.

The ecosystem OSS should provide systematic guidance and sustainable opportunities and facilities for students to explore and practise and solve real-life problems. The ecosystem partners are motivated by the significance and relevance of their contributions, such as improvement of education, fulfilment of their own missions and societal impact and communication with the younger generation. However, the success of OSS is really dependent on the accessibility of the

external partners/sources, willingness of school educators and the flexibility of the school system in terms of curricula and time reconciliation.

This project provides an overview of the OSS ecosystem from the perspectives of both the national groups and stakeholder groups. More in-depth longitudinal studies could be designed and conducted to see how the OSS missions enhance the sustainability and effectiveness of OSS ecosystem.

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INTRODUCTION

Traditional science education in primary and secondary schools was previously delivered in an enclosed and independent way. Such a way has gone through a paradigm shift in recent years. A move to establish a collaborative climate to involve community partners, such as universities, companies, scientists, technology experts and government agencies, is high on the agenda of many schools around the world (Linn, 1996). Schools now are more interested in how students integrate science into their lives rather than whether they can explain fragments of theoretical science (Lee & Wolff-Michael, 2002). Science learning involving external partnerships allows students to be engaged in knowledge integration as they participate in a community of practitioners, use powerful scientific tools and investigate science problems of their own interests (Linn, 1996). However, the experience of integration and partnership within the community is not without challenges; it requires feasible careful planning, effective negotiations, sufficient preparations and an overhaul of school curricula. A sustainable, interactive, and efficient system is necessary for the mobilisation of the resources for learning in the community, and this is explored in the present research.

"Open schooling" with regards to science learning is advocated by the European Commission (2015) in which "schools, in cooperation with other stakeholders, become an agent of community well-being; families are encouraged to become real partners in school life and activities; professionals from enterprise, civil and wider society are actively involved in bringing real-life projects into the classroom" (European Commission, 2015, p. 10). It also calls for the promotion of partnerships between "teachers, students, researchers, innovators, professionals in

enterprise and other stakeholders in science-related fields, in order to work on real-life challenges and innovations, including associated ethical and social and economic issues" (ibid.).

The Erasmus+ Programme first Open Science Schooling (OSS) project was funded by the European Union and carried out between 2017 and 2020. The project proposes that science-learning processes should involve students in real-life societal science challenges and innovation circles; it aims to find science in the real-life community through students' involvement in local practical activities outside school and bring the acquired knowledge back to school; it was found that, through the OSS approach, educators and students were able to make significant progress towards enhancing their digital competence as well as developing their cognitive skills (Montero, Baranowski & Gejel, 2019).

The follow up project, on which this research paper is based, is called the Ecosystems of Open Science Schooling (Eco-OSS) project which spans two years from 1st October 2020 to 30th September 2022. Its main aim is to help secondary schools and science teachers to be involved in changing traditional science teaching into mission-based science learning together with other members of the ecosystems, such as families, professionals and institutions. The missions in the context are the science-learning assignments or projects focusing on a particular real-life topic, question, or challenge with the support of schools and external partners.

LITERATURE REVIEW

Science education in schools over the past few years has been criticized as not providing meaningful learning to students (Montero, et al., 2019; Tobin, 1990; Tobin & Gallagher, 1987). Schools tend to be isolated from the society and community due to the closed curriculum and teaching based only on textbooks. Thus, the boundaries become visible between knowledge taught at school and real life, such as community and social activities, economics or politics, etc., and in a fundamental approach not bonded with many aspects of daily life (Lee & Wolff-Michael, 2002; Latour, 1993). Because of that, students have this limited idea that science is what goes on in science laboratories and they are oblivious to the fact that much of everyday science is present in the environment, in their own homes, and practically everywhere (Lee & Wolff-Michael, 2002). Humans interact with science in their day-to-day life, such as how to eat and live healthily, what causes diseases, or whether certain activities are good or harmful for them. It is a tool humans use to make sense of and help them in their decision-making process (McLeod, 2007). Evidence has shown that learning science simply by doing activities in laboratories falls short of enhancing students' potential (Tobin & Gallagher, 1987), especially in terms of problem-solving skills or constructing relevant science knowledge to understand societal issues. To find real-life science in the community and environment, students need to be involved in local practices outside the school with other members of the community and organisations (Howaard & Mataheru, 2019).

The traditional curriculum and isolated classrooms will not help Europe to meet its goals of ensuring a sustainable future (European Commission, 2015; Scharmann, 2007), especially when the European Union (EU) has set up many initiatives to promote a smart and sustainable way of life (European Commission, 2015). With widespread internationalization and globalization, the

world has become more inter-connected, bringing in more new opportunities, developments and prosperity. However, these also bring along more complicated and intricate societal issues and challenges. In order to overcome these issues and challenges, citizens need to have a better understanding of science and technology (European Commission, 2015). Science education policy and activities should expand beyond the schools and involve the participation of enterprises, industry and the community at large (Montero, et al., 2019; European Commission, 2015; Lee & Wolff-Michael, 2002).

According to Tobin (1990), learning is the process of constructing knowledge from sensory data and prior knowledge (Tobin, 1990; Kara, 2018). This definition is in line with the theory of constructivism, which states that students should experience what they are learning in a direct way so that they can make sense of what they are learning (Driscoll & Burner, 2005). Thomson (2018) underlines that to understand any kind of information for whatever knowledge that is gained, it must be based on experience. Driscoll (2005) also said that under constructivism, educators should provide students with opportunities to explore, interact with society and learn something that is of their own interest. In addition, Kamphorst (2018) stresses that for a student to acquire useful knowledge, they must be able to associate the available information with a real-life situation. Therefore, students should be allowed to deal with actual-life complications (Suero, et al., 2019). Howaard & Mataheru (2019) in their article 'Open Schooling in the Netherlands' stated that by getting students to be connected with the world outside the school, they would have a better perspective of how society functions, the challenges society faced and how they cope with these challenges.

According to Lev Vygotsky's Sociocultural Theory (Vygotsky, 1978), children acquire their "values, beliefs and problem-solving strategies" through interaction with more

knowledgeable persons in the society (Mcleod, 2022). It stresses the significance of social interaction in the cognitive development of children, as he believed that community is the centre of children's 'meaning making' (Vygotsky, 1978). Tomasello, et al. (1993) interpreted that children learn in three ways; by imitative learning (copying another), instructed learning (learning from teachers) and collaborative learning (learning from peers). Vygotsky's theories on cognitive development are centred around two main principles: the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD). The MKO need not always be a person who is older or a teacher, but can also be the child's peer, or an electronic device or electronic tutor (McLeod, 2007). The ZPD on the other hand refers to the concept that children when left alone can develop, but with collaboration with adults and others, they can reach their full potential. The ZPD is the gap between the knowledge learned independently and the knowledge achieved with guidance from a skilled person/s (Figure 1). This points out that social interaction and involvement in the community supports students' cognitive development as well as develops various skills and strategies (McLeod, 2007).

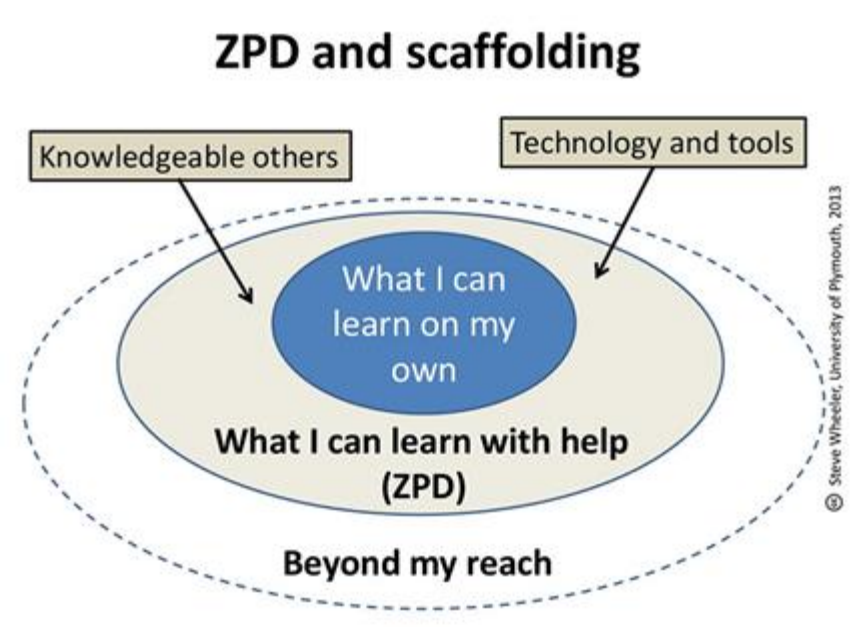

Figure 1: ZPD and Scaffolding (Wheeler, 2013)

Vygotsky's theory of the relationship between social interaction and cognitive development is further supported by Urie Bronfenbrenner's Ecological Systems Theory (Bronfenbrenner, 1992). This theory posits that the child's development is seen as a complex system of relationships affected by multiple levels of the surrounding environment. The child's interaction with their own biology, their family, the community, the environment and the societal landscape promotes and steers their development (Ryan, 2001). The model of Entrepreneurship Education Ecosystem (EEE) illustrates further the relationship between curriculum framework and other dimensions, such as connections, culture, pedagogy, spaces and materials, and motivation in the multidimensional ecosystem (Mueller & Toutain, 2015; Toutain, Mueller, & Bornard, 2019) (see Figure 2).

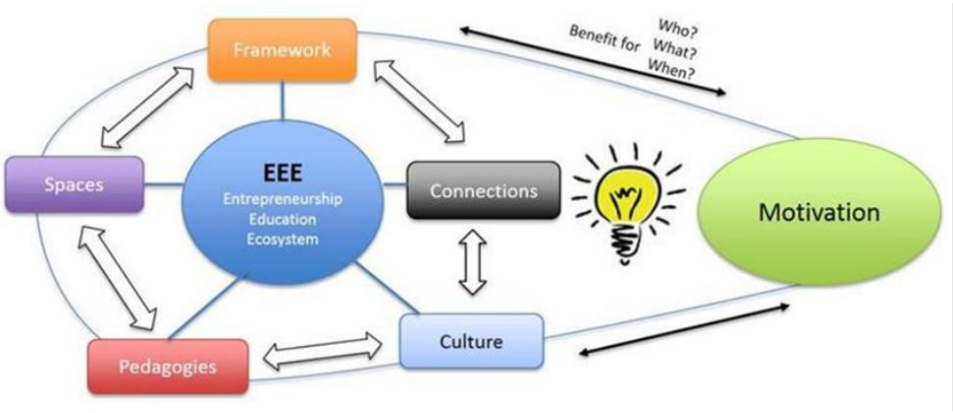

Figure 2: Dimensions & Dynamics of Entrepreneurship Education Ecosystems (EEE; Mueller & Toutain, 2015)

The Open Science Schooling (OSS) approach is basically an initiative to encourage science learning through science missions carried out in the community. Infrastructures of science resources (also known as ecosystems) should be made readily available to educators and schools to help them change traditional science teaching and learning into mission-based science learning in collaboration with the ecosystems. The aim of Ecosystem OSS project is to create and test these ecosystems in practice in the respective communities of the partner institutions and provide relevant guidance for future implementation in other schools in Europe. In a study done by Mulero, Grau & Torra (2019), it was found that OSS provides a much broader perspective to students, as it instigates them to find solutions to real problems plaguing society and encourages the involvement of other members of society. Another study done by Torra (2018) highlighted the difficulty for school and science educators to integrate OSS methodologies in real-life practice. One of the highlighted issues, as also shown in another study by Mulero et al. (2022), is the issue of school curriculum, which is often categorized by subjects, each having its own contents and structure. In real life, challenges are not divided into subjects. Schools too, often have strict

confines of timetabling of subjects and doing away with this often has to go through much red tape with the ministry or regional governmental offices. Teachers, despite agreeing that OSS helps to make their students more engaged with science, find OSS rather challenging to implement (Mulero, et al., 2022). Another common challenge is getting other stakeholders to participate in the activities.

RESEARCH METHODOLOGY

As planned in alignment with the objectives of the project and previous research of open-science schooling, we focus on the following questions in the research:

1. What must characterize open science schooling activity to engage and re-engage young students in science learning? What are the major criteria? And what does it take to allow young students to integrate science as a positive value in their identity creation?
2. What characterizes the open schooling learning processes compared to traditional science teaching?
3. How can schools become ‘agents of change’ (OECD) in the community and how can this lead to ecosystems of open science schooling?
4. Which motivational factors can dedicate science resources in the community to participate in ecosystems of open science schooling? What roles might ‘responsible science’ play in this context?
5. How can schools and ecosystems integrate local and global science missions for the students, allowing students to be motivated through the use of their own social and gaming networks?

To answer the above 5 questions, teachers’ surveys and interviews were developed and conducted to address teachers’ motivation (Do I want to do it?) and needs (What do I need to do it?), as well as the support they have (or not) from the school administration and easiness/difficulties to collaborate with the ecosystem (How the school administration can help me to do it?). We also conducted surveys and interviews with school administrators to address their motivation and attitude towards engaging ecosystem partners, their ability to offer support (financial, technology,

equipment, contacts etc.) to develop and maintain the school's ecosystem. As mentioned above, our research was designed based on Lev Vygotsky's Theory of Cognitive Development and Urie Bronfenbrenner's Ecological Systems Theory. We also considered the model of Entrepreneurship Education Ecosystem (EEE) when describing and analysing the OSS ecosystem.

We developed and conducted the research in two parts, i.e., a preliminary survey and in-depth interviews. The survey was administered in December 2021 to collect from the participants their first experiences with the OSS ecosystem missions. The interviews were conducted in January and February in 2022 to obtain more in-depth information from the participants about their opinions towards OSS ecosystems and the challenges. The framework of both studies in relation to the five research questions are listed in Appendix 1. Though both the survey and interviews address the five research questions, the survey offers some insights that are integrated into the interview protocols, and the findings of the interviews provide explanations to some of the answers in the survey.

The participants in both studies are students, teachers, school administrators and Ecosystem partners in the project. We adopted opportunity sampling by asking the project coordinators in each national group to contact the participants who were available and willing to join the research. Due to the busy schedule of the participants and the situation during the pandemic, we offered the participants more flexibility in taking part in the research. In the following we explain the research methods and report the results of the survey and the interview.

PRELIMINARY SURVEY

To better understand the processes of collaboration between schools and students with their ecosystem partners to enhance the educational value of learning outcomes, a short survey was developed and conducted by UEF with the support of the project team. The short survey questionnaires (see Appendix 1) consist of questions regarding the first experiences of the students, teachers, and school administrators in implementing missions together with their Ecosystem partners. The partners were invited to fill in the questionnaires as well. The number and distribution of the participants can be seen in Table 1.

Table 1: Distribution of short survey participants (N=25)

National groups	**Students** (*n* = 13)	**Teachers** (*n* = 7)	**School Administrators** (*n* = 3)	**Ecosystem partners** (*n* =2)
Romania	6	2	1	1
Lithuania	3	1	1	0
Poland	2	2	1	1
Turkey	2	2	0	0

The questions in the questionnaire cover 1) the background information of the participants, e.g., age, gender, country, and teaching experience (for teachers), 2) local ecosystem and the missions, 3) new knowledge and skills developed in the project, 4) engagement/contribution of ecosystem partners, etc. For the purpose of the preliminary study, we report in the following the results of the survey in the four groups of students, teachers, school administrators and ecosystem partners. We do not differentiate further the age, gender, country, etc., in this report.

Results of the Survey

Students

In general, the first experience of students with the OSS ecosystem was challenging because the concept of ecosystem was not familiar to them and quite different from the traditional type of schooling. Besides, it would be difficult for a student to get an overview of the ecosystem due to the limited needs in learning and roles in the ecosystem assigned by the teachers and school administrators. To be more specific:

1. Students do not necessarily understand the concept of the 'ecosystem'. When asked to describe their ecosystem they elaborated on the activities of their mission.
2. Students found working with the ecosystem partners easy (50%) or very easy (23%).
3. Students found that the ecosystem partners contributed to the missions well (54%) and very well (46%).
4. Students positively assessed the school administration's support to the missions but their assessment of it was less strong than on the teachers' assessment. This may be explained by the different perspective of the two groups and proximity to the school's administration.
5. Students evaluated the teachers' support to the mission as very high (77% said "very well", the highest value).
6. Students' impression of the benefit of collaboration with the school for the ecosystem partners were various with some answers indicating the opinion that the partners did not benefit at all from collaboration.
7. The benefit of collaboration for the students and the school was very evident for the students.

8. Students expressed the opinions that they would like to collaborate with the ecosystem partners often and very often.
9. Students assessed less enthusiastically the “amount” of new knowledge than the teachers (100%, a lot of new knowledge): only 38% said “a lot”, 54% said “more new knowledge”, 8% (1 student) said “less new knowledge than at school”.

The new knowledge developed in the project, according to the students, covers not the subjects they learned, e.g., biology, physics, etc., but also the knowledge about study, social communication, etc. The knowledge in the field of psychology includes knowledge on emotional intelligence, emotions, animal behaviour, neurology, being one-self, etc. The knowledge about research methodology includes principles on conducting scientific research like how to retrieve fossils. Knowledge about the environment includes biodiversity, sustainable agriculture, ringing storks, protecting the planet and environment, etc. They also acquired knowledge related to art and design in the missions. Here are some of their answers:

- *More about emotional intelligence, emotions, environment, biodiversity, sustainable agriculture, art, and design.*
- *I have learned more about carrying out the research from the beginning to the end. Moreover, I have gained a lot from the lectures about animals' behaviours and the human brain. The tours to dig for the fossils and ringbark the storks also were really illuminating.*
- *I learned how to collaborate and how to be myself.*
- *I have learnt a lot about nature and the things you could do with a little imagination.*
- *While participating in these activities I learned about the value of protecting nature.*

- *I learned how to take care of our planet and which aspects of my life can affect it.*

The skills developed by students in the missions include communication skills in general (e.g., communication, collaboration, team building, etc.), communication skills by using the English language, social skills (e.g., empathy, socialization, confidence, etc.), problem-solving skills (including creativity), and ICT skills. Here are some of their answers:

- *I am better at understanding English language, I got to know how to do an infographic, how to excavate for the fossils and how to manage the Google account (and many other platforms).*
- (I learned) *Collaboration, Creativity, Communication.*
- (I learned) *Better socialization I'm more confident (and) I'm more responsible now.*
- *I'm more confident when I speak English.*
- (I learned) *Collaboration, Teamwork, Build self-esteem, Empathy skills.*

Teachers

Most of the teachers seemed more confident about the OSS ecosystem than their students and to have a clearer overview of the missions and collaboration with the ecosystem partners. To be specific:

1. The majority of teachers (67%) said it was easy to build the ecosystem. No one declared the task to be “very easy,” some (33%) did not assess the difficulty of the task as either difficult or not difficult (“neutral”).
2. From the teachers’ perspective, the ecosystem partners were very positive to take part in the mission: 33% said the partners were “very eager”, half said “eager”, for 1 respondent the attitude of the partners was “neutral”.

3. The teachers highly evaluated the school administration support for the mission development: 87% rated the highest value (“very much”). The students’ impression on the issue was also positive but less strong.
4. All the surveyed teachers were noticeably confident that the mission offered the students a lot of new knowledge – compared to the students’ response: 38% in the same (highest: “a lot”) category.
5. Teachers were positive regarding the acquisition of the new skills by the students. One half of the teachers were of the opinion that the mission provided students with a lot of new skills, the other half were of the impression that students got “some new skills”.
6. Teachers declared they themselves acquired new skills while implementing the mission.
7. Teachers were in agreement with the students regarding the contribution of the ecosystem partners to the development and implementation of the mission. However, the level of contribution depended on the partner, as responses ranged between “very big” to “big” to “neutral” contribution.
8. Teachers evaluated students’ engagement in learning in mission as much bigger (50% said “very eagerly” about the students’ engagement) compared to the learning in the traditional classroom environment.
9. According to the teachers, students very significantly participated in the design of the mission activities. Half of the surveyed teachers said that the students’ participation in the designing of the mission was very big (“very much”) and one third (33%) that it was significant (“much” in the survey answer option).

10. Ecosystem partners were significantly engaged in the designing of the mission activities (66% said “much”) as well as in development of the assessment of the outcomes of learning (67% said “very much” or “much”).

School Administrators

We received replies from 3 out of the four schools. The administrators provided substantial information about the collaboration with the ecosystem partners. Among the responding schools:

1. All schools have previously collaborated with the ecosystem partners with two of the schools on a regular basis and one sometimes.
2. As it comes to the teachers’ collaboration with the ecosystem partners, all the surveyed schools declared that only “some of the teachers” actively and regularly collaborate with the ecosystem partners. This suggests that the sustainability of the school collaboration with the ecosystem partners might depend on the initiative, attitude, and/or availability of the individual teachers.

The schools’ ecosystems partners (including the ones with whom the school collaborated in the ecosystem of OSS project) include a variety of partners among them: NGOs, private sector entities, public institutions, higher education institutions, other local community members. None of the schools declared collaboration with cultural institutions, research centres, vocational education centres. The present OSS ecosystems of the schools can be explained by the motivations of the schools to join the project, e.g.:

- Boosting students’ interest in science by showing science’s practical application
- Providing the students with new skills - entrepreneurial skills

- Provision of new types of education, introduction of new purpose of education - education for sustainable development
- Shifting the students' learning style (to academic style)
- Development of cooperation with ecosystem partners (higher education institution)

In addition, the school administrators considered three values of the OSS ecosystem missions for students and teachers, including:

- Activities that are more meaningful and interesting (than the traditional schooling) with the characteristics of learning activities and process of the OSS mission
- Access to the learning environment of higher education through collaboration with ecosystem partners
- Students' personal development and development of their entrepreneurial skills (that supposedly cannot be developed to the same extent in the traditional classroom activities)

The school administrators described the areas in which the ecosystem partners supported the schools as follows:

- All the schools declare to have received "strong support" from the partners concerning "development of skills, in general" as well as in "development of interest" of the students.
- The school administration highly evaluated the partners' support in other areas: delivery of theoretical knowledge, application of theoretical knowledge, socialization including development of social skills.
- For one respondent the support from the ecosystem partners the school received in the area in "Socialisation including development of social skills" was "very strong".

- The respondents also included other forms of support from the ecosystem partners which encompasses “financial support” and “mobilising for proactive attitude”.

They also explained how the schools facilitate collaboration with partners by:

- Helping to find partners and facilitate contacts,
- Supporting partnerships at the organisational level,
- Providing opportunities to collaborate,
- Lending school equipment for the missions,
- Making the school premises available for mission activities with the ecosystem partners, and
- Offering financial resources.

It was easy for the school administrators to list benefits of collaboration with the ecosystem partners. The benefits include:

- Outward-oriented school (school being open to public, exchange of opinions, important learning outside of school, access to financial support),
- Increase in the teachers’ qualifications and competences,
- The new aspects of knowledge for students (practical application and academic and scientific knowledge), and
- Being closer to the community with insights into the decision-making process, knowing the community, and engaging the community (parents).

In the meantime, they also see two benefits for the partners in the collaboration from their own perspectives, i.e.:

- Enhancing mutual development and learning, e.g., the partners can update their knowledge and fulfil their educational mission when sharing their knowledge with the students.
- Boosting the partners' image and position in the community.

In the opinion of the school administration, the collaboration in the OSS ecosystems is different from other educational collaborations, in that the former is more systematic and planned with OSS missions, with higher motivation of the students and teachers in the mission.

The school administrators that took part in the survey were of the same opinion regarding the regular frequency ("often") of collaboration with the ecosystem partners. They have very positive (67%) and positive (33%) experience collaborating from the perspective of school administration. This contrasts slightly with the experiences of the teachers collaborating with the partners that ranged from not challenging to very challenging. The proximity of the teachers to the partners may explain the discrepancy in the evaluation of collaboration between the perspectives of the teachers (front line) and the school administration (background).

The administrators saw some challenges in the collaboration with the ecosystem partners, e.g., COVID-19 and the related lockdown brought a challenge for the school administrators in planning and coordinating the missions.

- The challenges in organization of the activities, e.g., time reconciliation ("It is difficult to reconcile the time of practical activities").
- The challenges in the adaptation of the OSS methodology to practice.

- The low motivation of students in participating in the missions (named as the challenge number one by one of the respondents. However, this is different from what teachers reported in the survey that the students were motivated).

The school administrators provided some constructive insights as well on how to ensure good collaboration with ecosystem partners, e.g.:

- Openness and effective communication
- Involvement (of the partners in the project from the beginning)
- The partner has an educational mission for their organization
- Convergence of objectives
- Strong interest in developing the school
- Interest in mutual learning (learning from each other)
- No administrative obstacles
- New educational value provided by the partner to the school

Ecosystem Partners

Two ecosystem partners participated in the survey. One of them is a higher education institution in Poland, and the other is a non-governmental organization in Romania. Both have previously collaborated with some schools (primary, secondary, and vocational training schools). The two partners shared their expertise with the schools as requested by the schools for the mission. They provided hands-on activities for the students as well as implemented educational activities during the mission. They also participated in the mission activities organized by the school.

The partners did not take part in the design of the learning outcomes from the mission, which is different from what the teachers stated in the survey that they were involved in. However,

the inconsistency was probably due to the limited participation of the partners in the survey. The partners listed several advantages of the collaboration in OSS ecosystem over the traditional collaborations. E.g., it is less formalised and more comfortable for both sides. It is more sustainable and provides more visibility nationally and internationally. To quote one of the partners, "the collaboration in this project helps us feel much more comfortable, sustained and more visible both at national and international level."

The partners would like to collaborate often with the school, which is compatible with the views on collaboration intensity expressed by the school administrators. They saw some benefits for both sides as follows (Table 2):

Table 2: Benefits of collaboration for the school and partner: The partners' perspectives

Benefits for the school	**Benefits for the partner**
1. Development of creativity	1. More visibility for the partner organization
2. Development of entrepreneurial skills	2. Enhancing motivation of the partner in supporting science and education
3. Development of critical thinking	3. Exchange of experiences
4. Getting a new perspective	4. Widening horizons (of the partner in knowledge and experience)
5. Improving communication	

While the partners described the collaboration as successful in both the relationship with the schools (incl. teachers, students and school administration) and the feedback from their staff members, in their opinion, there were some challenges in communication, not being able to meet as often due to the pandemic, limited involvement of staff members (maybe referring to both sides), and "helping children to overcome the loss of learning together".

From the perspective of the partners, good collaboration with the schools depends on effective communication, strength of collaboration, the idea of 'lifelong learning', the availability of human resources, and the development of skills for the future. To enhance the collaboration, the partners think that the school could become an outward-looking school by reaching out to the community and creating an open culture, and the partners could analyse better the needs of the teachers to facilitate them better and in a more sustainable way. Within their own organisation, they also need to find the most suitable people to participate in the collaboration.

Summary of the Survey

The findings of the survey showed how students, teachers, school administrators and ecosystem partners regarded the OSS ecosystem, as well as its missions and collaboration. In general, it has been a positive experience for all the participants in the development of knowledge and skills, the motivation and engagement in the learning, the enrichment of social experiences and collaboration, etc. The school administrators and ecosystem partners saw both benefits and challenges in the OSS ecosystem projects.

We also found some inconsistencies in the answers from diverse groups. For example, when asked about the motivation of students for the OSS ecosystem missions, teachers seemed more optimistic about it than school administrators. The ecosystem partners who participated in the survey were not engaged in the design of the missions as mentioned by some teachers. Due to the limited space in the survey questionnaire, there is some vagueness in the answers, e.g., the 'motivation' mentioned by ecosystem partners can be interpreted in multiple ways.

To meet the challenges as listed by school administrators and ecosystem partners, we need to know more about the details in the administration and collaboration of the OSS ecosystem

missions. We developed interview protocols based on the theories in use and the insights collected in the survey. Shortly after the survey, we arranged interviews with the participants in the project, some of whom also participated in the survey. In the following, we report the methodology and findings of the interviews.

RESEARCH INTERVIEWS

We developed the interview questions about 9 topics of the OSS ecosystem missions, namely, views on science and teaching science, idea of the Ecosystem of your school, planning the mission, choosing the partner, implementing the mission, collaboration with the ecosystem partner(s), place of learning, resources and sustaining the practice of ecosystem collaboration, school becomes agent of change, etc. The insights and findings from Study 1 were integrated in the objectives and issues to be addressed in the design of the interview protocols. The objectives and questions for each topic are listed in Appendix 1. The main expected outcomes of the interview are as follows:

1. What the key Open Science Schooling methodology characteristics are when the school is actively collaborating with the ecosystem partners.
2. How students (re-)engage in science learning when they learn with and from the school ecosystem partners.
3. How the school can become an agent of change in the community using collaboration with ecosystem partners.
4. What factors motivate ecosystem partners to collaborate with schools.
5. How students' social and gaming networks can be used to support learning in missions.

The invitations to the participants in Study 2 were sent out via the project coordinators in each of the schools. Due to the limited accessibility during the pandemic, we offered three ways of joining the interview, e.g., online interview via Teams (with or without a translator) by the research team, (group/individual) interview by the teachers in the school, and email interviews. The number of the participants in each of the schools and their ways of participating in the interview are listed in

Table 3. All the participants were well-informed about the purpose, procedure, and confidentiality of the research before the interview and agreed with them before proceeding.

Table 3: The distribution of the interviewees and the means of interviews

National groups		**Students (school captains)** (*n* = 8)	**Teachers** (*n* = 9)	**School Administrators** (*n* = 4)	**Ecosystem partners** (*n* =4)
Romania	Online interviews		1		
	Interview by the teachers	2			
	Email interviews		1	1	1
Lithuania	Online interviews	2	1	1	
	Interview by the teachers				
	Email interviews		1		2
Poland	Online interviews		1	1*	1
	Interview by the teachers				
	Email interviews	2	2		
Turkey	Online interviews				
	Interview by the teachers				
	Email interviews	2	2	1	1

Note: * interview with a translator.

The data were collected and coded by WUAS and UEF research teams. The results were both summarised for each of the national groups to provide a clear picture of the OSS ecosystem in each of the schools and visualised by word cloud for each of the stakeholders to highlight the features of thoughts and challenges. We report the findings below.

Results from Interviews

The following case study summaries follow the same structure designed based on research questions and the microsystem and mesosystem in the ecological systems theory involving the interactions among students, teachers, schools and ecosystem partners (see Table 4). In the following quotations from the interview, the initials of the countries and the abbreviations of their roles are combined to refer to various participants in the interview, e.g., Romanian Student 1 (RS1),

Lithuania Teacher 2 (LT2), Polish School Administrator (PSA), and Turkish Ecosystem Partner (TEP).

Table 4: Case studies' structure

Aspects	Key points/highlights, and examples
Ecosystem and mission overview	Ecosystem's overview and special purpose
	The role of external partners in ecosystem
Open Science Schooling Implementation Outcomes	Highlight 1, e.g., Science is everywhere, 'Classroom can have no walls', etc.
	Highlight 2, e.g., Deeper meaning and effect of the (mission) outdoor education, development of the students' multiple competencies, etc.
Ecosystem Implementation Outcomes	Highlight 1, e.g., Ecosystem collaboration as a way to find a solution to the school need/problem.
	Highlight 2, e.g., school's organizational culture of collaboration, prerequisites to effective ecosystem collaboration, etc.

CASE ROMANIA

Ecosystem of Learning – Outdoor Education

The ecosystem of learning in the case of Romania has been understood in two ways: as internal and external to school (see Figure 3). The internal dimension of the ecosystem included students, teachers, and parents, while the external dimension meant the school's collaboration with the external partners. The school's collaboration with external partners is understood as a way of finding solutions to the issues that are beyond the school's capacity (utility), while one of the partners explained collaboration as shared leadership and responsibilities, aligned objective and coordination (commonalities-responsibilities).

The idea of the ecosystem as understood by the teachers reflected the interconnectedness between the ecosystem partners and between different branches of science, while the school's partner considered the ecosystem in relation to the school: as an attitude to change and responding to the students' needs.

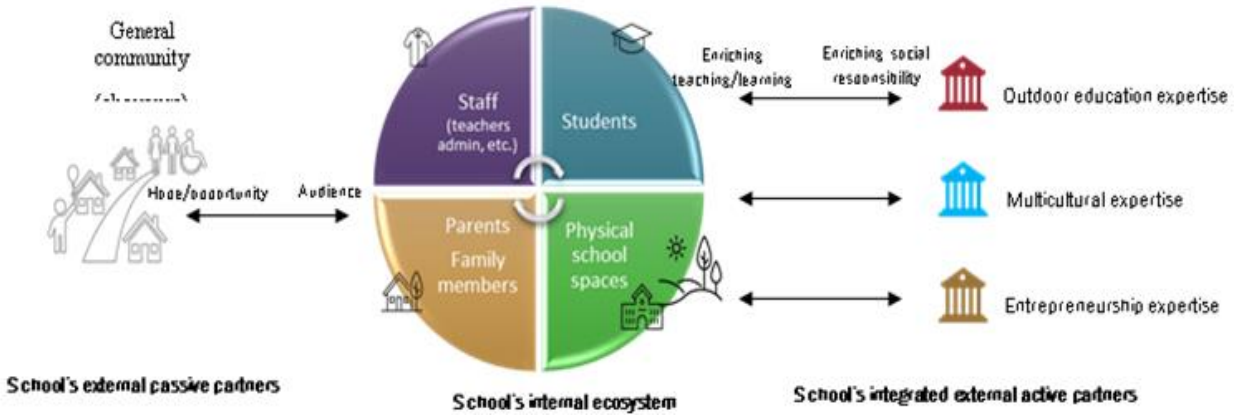

Figure 3: Romania Ecosystem of Open Science Schooling

Ecosystem's Special Purpose

The project was implemented in the middle of the COVID-19 pandemic in Romania. While it was again allowed to go to schools, students and teachers had to follow various restrictions like wearing face masks indoors and being separated by plexiglass. Following these measures significantly interrupted comfort and effectiveness of learning. Additionally, many students who returned to school after the prolonged lockdown felt anxious about being among other people again and in a noisy environment. Finding a solution to these new challenges was exactly what drove the creation of the ecosystem in the Romanian partner's case.

"So I talked to my colleagues, tried to make them understand that the pandemic maybe can be for years now and we have to find some other solutions to change something for our students." (RT1)

The school decided to join and follow a national campaign promoting outdoor education and the project mission focused on the development of outdoor education at the school (Figure 4). The objective of the outdoor education was to create a friendly environment to develop the students' social and psychological (emotional regulation) competencies as well as to address COVID-19-related obstacles to learning such as face mask requirement indoors.

Figure 4: Outdoor Education

External Partners in Outdoor Education

The school's ecosystem was composed of three external partners. One of the ecosystem partners supported the school by the provision of know-how related to outdoor education in the beginning and outdoor learning equipment in the more advanced stages of the project. Other partners collaborated through sharing the international young volunteers who delivered science-

oriented workshops outdoors. The third partner helped to organize a camp with entrepreneurial education (outdoor entrepreneurial education).

Open Science Schooling Implementation Outcomes

Highlight I – Science is Everywhere: "Classroom Can Have No Walls". *"It was (a) kind of slogan we created: classrooms can have no walls. Maybe it was reinventing something in our school."* (RT1)

As learning took place in the school's chestnut garden, the practice reinforced the idea and strong conviction that you can learn anywhere, which is also emphasised in the open science schooling methodology. The school garden became a highlighted part of the school's internal ecosystem. This implementation came, however, with challenges as indicated by one teacher who highlighted that outdoors is a noisier environment and it is more demanding to structure and manage the work of a group of 30 students, and the curricular goals might not be attained. Nevertheless, teachers also pointed out the benefits of learning outdoors for the students' motivation, interest and confidence, their better communication, and relations they have with each other as they leave the desks.

"What I appreciated was that the students were much more motivated. The students were more active listeners. Because it is a problem, nowadays - students' attention. I could see that they became more active listening to their peers, you know." (RT1)

Taking the classes outside also passively involved community members who lived close to the school, who now had the opportunity to observe and hear the students during their meetings and discussions, even admiring them. These 'observers' can be also considered as the ecosystem partners – passive elements of the ecosystem.

Highlight II – Students' Transversal Skills Development. The freedom offered by the reinvented learning space (outdoors) without visible limits and barriers (desks and plexiglasses) translated into more freedom and autonomy that the students could enjoy during their learning experience – freedom of opinion and expression. The focus on the students' autonomy, their interests and needs mediated by the Open Science Schooling methodology, encouraged them to experiment, to try, to ask questions, to inquire and to make mistakes that was an integral part of the mission's implementation.

"*Experiments always arouse students' curiosity about science. For example, one of the fascinating experiments for them was the one in which, with the help of a converging lens, they managed to light a match, concentrating the sun's rays. This experiment requires sunlight, so the mission proved very useful here.*" (RT2)

From this we could observe that:

- The openness of the outdoors translated into more openness between the students – better communication and quality of relationship between the students, better relationship with the teacher (partner's teacher volunteers), facilitation of curiosity, interest in learning, confidence, motivation, provision of autonomy and freedom of expression.
- The lack of physical boundaries of the outdoors eliminated psychological barriers of the learning and teaching experiences. (OSS method in synch with ecosystem, mutual reinforcement)
- The greenness of the outdoors enabled the students to better regulate their moods and learning-related anxiety.

- Also, the OSS method and ecosystem environment unlocked the teacher's ability (often constrained by the curriculum focus) to see and appreciate students' talents, initiative, and creativity.

"*(...) I was happy to discover that one of the 8th grade students managed to design a rocket using a program. During that meeting I realized that, in fact, the student had not taken the project from the internet, as I had the impression, but created it. That's how I realized that I'm often too focused on what I have to teach (adherence to the curriculum) and I fail to pay attention to the talent that often goes beyond the patterns of the school curriculum.*" (RT2)

Ecosystem Implementation Outcomes

Highlight I – Organic Interactions with the Local Community for Better Learning. The task of the creation of the ecosystem was led by one of the teachers and was further supported by the school principal and later endorsed by the students who could not resist the teacher's enthusiasm in the beginning and later became genuinely involved in the mission too. It must be noted that the teacher who created the school's ecosystem of learning displayed a lot of enthusiasm, belief, interest and passion alongside patience while building the ecosystem. Both enthusiasm and patience had to be skilfully applied in encouraging other schoolteachers to take their classes outdoors (sustainability of the project results).

- The ecosystem collaboration enabled the school to implement outdoor learning activities (following a national campaign) in the context of the COVID-19 pandemic-related restrictions: face mask requirement indoors.
- To be able to follow national campaigns that promoted outdoor education.

- Participation in the Open Science Schooling project helped the school to understand and accept the need to change teaching methods, to make learning more appealing and engaging for the students. The role of ecosystem partners has been recognized in helping the school in making this transition easier.

"*In the project I understood that we must not be reluctant to change, that we must adapt "on the fly" the teaching style to make science disciplines attractive to students and that we can always learn from the experience of others, collaboration being beneficial for all. We must accept the challenge of changing teaching in our school*." (RSA)

Highlight II – Ecosystem's Circular Benefits. The ecosystem collaboration enabled the school to conduct learning activities outdoors by provision of know-how and necessary equipment. Partners' engagement also included carrying various outdoor activities for the school students (workshops, camps) covering such areas as entrepreneurship and being based on experimentation, which went beyond the traditional school curriculum both regarding the content and method of teaching.

For the external partners, the benefit of collaboration with the school was entailed in the fact that the mission activities aligned with the partner's mission – promotion of outdoor education, support of professional and personal development of the young people in the region. The staff's participation in the school mission was considered an enriching experience for the partner organization. Collaboration added value was also seen by the partners in the national and international visibility they got through joint activities.

"*Getting the chance to interact with our beneficiaries, with the help of our school partners, increases our practical expertise and gives us new data points to use to improve our methods.*" (REP1)

"*The collaboration in this project helps us feel much more comfortable, sustained and more visible both at national and international level.*" (REP2)

The Romanian team did not experience any major challenges planning and implementing the project missions and collaborating with the external partners. Importantly, the teachers emphasise the need to develop a stronger school culture of collaboration with external stakeholders, even making this kind of collaboration part of the school's philosophy. An important aspect of this culture would be a change of the teachers' 'old' (conservative) mentality, their competitive attitude, and the de-facto hierarchical relationship with the students.

Furthermore, as the ecosystem collaboration enabled the school to conduct learning activities outdoors, this increased the students' motivation and gave them more confidence. International volunteers from one of the ecosystem partners also created a less formal atmosphere during the workshops they carried out for the mission, supported by being outdoors. This more relaxed environment helped the students to be more open and feel more comfortable as compared to more hierarchy-based relationship with the teachers). Having contact with the international students exposed the school students to different cultures, which may be considered as an additional, multicultural dimension of the ecosystem of learning.

"*(…) the persons from the ecosystem are young and I think more connected with us than some of the teachers from our school, so we can learn better and understand better, more things than from some teachers at the school. (…) I think they really helped us with skills,*

because like I've just said to you, they are young people and make us feel more comfortable and more relaxed." (RS2)

The school students also benefited from the surrounding environment – a physical part of their school's ecosystem to develop their emotional balance and self-regulation skills.

"We can learn in a place where we can feel free or very happy. For example, in nature, we can feel like that and that helps us a lot." (RS1)

CASE LITHUANIA

Ecosystem of Learning -- An improvement of school education

From the students' perspective, ecosystem is a broad concept; all elements surrounded the school are considered a part of the ecosystem from bodies such as students, parents, teachers, communities, staffs, partners, to larger surroundings such as the environment, the economy, and so on. In addition to the student's perspective, the teachers stated that ecosystem includes the collection of works and interactions of the school with other parties and its surroundings. The connection between all parties is considered a shared partnership to gain mutual support and enhance quality of work, which eventually leads to improved living for all (Figure 5).

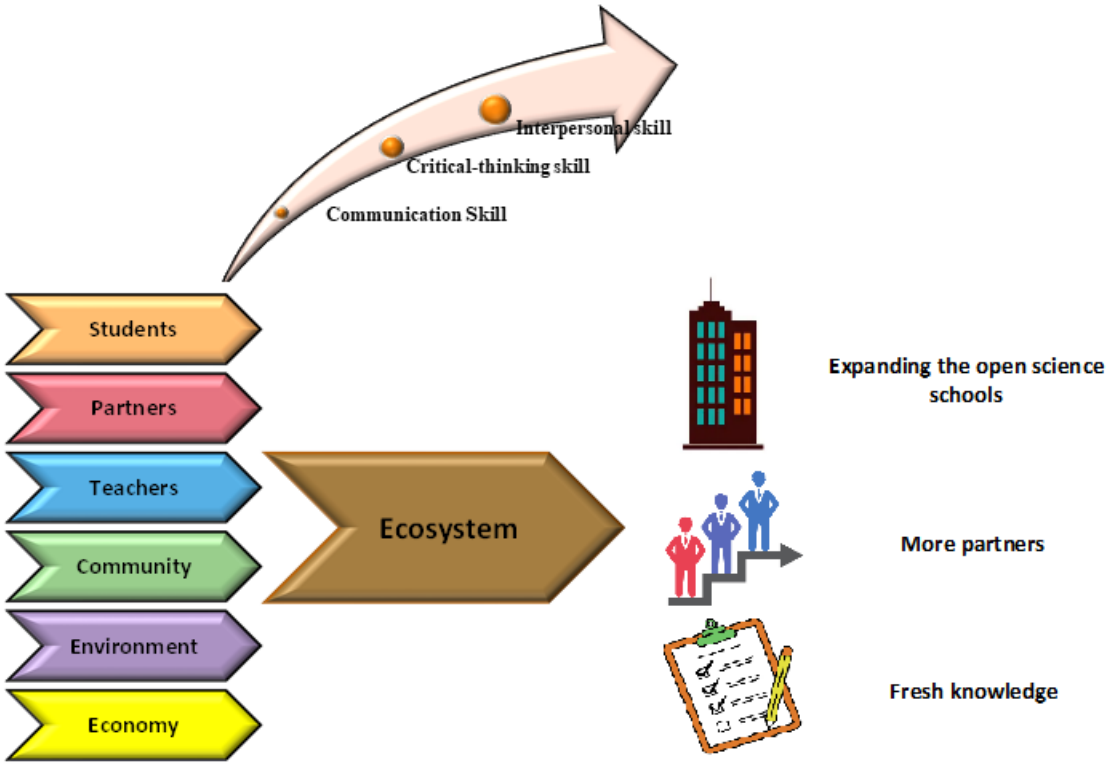

Figure 5: Lithuanian Ecosystem of Open Science Schooling

Ecosystem's Special Purpose

The ecosystem of the school is very much based on the needs of the community, for example, the awareness of environmental issues, knowledge about the virus and vaccination, etc. Students use the information they received from the school, museums and many other sources in helping people in the community to solve problems. As said by LT2, the purpose is "to go outdoors and find an avenue to improve the ecosystem and environment through a campaign or work session". LT1 gave an example of designing a mission based on their curiosity of the behaviour of bees and the change of environment (Figure 6).

Figure 6: Learning about Bees

External Partners in Win-win Partnerships with School

Lithuania partners were chosen based on 3 main criteria including relevancy of knowledge, financial ability, and accessibility. In relation to relevancy of knowledge, the partners were able to enhance current understanding and provide new knowledge beyond the school to the students in the scope of chosen missions, which triggers curiosity and sharing of knowledge. To illustrate, the vaccination centre allows accesses to medical sites, provides in-depth knowledge on the history and usefulness of a vaccine, which the students were sufficient and inspirational to make posters, videos, and educate others to get vaccinated.

In relation to financial ability, the partners were willing to finance the missions with their available resources, which motivates students to carry out their works. For example, an agriculture company gifted the students available products (i.e., seeds) for conducting a mission protecting bees to increase natural pollination. In relation to accessibility, the partners were easy to approach. As the school was located in a small town, most partners were easy to contact. Some of the partners were parents of a student.

Beyond the personal acquaintances from being in previous projects or the school parental club, there are two main reasons which encourage partners to enter into collaboration. Firstly, the partners wanted to help young children in the missions, which benefit not only the youngsters in their studying and development of skills but also their ability to leave positive impacts on the surrounding environment and community. Secondly, it helps the partners to be recognised better in the community. During the mission, they were able to help the students understand the field of work tied to the economy and ecosystem. The students could then be inspired to pursue their ambitions in the field, which is considered a future human workforce.

Open Science Schooling Implementation Outcomes.

Highlight I -- Place of learning anywhere, open for discussion and well-equipped. According to both interviewed teachers and students, learning can take place anywhere inside and outside of school or even at home. For individuals, it is important that the learning place is comfortable for thinking and generating ideas. For bigger group learning, the learning place should allow comfortable discussion and can trigger sharing of ideas. In addition, the place is well-equipped (i.e., a learning lab) that increases motivation and enhances the learning experiences of the students. Teachers want to show students "science is not only numbers or calculations" (LT1).

Highlight II – Students' skill development. Students developed practical skills in the missions, e.g., English (public) speaking skills, communication skills, critical thinking skills, social skills, and skills in doing research, experiments and projects, etc. They learned how to deal with stress in the missions and developed interest in learning science. More importantly, it changed their views of life and people around them. They became more optimistic about people and more confident in speaking their minds. In the meantime, teachers are aware of their own development as well, e.g., feeling more confident in contacting (potential) partners for the EU sponsored project, becoming more informed and open-minded during the missions and project mobilities, etc. One of the teachers thinks she "gathered enough knowledge" and transformed her personality "to become a more professionally-suited person for this type of job in terms of social skills" (LT2).

Ecosystem Implementation Outcomes

Highlight I --Problem-solving through Ecosystem. The ecosystem of the Lithuania team is derived from the problem-solving approach initiated by the internal parties of the school - the

students and teachers. They began with the identification of outdoor problems through brainstorming and the mission was formed after voting for the best ideas. The missions were created through a shared knowledge and consensus among the students who did self-research and proposed ideas with verbal guidance and administrative support from the teachers.

The chosen ideas were based on the objective of allowing students to go outdoors to improve the living environment which is connected to their daily life, such as increased COVID-19 vaccination rates in town, secure honey supply by increasing natural pollination in the environment. Then, the partners are involved as a part of the ecosystem.

Highlight II -- Advantages of outdoor learning: more engagement and better improvement in communication. The open learning space encourages open discussion and sharing of ideas. Students were braver and more patient as they learned to speak their minds and listen to others' opinions.

It was motivating and exciting to visit places and interact with different people. Students were more interested in learning because of better exposure to more knowledgeable, open-minded, and flexible colleagues and partners. In addition, the exposure offers more hands-on experiences and enables learning by doing, which leads to better absorption, storage, and application of the knowledge. They used social media to share their achievements with the community. As one of the students described, "*like Facebook, we create the pages of what we do. So, the community can also see what kind of projects we do in Messenger, we communicate with each other, we talk about the missions, we organize them on YouTube, we upload videos sometimes. Also relating to dimensions*" (LS1).

Professional interpersonal and communication skills were improved. The bigger circle with companies and representatives out of school made both students and teachers more professional,

better in terms of English communication, public speaking and presenting ideas in the collaboration.

Highlight III -- Various challenges faced by different participants in the missions besides the COVID-19 pandemic. It is shown that the most prominent challenges came from COVID-19, which includes restrictions on being outdoors or visiting partners' sites, lack of physical contact, which affects communication and unmet deadlines or plans.

From the student captain's point of view, beside uncontrolled factors such as the weather and restrictions from COVID-19, one mentioned challenge is to manage the engagement and interest of different student team members in the mission. Their reasons were said to be personal, which were hard to influence; however, there were just a small number of disengaged students. From the school headmaster's point of view, out-of-school learning puts more time pressures on current administrative tasks because more planning is required, which sometimes did not work out, especially during COVID-19.

From the teacher's point of view, teaching through missions posed the challenge of reaccommodating to new ideas inside the classroom. In addition, with involvement from the partners, it is a challenge for students to work in a more professional setting compared to the usual classroom learning.

CASE POLAND

Ecosystem of Learning – A bridge towards Academia

The Polish participants described ecosystem and OSS missions in various ways. It can be a place and atmosphere built internally around school for teaching and learning, or the interrelationship among all the teachers, students, school council who worked together to share knowledge. Externally it is the occasions, e.g., meetings, visits, events, etc., where learning takes place with the cooperation with local people and educational institutions and students are motivated to learn, i.e., in the words of a teacher, "a system of out-of-classroom learning opportunities for students" (PT3) (Figure 7). However, to the ecosystem partner in the interview, i.e., Cardinal Stefan Wyszyński University in Warsaw (UKSW), the concept itself seems very vague and limited in his understanding about the biological environment.

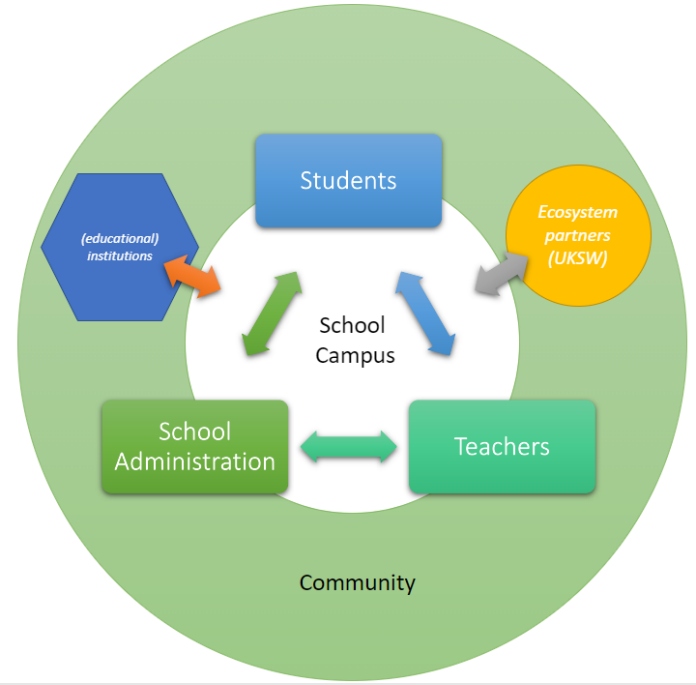

Figure 7: Polish Ecosystem of Open Science Schooling

Ecosystem's special purpose

According to the school headmaster, collaboration in the ecosystem helps the school and teachers to motivate students in learning science and working hard together. It enhances the social skills and contacts of the students. The collaboration with the university as ecosystem partner gives parents confidence in the quality of education. It also enables the school to get more access to external partners and diverse cooperation opportunities on the one hand, and on the other hand it offers opportunities to the school to help the community by organising events for charity or environmental protection (Figure 8). Such collaboration is also supported by the local administration in their policy of supporting universities to recruit more talented students from secondary education (PT2 and PEP1).

Figure 8: Learning about Fossils

External partners in outdoor education. Students participated in online events hosted by the main external partner UKSW, such as Biologists' Nights, the history of medicine, lectures by the professors, etc. A trip to discover fossils was organised by them when students went back to school. The biocentre gave students workshops on biology. The external partner not only provided knowledge but also encouraged students to learn and explore. Other external partners, such as the Biology Department at the University of Gdańsk, Faculty of Biology and Biotechnology, Icelandic Institute of Natural History, University of Cambridge School of Clinical Medicine and the local manufacturer Fine Wood Creations, shared also their knowledge and experiences in science and industry.

Open Science Schooling Implementation Outcomes

Highlight I -- 'Teaching takes place everywhere'. In the missions, there are four locations where learning took place, the school, online, the place of the external partner (UKSW) and the field (nature, community, etc.). During the pandemic, all the classes were online. The plan of the missions was changed due to the lockdown. It was on one hand limited in mobility, and on the other hand more connected to the family and online community. Some of the missions were completed online, and the others at school, the university or in the countryside. All participants considered it rewarding and inspiring to learn knowledge out of school, especially the students. As the ecosystem partner put it, "teaching takes place everywhere". However, teachers might have different opinions on the effectiveness of teaching. One of the teachers admitted that it would be more comfortable for her to teach at school while students learn better in the laboratory, while one of the other teachers considered learning better takes place out of school, "I feel comfortable giving lessons with students outside the classroom. Of course, it is better when the group is not too large. When it is possible to create such conditions, teaching outside the school is, in my opinion, most beneficial for the students." The school headmaster considered also the emotional factors, "...all those trips and going outside, having contact with the university teachers, are what is desired. (The) positive emotions outside school will definitely (make them) memorise better."

Highlight II – The development of students' skills and attitudes. Apart from the view of science and understanding about knowledge, the missions improved students' various practical skills, e.g., social skills, organisational skills, teamwork, skills of communication in English, computer skills, etc. Students also became more confident. Compared with the "boring" traditional

classroom which "doesn't encourage students to talk and communicate their points of view" (PS1). In the missions, students are much more involved, and they were "encouraged to ask more questions and be more curious about science" (ibid.). The missions "broadened their thinking about science" and extended their "knowledge beyond the core curriculum" (PT1). The school headmaster regards it as important that the missions develop positive attitudes among students towards knowledge, the future, and the world. The missions brought 'the base of knowledge' to the students so that they will be happy to learn science. The external partner showed them a good example of lifelong learning. With more confidence in the missions, they are proud of their school and "view positively the university and other partners they had"; "they will appreciate the EU cooperation...between countries within the project", and "it will make the world better" (PSA).

Ecosystem Implementation Outcomes

Highlight I -- Creation of ecosystem internally and externally. The ecosystem of the Polish school was created both internally and externally. Internally, each of the profiles (or disciplines/study orientations of the students, e.g., science, history, languages, etc.) forms its own ecosystem of teaching and learning and provides students with interesting places for learning. The collaboration is formed by "establishing contact between those who have knowledge and want to share it and those who need it for their development" (PT1).

Externally, the collaboration with the OSS ecosystem partner was initiated by the school headmaster and teachers in their previous contacts and personal relationships. The collaboration is coordinated by one of the teachers as the programme coordinator. The coordinator keeps close contact with the ecosystem partner and plans and implements all the OSS missions with the teachers in the school who provide knowledge, language, or administrative support.

Highlight II -- The importance of collaboration to the academic achievement of students. The school sees the collaboration as a win-win opportunity for both the school and the ecosystem partner. The school can recruit more (talented and ambitious) students because of the good reputation of collaboration with universities. The ecosystem partners introduce more speakers/partners to the school. The universities also get more opportunities to understand the students in secondary education and inspire more local students to learn science and later apply for the university. They can bridge the gap between secondary and higher education and make education a "continuous process" (PEP). The teachers benefit from the contact with the ecosystem partners in their professional development and the expansion of their network. Such collaboration allows students to learn out of school in a more interesting, open and relaxed way.

One of the questions for the school is to select competent and committed teachers to oversee the coordination in the collaboration (PSA). It is also a challenge that the ecosystem partner is located far from the school. From the perspective of teachers, it is very important to get the action plan for collaboration developed and presented in advance to the school community (PT3).

We can observe from the experiences of the Polish group that:

- The internal and external parts of the OSS ecosystem are connected by the missions designed based on the school curriculum. It is important for the school administrator and teachers to coordinate the missions well.
- The missions can expand the view and knowledge of the students, develop various practical skills, and more importantly forge their attitude towards science, society and the world.

- The ecosystem focuses on the academic achievement of the students.
- The ecosystem is sustained by the common interest in education of the school and the ecosystem partner (the university) and supported by the policy of the local administration.

CASE TURKEY

Ecosystem of learning -- An Enlarged Body of School

From the perspective of interviewed students and teachers in Turkey, ecosystem is created when the school is at the centre connecting all surrounding things and people without any borders or limitations (Figure 9). In other words, it is understood in a way that ecosystem is an enlarged body of the school that includes the families, partners, social environment and so on. In the Turkish partners' point of view, the connection (i.e., between the school and the partners) should not be an obligation but an added value to the school for the purpose of lifelong education.

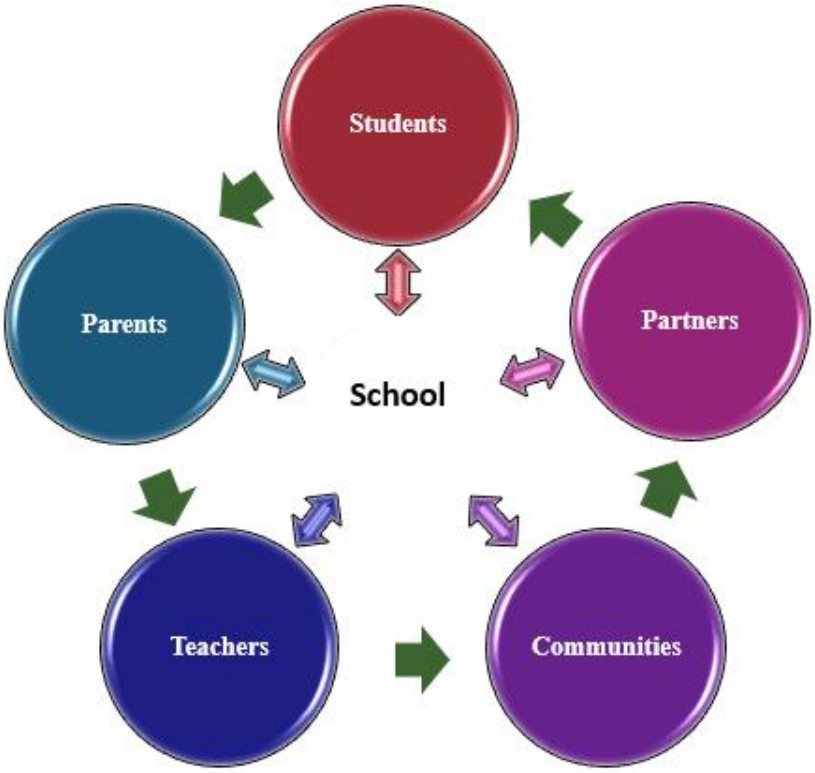

Figure 9: Turkish Ecosystem of Open Science Schooling

Ecosystem's Special Purpose

The ecosystem of Turkey's team is derived from a problem-solving approach. Students and teachers brainstormed and voted for the best mission ideas, i.e., pet therapy and supporting science teachers, which were based on criteria such as possibility of implementation and amount of support from the partners. The process happened in an open discussion where students were those who share the ideas and the teachers acted as advisors on the partners and project's possibilities. As explained by one of the teachers, "We helped them to determine to what extent their ideas could be realized and from whom they could get support. We also offered them ideas about the organizations" (TT1).

School is an initiator of change. School can be the place where change takes place. It is believed that change can begin with education at school to youngsters who are the building blocks of society, which includes their knowledge, thinking and behaviour changes. As school is considered the centre of an ecosystem, it connects all important participants together, such as teachers, partners, parents, which can be considered a connector and a point for change.

Benefits of choosing sustainable and willing external partner to students. With more experiences and connections, partners were suggested and approached by the teachers and school administrators. Most of the partners were chosen based on two main criteria, suitability and willingness to participate in the projects. From the internal perspectives including students, teachers, and headmaster, suitable partners whose job and abilities are related to the project ideas is key. In addition, it is important for the partners to be active and willing to contribute to the mission.

Ecosystem partners agreed to join the mission with the pure intention of doing good. The good intentions of helping education and improve living environments motivate them to join the

missions. The missions were new and positive initiatives, especially the collaboration with youngsters. With all available resources, the company did not have any hesitation in collaboration with the school (Figure 10).

Students were “enthusiastic, enterprising, interested in learning and research during the missions with the ecosystem partner” and they were attracted by “the idea that we would cooperate and exchange information with a partner from outside the school” (TT1).

Figure 10: Learning about Pets

Open Science Schooling Implementation Outcomes

Highlight I – Place of learning outside school. In the general view of all interviewed respondents in Turkey, learning can take place everywhere and education should take place beyond

the border of the school classroom. The starting point or basic education (i.e., the theory) can take place at classroom level but more learning should be carried out out of school (i.e., laboratories, library, city science centre, etc.). Hence, compared to the traditional classroom, the outdoor learning space is more interesting and practical, triggers more curiosity, and is sometimes better equipped (i.e., laboratories). As observed by the school administrator, "The atmosphere of the school has changed, and a different atmosphere has been created in the school. We especially noticed that students showed interest in learning in this way."

Highlight II – Students' skills development. Similar to other groups, students in the Turkish school developed their communication skills (in English), planning skills, project management skills, research skills, etc. They became more confident in expressing themselves and more experienced in working as a team. They also developed interest, understanding and empathy towards science and the environment. Teachers and the school got more experience in collaboration with different institutions. The teachers saw that "the participation of the partners and their support of the students in addition to the education at school have increased the quality of education" (TT1). The teachers became more supportive towards the collaboration with ecosystem partners and started to integrate such collaboration in their planning of teaching.

Ecosystem Implementation Outcomes

Highlight I – Learning outdoors enhancing understanding and engagement. Compared to traditional learning in classroom, open science schooling promotes more engagement of students into learning compared to the traditional classroom, which is more of one-way communication from teachers to students. In addition, with learning by doing, more observation, and experiment, learning outdoors enable better understanding of theory and more permanent

knowledge. Furthermore, “Students had the chance to observe how science takes place in life in a real environment” (TSA). By being outdoor learning through senses, open science schooling also promotes their sympathy to the surrounding environment.

Highlight II – Challenges in the implementation of the missions during COVID-19. The school administrator believes “We are educating the members of society. They should be willing to ‘learn to learn’ and know that education is not limited to school only”. However, learning outdoors requires a heavy preparation process, planning. Hence, it is considered a time-consuming process for students and teachers. From all interviewed participants, there were no major challenges in terms of collaboration with partners in carrying out the mission. Most challenges came from the pandemic COVID-19 including time-management, scheduling problems, traveling and outdoor restriction or quarantine. In addition, due to the pandemic, some participants hesitated to join the mission including partners and parents.

DATA VISUALISATION AND NETWORK ANALYSIS

In the following, we visualised and analysed all the answers in the interviews using InfraNodus network analysis (Paranyushkin, 2019) about the features and challenges of ecosystem and OSS missions in general and in the stakeholder groups. The purpose of the visualisation is to illustrate and analyse the text network structure of the interview data to highlight the focuses and gaps in the descriptions about OSS ecosystem by different stakeholders. The focuses show the features of the present ecosystem, while the gaps reveal the possible missing connections or future challenges of it.

InfraNodus is a "web-based open-source tool and a method for generating insight from any text or discourse using text network analysis" (ibid.). The convenience of using the tool is that it can generate clusters of words that appear most often on the shortest path between any two randomly chosen words (i.e., the most influential words) that can often connect different topics together in the context (ibid.). A combination of clustering and graph community detection algorithm is used in the InfraNodus platform to identify the groups of nodes more densely connected together than with the rest of the network, or distinctly dispersed in two or more communities with a structural gap in between (InfraNodus, 2022). GPT-3 AI is also embedded in the application for proposing questions, facts and ideas based on text analysis.

After the removal of some repetitious, redundant, and irrelevant words, we uploaded the answers to the website for analysis and used at the same time the filter to prevent some words commonly used in conversation interfering with the results, e.g., lot, thing, things, yeah, yes, OK. In the following, we report the findings about the features in the participants' answers about

ecosystem in three parts, i.e., the most influential elements and network structure of the data, the topical groups in relation to ecosystem, and the structural gaps.

Table 5: Comparison of the Most Influential Words among Groups

Groups	Most Influential Elements	Network Structure	Modularity	Influence distribution
Students	teacher, school, learning	Focused	.23	50%
Teachers	student, school, teacher	Focused	.2	50%
School administrators	school, student, science	Biased	.2	80%
Ecosystem partners	school, student, science, project	Focused	.24	50%
All groups	student, school, science	Biased	.18	80%

Table 5 gives an overview of the most influential elements and the network structure of the groups. The most influential elements in all the interview data are “student, school and science”. The most influential groups show not only that students, teachers, school administrators and ecosystems all focused on the key word clusters of “teacher, school, student, learning, science and project”, but also their slightly different perspectives based on their roles in the ecosystem and missions. Students and teachers mentioned each other, while administrators and partners focused more on students and the open science project.

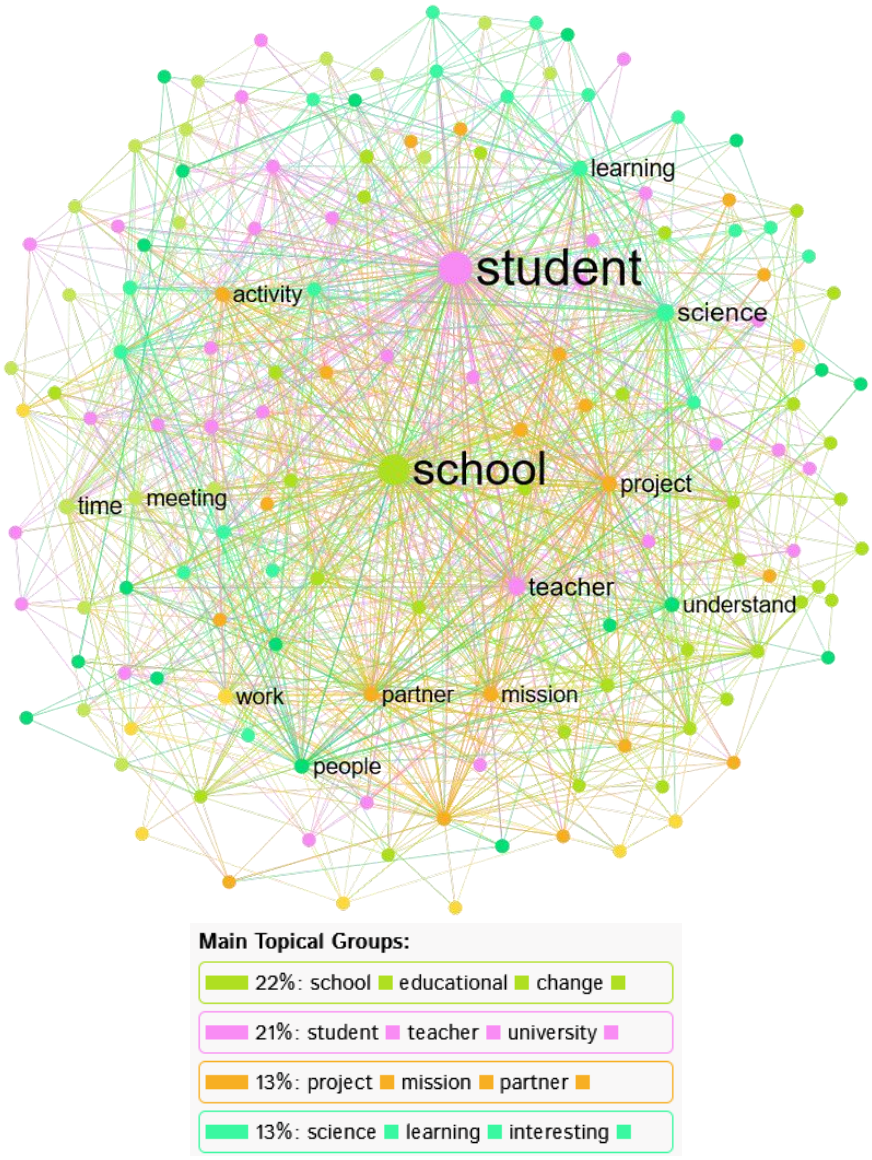

Figure 11: The Network Graph of all the Interview Data (Source: InfraNodus)

The network structure gives an overview of the text by a combination of text network modularity, distribution of influence and narrative dynamics. The network structures of all the interview data and the group of school administrators are described as “biased”, while the other groups are described as “focused”. Biased means a least diverse structure focusing on one topic. Focused means a structure focusing on a certain idea, but there is also some diversity on the global level

(Paranyushkin, 2022). The wider distribution of the nodes in the groups of students, teachers and partners can result from their more various experiences from field work. While in general, the answers from different groups of participants are still focused on the common topics about OSS ecosystems. In Figure 11, it can be seen that the most commonly mentioned nodes are “student, school, and science”. The main topical groups are also consistent with the descriptions in the above case studies, e.g., schools as educational institutions make changes in the community, students and teachers working together with universities, the projects and missions supported by partners, and the missions make science learning interesting. However, it seems from the gap that the interview data about the project does not reveal much about the connections between the ecosystems and the components of the missions, e.g., how each of the missions contributes to the formation of the ecosystem, or how the ecosystem is developed and sustained by the missions.

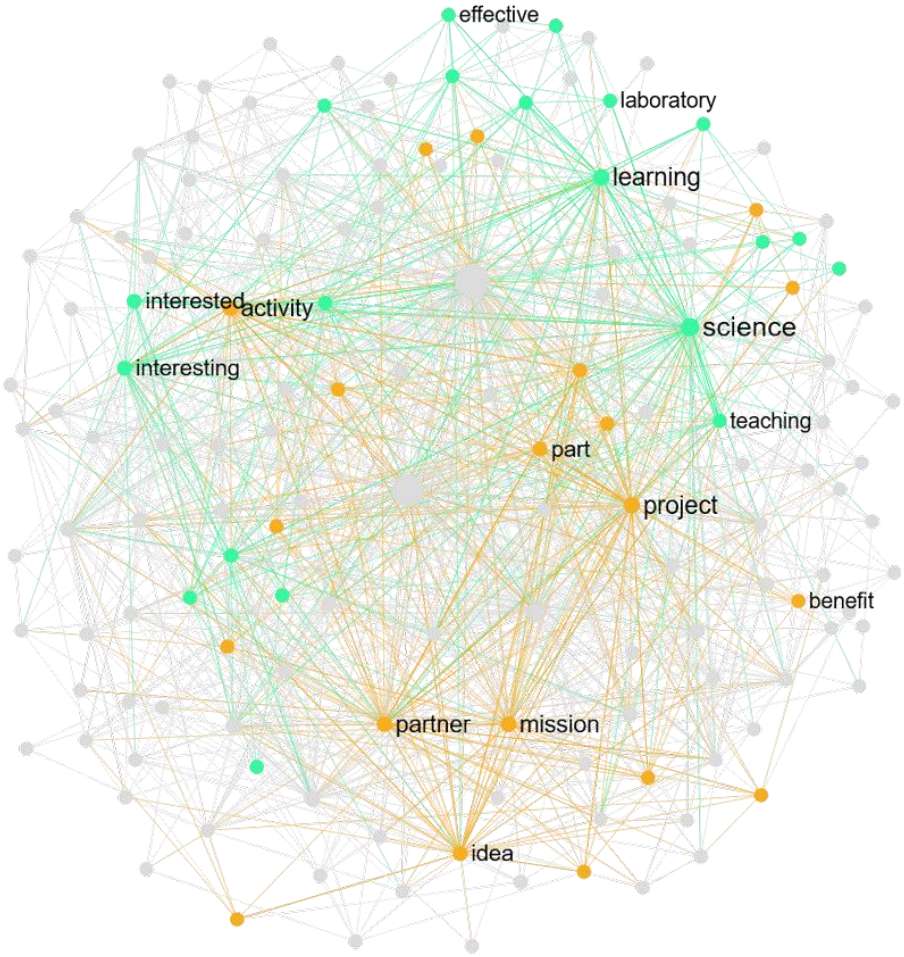

Figure 12: The Structural Gap in the Whole Group Interview Data (Source: Infranodus)

From the perspective of structural gap, it can be seen that in the data of all participants, the nodes about OSS activities, such as project, mission, partner, etc., are distant from those describing school education, such as science, learning, teaching, laboratory, etc. (Figure 12). The two distinctive topical groups showed that OSS activities were perceived as very different from teaching and learning at school, as can be illustrated by the quotations of interviewees.

Topic summaries in groups

In the following, we report the findings based on the graphs of each group of the stakeholders. We chose ‘ecosystem’ as the key word to reveal the structure of their ideas about it.

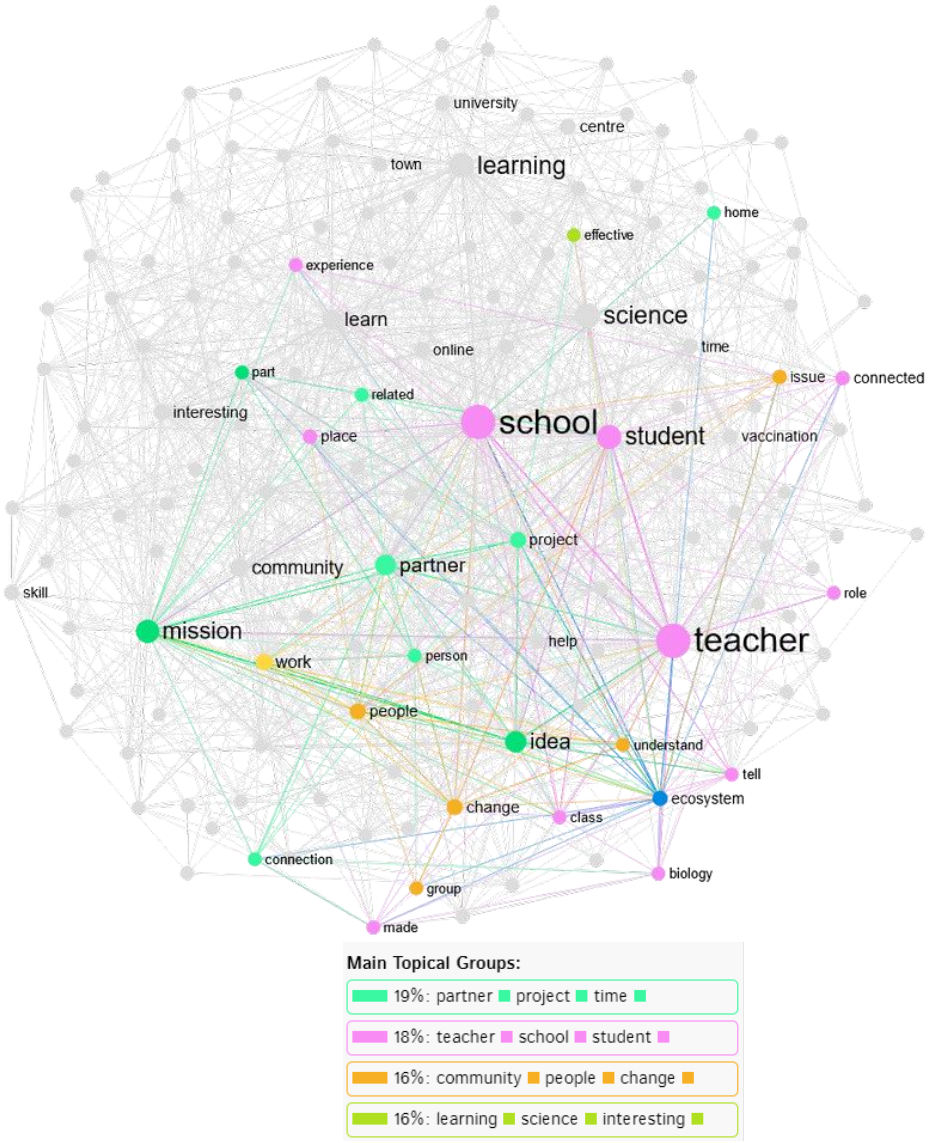

Figure 13: The Main Topical Groups in the Students' Answers (Source: Infranodus)

Students

Four topical groups are prominent in students' answers (Figure 13). The first combination was apparently about the open science schooling project with partners. They defined ecosystem by the connected learning environment cocreated by teachers, the school and students. As the students described, "Ecosystem for me is a place, an atmosphere built around a school and learning" (PS1) and "I think, each school is, an ecosystem. ... we have to be interconnected, the principal with teachers, teachers with students, and also students with their parents or friends" (RS1). As described in the previous case studies, the students in the project are quite aware of the change they can make for the community and people, which has raised their interest in learning science, as said by one student, "I believe I have taken a step to protect our home" (TS1). They also described their frustrations due to the pandemic, "we were unlucky to come across the pandemic, so we were sitting in front of our computers both realising school's material and fulfilling the missions in the Ecosystem project" (PS2).

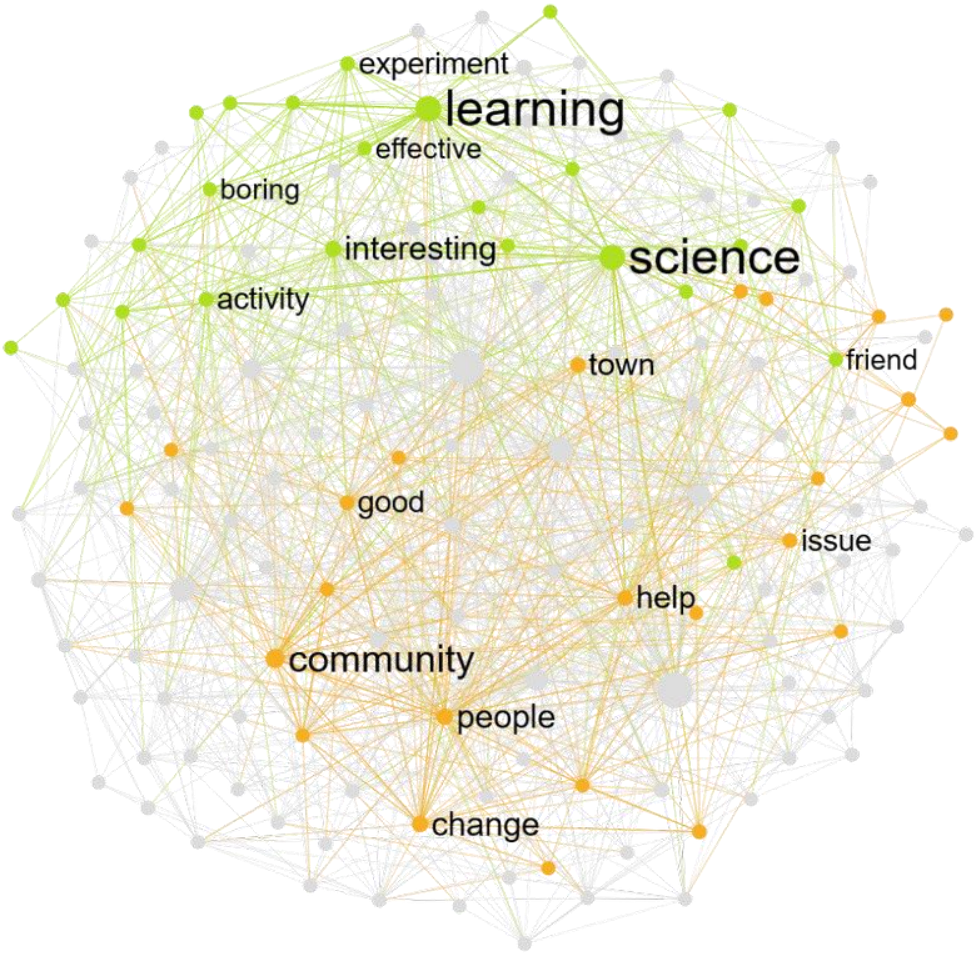

Figure 14: The Structural Gap in the Students' Interview Data (Source: Infranodus)

There is a gap between the two topical groups of “learning, science and interesting” and “community people and change” (Figure 14). It seems from the data in general that the students did talk very much from their perspective about how the change on the community and people can be made by their ‘interesting’ science learning, though in the case studies they showed their awareness about the contribution to the community of the OSS missions.

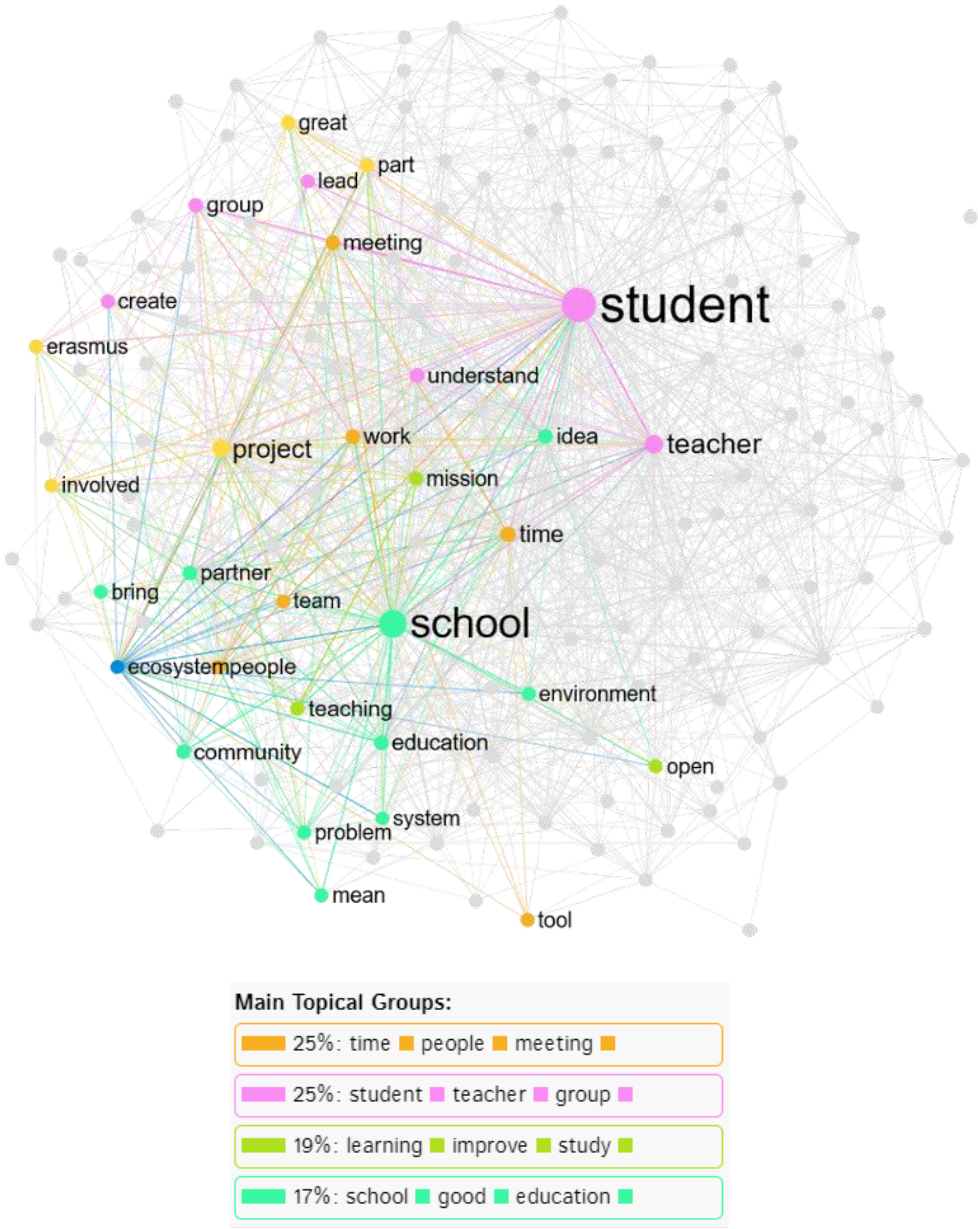

Figure 15: The Main Topical Groups in the Teachers' Answers (Source: InfraNodus)

Teachers

Figure 15 shows how ecosystems work in the eyes of teachers. It involves time and meeting with people, "all staff (employees, teachers, managers), students, families, institutions out of the school related with education in general" (TT1), and "the collective works of our school and

the interactions it has with the rest of the community around it" (LT2). It enhances the skills of teachers and students in the group work and management of the project. The educational missions help students learn in and out of school with good quality of education. One of the teachers described what they did typically, "We were in a camp, and we studied outside as well. We went to the museum. We went to people to have these kinds of investigations ... about customs, about some medicinal plants we didn't know very well" (RT1). Teachers also realised that "the initiative to maintain the ecosystem created must come from the teacher" because the "teacher knows best what benefits the students get from these activities" (PT1).

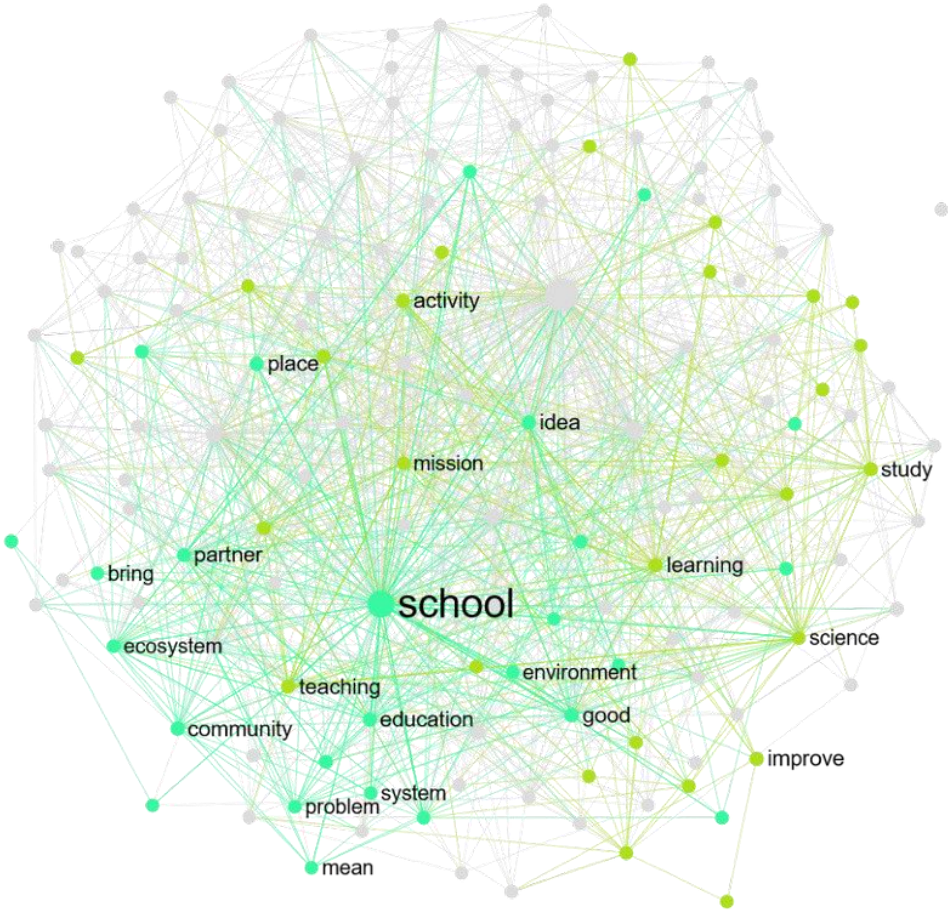

Figure 16: The Structural Gap in the Teachers' Interview Data (Source: InfraNodus)

From the structural gap we see a missing link between the school education (e.g., school, education, teaching, etc.) and the improvement of learning (e.g., learning, improve, study, etc.) (Figure 16). This might be due to the focus of the OSS missions and ecosystem in this interview instead of school education. However, it can be also a reminder for us how the missions can be embedded in school education that can develop students' learning in the long term.

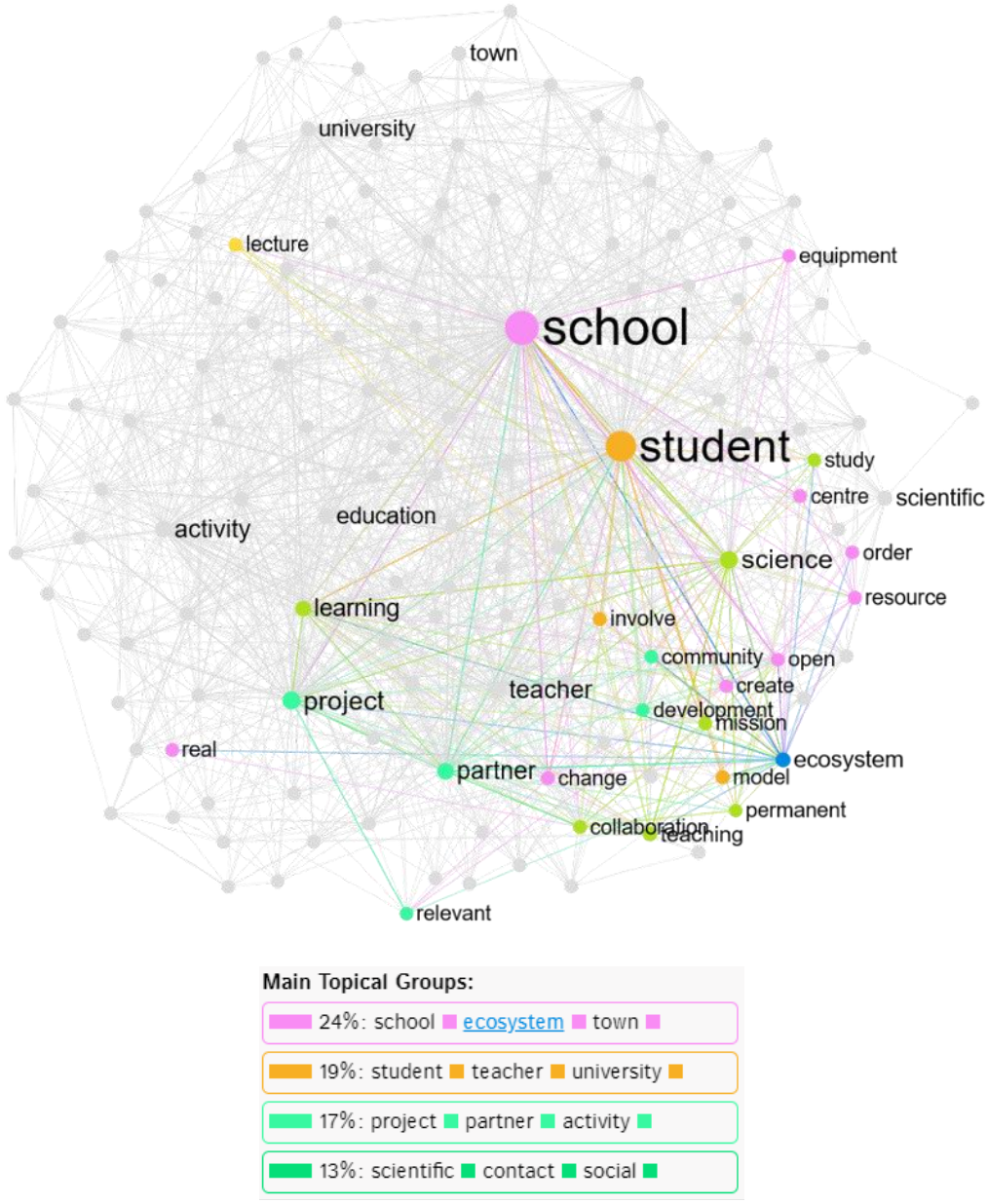

Figure 17: The Main Topical Groups in the School Administrators' Answers (Source: InfraNodus)

School administrators

The school administrators are aware of the central role of the school in the ecosystem and the local community (Figure 17). One of them considers their students as “being the centre of the ecosystem” and the students are influenced by teachers in the education and partners in the activities; the project “leads and facilitates the introduction of open science school in the community,” while “changing traditional teaching into mission-based science teaching in collaboration with open-ended school ecosystems - has been and continues to be a real challenge” (RSA). Another administrator thinks they need to adapt the collaboration with ecosystem partners to the school culture, but “it doesn't happen very quickly, because cultural changes take time” (TSA).

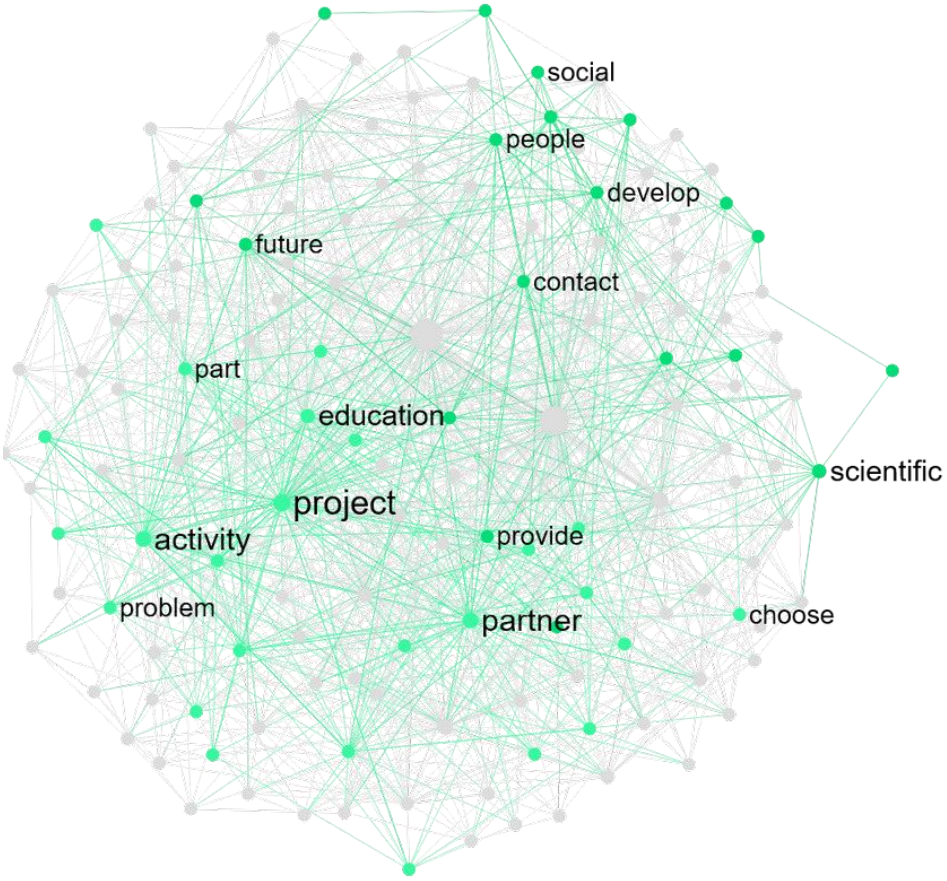

Figure 18: The Structural Gap in the School Administrators' Interview Data (Source: InfraNodus)

We see a missing connection in the narration of the school administrators between the school ecosystem and OSS missions (e.g., scientific, contact, social, etc.) and the activities of the ecosystem partners in the project (e.g., project, partner, activity, etc.) (Figure 18). It could result from the fact that the missions were designed from the perspective of the schools instead of for the partners. The sustainability of collaboration can be more enhanced if the activities of the partners can be better facilitated through the missions, e.g., the visibility and the fulfilment of the educational visions of the universities in the secondary schools and the community.

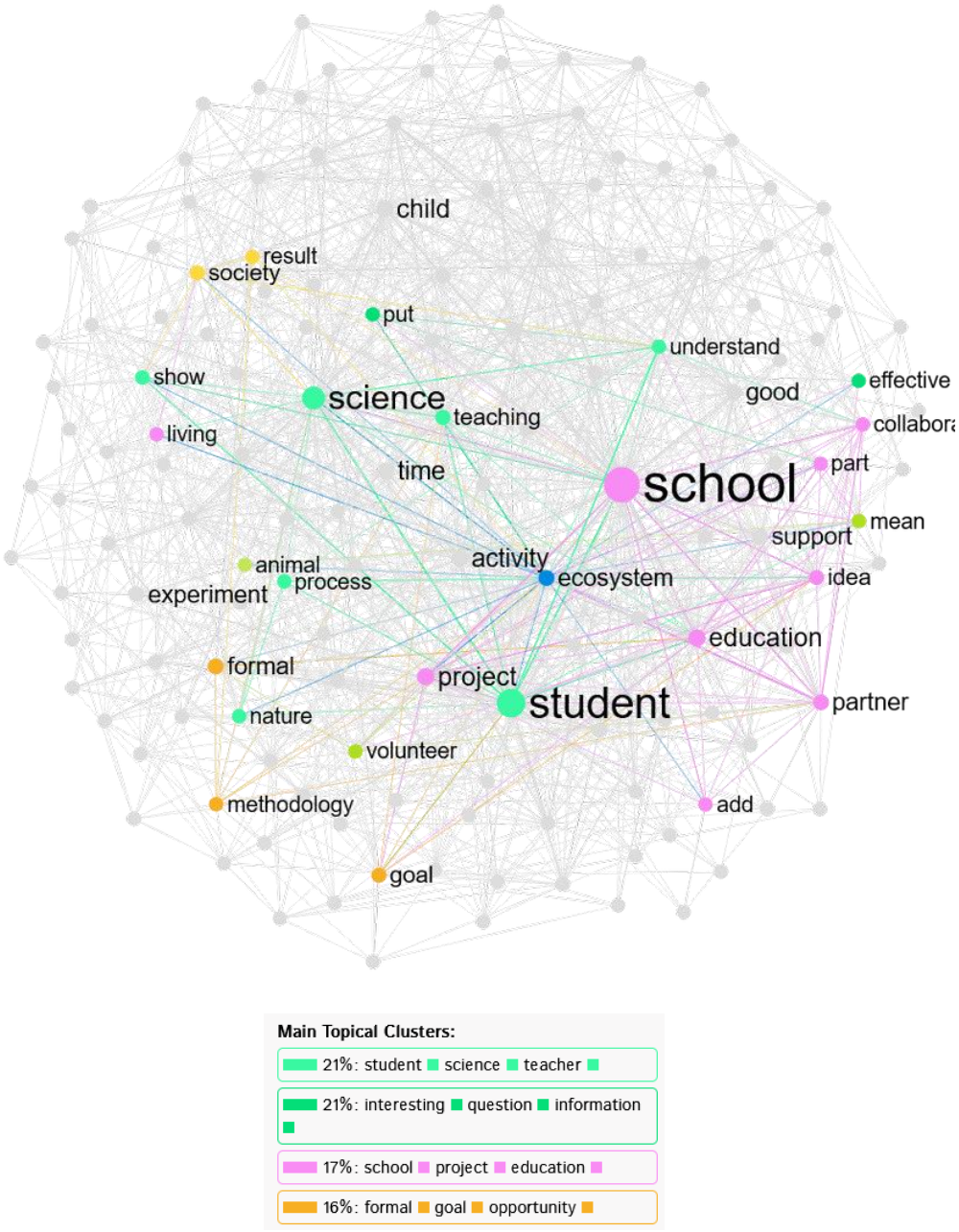

Figure 19: The Main Topical Groups in the Ecosystem Partners' Answers (Source: InfraNodus)

Ecosystem partners.

The ecosystem partners highlighted their actions on science education in the school and their awareness about the goals and opportunities in the project and the questions students and

teachers have in experiments (Figure 19). As explained by one of the partners, “We wanted to help the students understand the field of work we occupy and how it ties into the economy and ecosystem”. It is interesting to note that all the ecosystem partners in the interviews are in the field of biology, a discipline most closed to ecosystem, e.g., the Lithuanian partner. “We work in the agriculture-based sector, so we know a fair bit about ecosystems and nature and we can share our knowledge with the students and become their tutors in a way” (LEP). However, it is possible that other disciplines, especially, those in the social sciences, can also be integrated into the OSS missions.

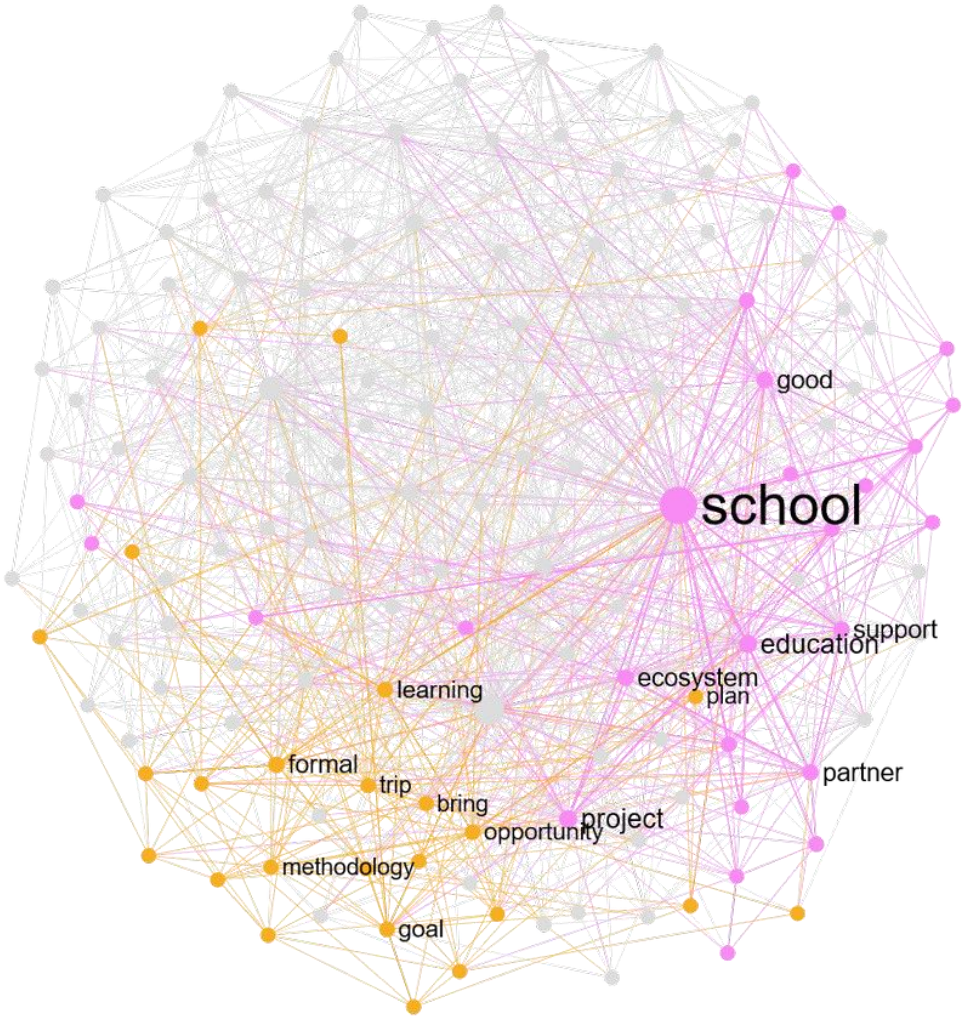

Figure 20: The Structural Gap in the Ecosystem Partners' Interview (Source: InfraNodus)

The structural gap in the graph shows that there is a missing connection in the descriptions by the partners between the specific OSS missions and relevant disciplines (e.g., experiment, question, biology, physics, etc.) and the overall goals of their activities and opportunities for the participants in the activities (e.g., learning, goal, opportunity, partners, staff, etc.) (Figure 20). It seems that the partners tend to agree with the goals and objectives of the school instead of mentioning different ones, and seldom gave details about the development of themselves in the missions. “We had the

same goals when we collaborated in this mission", and "All the actors that were involved understand the situation and they adapt to the plan changes" (REP).

CONCLUSION, DISCUSSION AND RECOMMENDATIONS

In the present studies, we collected data by surveys and interviews among the main stakeholders in the OSS ecosystem project. The research about our questions is based on the ecological systems and relevant theories. In the following, we conclude and discuss our main findings and propose the direction of further research for the sustainable development of OSS ecosystem.

General conclusions

In the project of OSS ecosystem, the schools work with different stakeholders in and around the school campus to educate the students for their future. Given the challenge of novice attempts and the unstable situation during the pandemic, the students learn from their teachers and ecosystem partners and work together in groups to find answers to their concerns about public health, scientific explorations and natural environment. They also give back to the community what they discovered and gained in the OSS missions.

The school, the student, the teacher, the ecosystem partners all have a part to play in education. In some of the countries, it is supported by the local government for the retaining of talents for the university and the future. The students develop not only academic skills, but also social skills when working together in the missions, e.g., in how to explore, study, and work together, how to think critically, present themselves creatively and confidently, and defend what they believe with evidence, etc. The most important thing is that the missions raised their interest in learning science, and they choose what they want to learn and give it their best effort.

The features of OSS ecosystems

Open science schooling activities are and must be designed to engage and re-engage students in science learning. Major criteria for such activities include engaging content, hands-on activities,

relevance to real-world issues, and opportunities for student-led investigations, etc. It has been shown that when children are exposed to scientific concepts at a young age, they are more likely to develop positive attitudes towards science and society and view it as an important part of their identity. In order for young students to integrate science as a positive value in their identity creation, they need to feel like they belong in the scientific community. Building bridges between ecosystem partners on different levels of education can be a very effective way to motivate students. A sense of belonging has been found to be an important factor in students' motivation and engagement in science. If students feel like they are part of the scientific community, they are more likely to be motivated to learn science and see it as a positive part of their identity.

OSS missions versus traditional classrooms

The OSS missions are more interactive and practical than traditional science teaching. Students have opportunities to take the lead and initiative in the activities, which give them confidence. In OSS missions, students are encouraged to be active participants in their own learning process, rather than passive recipients of information from the teacher. This type of teaching can lead to a more democratic learning environment where all students feel valued and respected.

School as 'agents of change'

All schools in the project are already agents of change in their communities through the OSS missions. They can become even more powerful 'agents of change' by promoting and supporting open science schooling principles and practices that seek to provide students with the skills, knowledge, and attitudes necessary to participate in the open scientific community, where students have greater access to scientific knowledge and opportunities to contribute to the

advancement of science. By becoming more involved in such activities, schools can help create OSS ecosystems that will benefit all members of their community.

Motivation of ecosystem partners in the community

From the interview data, it can be seen that all the ecosystem partners are motivated to join the project mainly by a desire to improve the quality of science education and make it more accessible to the students. The engagement of the partners in OSS ecosystems can lead to the development of new methods, technologies, facilities, as well as increased scientific literacy. Responsible science can play a number of important roles in open science schooling, including helping to ensure that students have access to accurate and up-to-date information about scientific discoveries, promoting public engagement with science, and fostering transparency and accountability in scientific research. Open science schooling can help increase critical thinking skills among the students. It can also help them understand the role of science in society and how to use scientific information to make informed decisions, e.g., about our environment.

The role of social and gaming networks

The use of social and gaming networks can help students to be motivated in their studies by providing them with a sense of connection to the larger world. Additionally, this approach can help students learn about local and global science missions in an engaging way. We know from the teachers that students who are engaged in local and global science missions are more likely to be motivated and perform better in school because they feel a connection to the work they are doing and see the impact it can have on their community or the world. Additionally, these types of experiences can encourage teamwork and problem-solving skills, which are valuable in any future career.

Sharing their OSS missions on social media encourages students to communicate with peers locally and globally. However, it is interesting to note that students tend to separate social networks from gaming networks. They communicate and share stories on social networks, like Facebook, WhatsApp, Instagram, etc., but they will not do that on gaming networks, which are more for their personal interests and entertainment.

Discussion and recommendations

The OSS ecosystem should provide systematic guidance and sustainable opportunities/facilities for students to explore and practise on what they learn in the classroom. Schools mobilise all resources within and beyond the classroom to contribute to the sustainable development of students and the community. The ecosystem partners are motivated by the significance and relevance of their contributions, such as the improvement of education, the fulfilment of their own missions, communication with the young generation, etc. However, it is dependent on the accessibility of the external partners/sources, especially during unexpected situations like the pandemic. In addition, the sustainability of the ecosystem needs to be maintained not only by funds, projects, but also by the integration in the school curriculum. For instance, a project-based learning curriculum can be created where students work on real-world projects in partnership with community organisations. The projects would focus on issues that are important to the community, like increasing the vaccination rate during the pandemic, and students would learn about the environment, community, and how to effect change.

The OSS missions are inspiring and improving various skills of students and teachers. They help also to develop students' interest in science, view towards life and people, and boost their confidence in communication. The communication among students from different countries really

motivates the students to participate in the missions. To motivate students to join the missions, a program can be created where the students in one school would be paired with another group of students from a different country. They would then be responsible for working on a project together that would focus on solving a problem in their community related to the environment.

Our research provides an overview of the OSS ecosystem from the perspectives of both the national groups and stakeholder groups. More in-depth longitudinal studies could be designed and conducted to see how the OSS missions enhance the sustainability and effectiveness of OSS ecosystem.

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Appendix 1 Research framework

Table 6: Research Framework

Research questions	Issues to be addressed	Relevant questions in the Survey *	Relevant sections in the Interview	Relevant literature/theories
1. What characterizes the open schooling learning processes when the school ecosystem is actively engaged in the learning processes compared to traditional science teaching? / What is OSS from the perspective of collaboration with ecosystem?	What OSS characteristics (e.g., real-time, real-world learning, student-centered learning, learning by doing, etc.) play key roles in the OSS model when it comes to collaboration with the ecosystem partners and how?	• Please, describe the ecosystem you have developed for the students' missions. • As a teacher, how easy was it to build the ecosystem for your students' missions? • As a teacher, how challenging was your cooperation with the partner(s) in the ecosystem? • How much did the missions partners' input contribute to the added value of learning?	View on science and teaching science Idea of the ecosystem of your school	Vygotsky's & Bronfenrenbreuner's theories (see Literature review and Methodology)
2. What must characterize open science schooling activity to engage and re-engage young students in science learning through their school ecosystem? What are the major criteria? And what does it take to allow young students to integrate science as a positive value in their identity creation when they learn through interaction with the school ecosystem?	Who designs learning activities and who defines how the learning outcomes will be assessed (students, teachers, partners)? Where does the learning take place (school, partners' premises, other premises)? Students' and teachers' assessment of the students' enthusiasm for learning in OSS ecosystem as compared to traditional learning. Their assessment of how much new knowledge they gain and new skills they acquire as compared to traditional classroom teaching.	• In your opinion, how much new knowledge the missions offered to the students as compared to the traditional lessons? Please describe the new knowledge the students obtained (if any). • In your opinion, how many new skills the missions offered to the students as compared to the traditional lesson? Please describe the new skills the students obtained (if any). • How eager were the students to engage in learning through the ecosystem as compared to	Planning the mission Implementing the mission Place of learning	Vygotsky's & Bronfenrenbreuner's theories (see Literature review and Methodology)

Research questions	Issues to be addressed	Relevant questions in the Survey *	Relevant sections in the Interview	Relevant literature/theories
	How do students form a positive science identity?	the regular classroom setting of learning? • As a teacher, how many new teaching skills have you developed during the missions? If you have developed some new teaching skills during the missions, tell us what those skills are. • How much were the students engaged in designing the learning activities during the missions? • Where did the learning during the missions take place?		
3. How can schools become "agents of change" (OECD) in the community and how can this lead to ecosystems of open science schooling?	What is the social impact of the ecosystem OSS missions and on what scale (local, regional, national, global)? How do schools create the ecosystem? How does the ecosystem develop and diversify? What are the synergies within the ecosystem? How engaged are the teachers and how engaged is the school administration in maintaining the ecosystem? What is the role of these factors for the OSS ecosystems?	• How much did the school administration support the development of the ecosystem?	School becomes agent of change Choosing the partner	Motivation system: on what interests and values the ecosystem is based. --> 'Culture' from the EEE Model
4. Which motivational factors can dedicate science resources in the community to participate in ecosystems of open science schooling? What roles might	What are the benefits for the ecosystem partners in the collaboration with the school?	• How eager were the community partner(s) to participate in your missions?	Collaboration with the ecosystem partner(s) Resources and sustaining the practice of ecosystem	Motivation system, on what mutual interests & values ecosystem partnerships are based --> 'Culture from the EEE Model

Research questions	Issues to be addressed	Relevant questions in the Survey *	Relevant sections in the Interview	Relevant literature/theories
"responsible science" play in this context?		• How much were the ecosystem partners engaged in designing learning activities during the missions? • How much were the ecosystem partners engaged in designing how the learning outcomes would be assessed during the missions?	collaboration (for school administrators) Common values of the school and ecosystem partners – towards culture of ecosystem collaboration	
5. How can schools and ecosystems integrate local and global science missions for the students, allowing students to be motivated through the use of their own social and gaming networks?	n/a	n/a	Gaming and social networks in the mission (for students)	Experience of the other OSS projects shows that the students do not use their social media and gaming networks to talk about the missions. It may be related to the fact that they strictly separate the school-learning spheres from the interests-hobby-entertainment spheres. Nevertheless, it may be different in this OSS project due to its outward nature. Questions regarding use of social media/ gaming networks will be included in the students' interview guide. Whereas teachers will be asked how they could encourage students to use those networks for learning, education and dissemination purposes

Notes: * The questions are quoted from the survey questionnaire for teachers. The questions for students, school administrators and ecosystem partners are similar.

The examples of questions in the interview can be found in Appendix 2.

Appendix 2

Table 7: Structure of the Interview Protocols

	Objectives	Examples of questions for the students	Example of questions for the teachers	Example of questions for the administration	Example of questions for the ecosystem partners
Views on science and teaching science	To probe the student's image of and attitude to learning science and how different, if at all has learning science been in the Ecosystem project. To understand how the teaching science in the ecosystem mission was different regarding students' engagement and interest in science.	How do you like learning science? What does 'science' mean to you?	What does 'science' mean to you? How do you like teaching your subject through the lens of science (as science is everywhere)?	n/a	What do you think science is? How interesting and effective, in your view, is science teaching at school?
Idea of the Ecosystem of your school	To delve into the students' idea of the school ecosystem and the students' motivation to engage in the project. To decipher the visceral understanding of the 'ecosystem' and 'collaboration with the ecosystem' as seen by the teachers, as well as getting some insights on how the project has been introduced to the students and received by them.	The project is called the Ecosystems of the OSS, how do you understand the concept of 'ecosystem'? How would you describe the ecosystem of your school?	Who introduced the Ecosystem project to you? What was your first reaction when this project was introduced to you?	What does the concept of the (school) ecosystem mean to you? Do you think your school was able to create the new form of collaboration between the different school players, from management to student teams?	The project is called the Ecosystems of the OSS, how do you understand the concept of 'ecosystem'? What does school as an ecosystem mean to you? How do you understand this term 'collaboration between the school and ecosystem partners'?
OSS methodology	To understand the perspective of the school regarding the OSS	n/a	n/a	What was your reaction to the methodology of	What was your reaction to the methodology of teaching science through ecosystem project –

	Objectives	Examples of questions for the students	Example of questions for the teachers	Example of questions for the administration	Example of questions for the ecosystem partners
	method, particularly its ecosystem collaboration emphasis.			teaching science through open science schooling – that is through missions and involving the ecosystem partners? How does your school evaluate in general the students' interest and engagement in learning science?	meaning learning through missions and involving YOU as the ecosystem partners? What can you do as a community partner to render learning science attractive to the students?
Planning the mission	To understand how the plan for a mission came about (process of planning) and what was the students' engagement in the mission definition and whether they created the mission based on the community needs' analysis. To understand the planning processes of the mission and the role of the stakeholders in designing and planning the activities	When you first started to talk about your mission what were your ideas? In other words: What ideas came first to your mind when you started talking about the mission? What did you want to do as a mission?	What were the objectives of the mission? How did the students present their ideas about the mission?	What was the school administration role in planning and implementing the Ecosystem of OSS missions? What were the challenges you faced as a school administration in this project so far?	Can you explain how you collaborated with the school in the mission that took place? How was communication with the school?
Becoming /Choosing the partner	To understand how the process of choosing and contacting the partners went on, e.g., who led the process, based on what criteria the partners were chosen and how they were approached by the school and how the teachers think the	Did your school team manage to establish a group of collaborators, meaning your ecosystem? How did you choose the ecosystem partners?	What was the teacher's role in choosing ecosystem partners for collaboration? In your opinion, how did these community partner(s) you collaborated with serve	What was the school administration's role in a) choosing and b) contacting the partners? In your opinion, how this (these) community	Who from the school contacted and invited you to take part in the project? What was your first reaction to the project?

	Objectives	Examples of questions for the students	Example of questions for the teachers	Example of questions for the administration	Example of questions for the ecosystem partners
	partners can deliver educational value.		for an ecosystem of learning?	partner(s) serve as an ecosystem of learning?	
Common values of the school and ecosystem partners – towards culture of ecosystem collaboration	To examine the role of having common values, objectives and organizational culture in establishing and maintaining collaboration in the ecosystem. Consequently, we want to know what those values, objectives and organizational cultures constitute.	n/a	n/a	n/a	What are the values and an organizational culture of your organization that allows you to collaborate with the school's activities and that makes you a good ecosystem partner for the School? What are the values, interests, and objectives you share with the school you collaborated in the ecosystem project?
Implementing the mission	To understand how the mission was executed from the teacher's point of view.	How did you put the plan for the mission (we just talked about) into action?	How did you put the plan for the mission (we just talked about) into action? Did you face any challenges while implementing the mission?	What sort of issues related to implementation the teachers and students asked you to help solve? What went well, what could be done better (in planning and implementing the mission), from your perspective?	Were there any (other) challenges in the collaboration? What was your reaction to the challenges?
Collaboration with the ecosystem partner(s)	To understand the processes of collaboration with the ecosystem partners and teacher's perspective on involving the ecosystem in teaching.	How did your collaboration with the partner(s) go? What was challenging in this collaboration?	How did your collaboration with the partner(s) go? Did you work with the whole organization or with some persons in the organization?	What was your role during the mission implementation? From your perspective, how did the collaboration with the partner(s) go?	What are the values and an organizational culture of your organization that allows you to collaborate with the school's activities and that makes you a good ecosystem partner for the school?

	Objectives	Examples of questions for the students	Example of questions for the teachers	Example of questions for the administration	Example of questions for the ecosystem partners
					What are the values, interests, and objectives you share with the school you collaborated in the Ecosystem project?
Participation, engagement, and curiosity	Here we probe into how best the students can be supported in the process of learning science, how much independence and how much support and guidance do they need as well as how to elicit their interest in the topics and subjects.	When learning science, how much of teacher's involvement do you think would be the best so the students learn effectively? How much independence should the students have when learning science?	n/a	n/a	n/a
Place of learning	To understand the students/teachers' ideas regarding the venue of learning/teaching while challenging the traditional view that the learning takes place at the school bench, e.g., can learning/teaching cross the school walls and how can places of learning be contacted/allocated, in a systematic and sustainable way, in the OSS ecosystem?	Where did your mission take place? Do you think that learning takes place only at school? What is your opinion?	Where did your mission mainly take place? What do you think about teaching outside of school?	Do you think that teaching takes place only at school. What is your opinion? What are the characteristics of an effective learning spaces?	Do you think that teaching takes place only at school? What is your opinion? What are the characteristics of an effective learning space?
Resources and sustaining the practice	To understand what kind of resources the school needs to engage to effectively	n/a	n/a	As a school how were you prepared to facilitate science learning in the OSS Ecosystem?	In your view, how was the school prepared to facilitate science learning in the OSS Ecosystem?

	Objectives	Examples of questions for the students	Example of questions for the teachers	Example of questions for the administration	Example of questions for the ecosystem partners
of ecosystem collaboration	collaborate with the ecosystem partners. We want to understand what structural and organizational changes the administration is able to introduce to facilitate regular school-ecosystem collaboration to understand the perception of the school and the stakeholder's capacity to sustain the ongoing and active ecosystem collaboration. Also, we want to gauge what need to be done i.e., what resources to be engaged to sustain the collaboration in the future.			How would you motivate or incentivise the teachers to collaborate with the ecosystem partners beyond the project?	What could the school do to be more open (for community and ecosystem collaboration)?
Skills development in the missions	To understand the students/teachers' impression on what skills the mission and the ecosystem partners helped to develop for the student and how the collaborative experiences were educational for the teachers themselves. How the OSS with the involvement of the stakeholders was different from the traditional learning in the classroom in terms of effectiveness and difficulty of implementation?	Many students who took the survey said that they gained some new skills while participating in the mission. How was it for you? Can you tell what skills the mission helped you to develop?	In your opinion, how did students' missions support the students' interest in science? What kind of skills have you observed the students developed during the process of mission development through open science schooling?	How do you think, facilitating mission developed students' interest in science? Can you share your observations? Do you think there was any capacity building for the teachers stemming from the collaboration activities?	How do you think, your participation in mission developed students' interest in science? Can you share your observations? Do you think that the collaboration offered skills development for the teachers too?
Gaming and social	To understand the possibilities to involve the students' social and gaming network in the	Are you using social media networks or gaming networks? Which ones?	Have you used the students' social media networks or	n/a	n/a

	Objectives	Examples of questions for the students	Example of questions for the teachers	Example of questions for the administration	Example of questions for the ecosystem partners
networks in the mission	process of learning in the mission, to what extent these two spheres that are so strictly separate can begin to merge in the missions.	Have you used those networks while implementing the mission? How?	gaming platforms while implementing missions?		
School becomes 'agent of change'	To discuss the potential of the school to make changes in the community.	Do you think that the school can make good changes in the community? Have you heard before the concept 'agent of change'?	What do you understand under the concept 'school as agent of change' in the community? What must be done so your school becomes such an 'agent of change' by involving ecosystem partners?	What do you understand under the concept 'school as agent of change' in the community? What must be done so a school becomes an 'agent of change' involving ecosystem partners?	What sort of changes in the community can be affected by a school, in general? What must be done so a school becomes an 'agent of change'?

Note: The examples of the questions are picked up from the first two questions in the sections.